Livelihood vulnerability assessment to climate change in a Vietnam coastal province

by

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DECLARATION

I certify that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university; and that to the best of my knowledge and belief it does not contain any material previously published or written by another person except where due reference is made in the text.

Signed:

Date: 12th November 2018

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ABSTRACT

Thua Thien Hue is a coastal province located in the central region of Vietnam. Due to the long coastline combined with a large lagoon system, this province has heavily suffered from impacts of natural disasters and climate extremes. The coastal area in this province is densely populated with the main livelihood means being agriculture and aquaculture which are highly depend on natural resources, for example, water, soil, humidity as well as the weather conditions. Consequently, these coastal livelihoods have been increasingly impacted by climate change and variability. This research aims to assess the livelihood vulnerability to climate change of coastal communities in Thua Thien Hue province, Vietnam, in order to contribute to propose proper livelihood adaptation options for the study area.

The main method that this research used was the Livelihood Vulnerability Index (LVI) developed by Hahn, Riederer and Foster (2009) for calculating the vulnerability of the livelihoods of the coastal communes to climate change. In addition, the statistic software (SPSS) and sensitivity analysis (SA) also are used to examine the statistical differences in vulnerability level of these communes as well as assess the influence of sub-indicators in the LVI model to the vulnerability of communes. The data used for this research, including the 5 coastal communes of Thua Thien Hue province, is extracted from the large survey database of the project 'Thailand Vietnam Socio Economic Panel' (TVSEP panel wave 6), under the acceptance for accessing from the project manager.

The research found that the vulnerability of the five communes were different in terms of specific sub-indicators and major indicators. Most significantly, there was difference in the vulnerability level of each commune between the LVI and LVI_IPCC model. The vulnerability of each commune was influenced by varied sub-indicators which constitute major indicators in the LVI. Both LVI and LVI_IPCC models reflect that choosing the sub-indicators for each major indicator has significant influences on the vulnerability of communes. The results have

potential to contribute to the policy development in order to make priorities in increasing the resilience and ability to adapt to climate change impacts for each commune.

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LIST OF ACRONYMS

CPIS	Climate Change-Induced Water Disaster and Participatory Information System for Vulnerability Reduction in North Central Vietnam Project
CRI	Long-Term Climate Risk Index
DANIDA	The Danish International Development Agency
DFG	The Deutsche Forschungsgemeinschaft
DFG FOR 756	DFG Research Unit 756 ‘Impact of shocks on the vulnerability to poverty: consequences for the development of emerging Southeast Asian Economies’
DFID	Department for International Development
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LVI	Livelihood Vulnerability Index
LVI_IPCC	Livelihood Vulnerability Index takes into consideration IPCC definition
PRA	Participatory Rural Appraisal
SA	Sensitivity Analysis
SL	Sustainable Livelihood
SLA	Sustainable Livelihood Approach
SLF	Sustainable Livelihood Framework
TVSEP	Thailand Vietnam Socio Economic Panel
USAID	U.S. Agency for International Development

1. INTRODUCTION

1.1. Introduction

Vietnam is one of the countries which is assessed as the most vulnerable to natural disasters and climate change (Yusuf & Francisco 2009). The effects of climate change in Vietnam has become more evident than ever. As reported by the Long-Term Climate Risk Index (CRI), Vietnam ranked as the seventh country among 10 countries most affected by climate change risk in the period from 1994 to 2013 (Kreft et al. 2014). Furthermore, Dasgupta et al. (2009) report that Vietnam ranks as the first country among 84 coastal developing countries that suffer from sea level rise (SLR) impacts on population, GPD, urban expansion, and the livelihoods of coastal communities.

Located in the central region of Vietnam, Thua Thien Hue is a coastal province, which has a long coastline (about 128km) and the largest lagoon system in Southeast Asia (Le, Nguyen & Nguyen 2017).

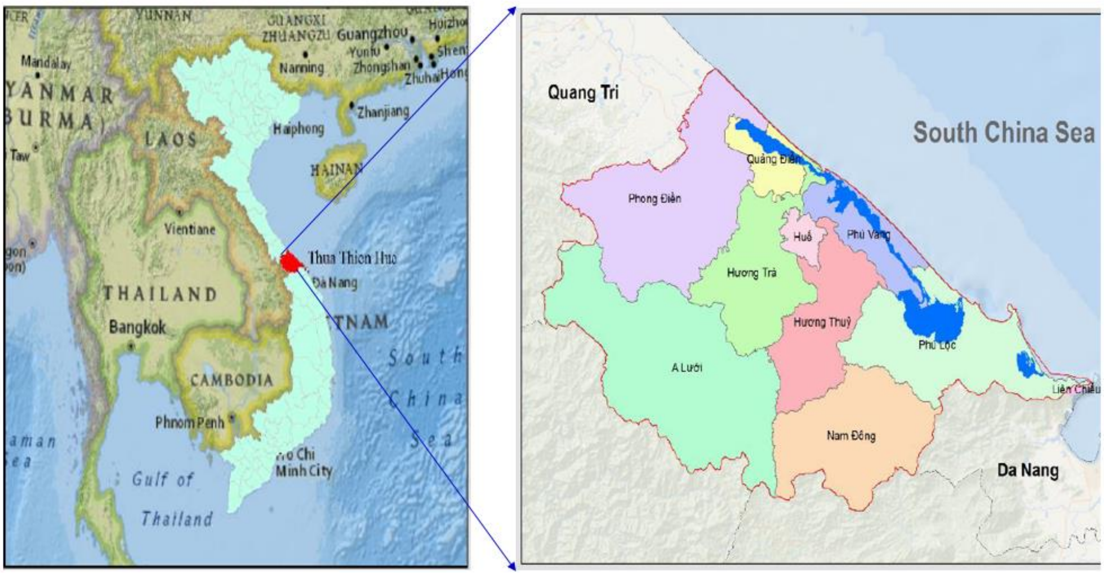


Figure 1.1. Administrative map of Thua Thien Hue province

(Source: Key Laboratory of River and Coastal Engineering, Vietnam Academy for Water Resource (cited in Nguyen 2017))

According to Thua Thien Hue Department of Natural Resources and Environment (2013) and Vietnam Institute for Social and Environmental Transition-International (2014), Thua Thien Hue province has often suffered from natural disasters, for example, hurricanes, tropical low pressure systems, droughts, floods, heavy rainfall, and coastal destruction. As reported in Vietnam climate change and sea level rise scenarios, by Vietnam Ministry of Natural Resources and Environment in 2016, Thua Thien Hue has been facing the highest risk of inundation with the sea level rise scenario of 100cm increase (Vietnam Ministry of Natural Resources and Environment 2016). Furthermore, Nguyen and Nguyen (2010) state that the occurrence of natural disasters and extreme climate events have increased from 1952 to 2010, with more than 40 storms which directly affected Thua Thien Hue province.

The report of Thua Thien Hue Department of Natural Resources and Environment (2013) points out that the coastal area has a high concentration of poor people. The coastal communes in this province are facing numerous difficulties in financial sources, limited access to and consumption of essential social services such as clean water, healthcare and educational system. These coastal communities are dependent for their livelihoods on agriculture (crop, livestock) and aquaculture, which highly depend on natural resources, for example, water, soil and climate conditions, and hence, are more vulnerable to risks and disasters related to climate change (Füssel & Klein 2006; Ha & Thang 2017; Le, Nguyen & Nguyen 2017; Tran & Ha 2014). As an illustration, in the coastal areas of Thua Thien Hue province, climate change has transformed the soil nutrient levels due to flooding, as well as increased salinity due to sea level rise (Tran & Ha, 2014; Tran et al. 2008). The change in soil nutrient conditions has affected the growth of crop plants.

In addition, coastal flooding has also led to significant damage for agriculture and aquaculture such as destruction rice crops, washing away aquaculture crops, and devastation of the fish and shrimp ponds (Tran et al. 2008, p. 127). Moreover, temperature changes due to climate change has led to temperature shock, growth restriction, and the expansion of pests and diseases in agricultural and aquaculture crops (Tran & Ha 2014). Further, Thua Thien Hue Department of Natural Resources and Environment (2013) reports that the extended drought (from May to July 2008) caused thousands of hectares of rice crops to be dry out and lost, and rural areas fall into the severe water shortage. Most importantly, with the scenario of a sea level rise of 100cm, a majority of coastal land (consisting of arable land and residential land) in Thua Thien Hue province will be lost, affecting livelihoods of coastal communities directly (Doan 2016; Thua Thien Hue People's Committee 2013).

1.2. Research aims and objectives

This research aims to assess how the livelihood of the coastal communities in Thua Thien Hue province are vulnerable to climate change, to provide the details of livelihood vulnerability of coastal communities for decision makers to contribute to the process of developing provincial strategies for climate change adaptation in Thua Thien Hue province.

This research uses the data that is extracted from the large survey database *'TVSEP panel wave 6',* for five coastal communes of Thua Thien Hue province. They include Loc Binh, Vinh Hien communes (Phu Loc district), Phu An, Phu Hai communes (Phu Vang district), and Huong Phong commune (Huong Tra district). The TVSEP panel wave 6 was conducted during the period from 1st May 2015 to 30th April 2016 under the long-term panel of the DFG FOR 756 that will be presented in Chapter 3. The objectives of this research are:

- To examine the impacts of climate change in the coastal area in Thua Thien Hue province.
- To adapt the existing Livelihood Vulnerability Index (LVI) developed by Hahn, Riederer and Foster (2009) to be relevant to the study area in order to create a local vulnerability index.

- To apply the LVI to calculate its outcomes to assess the livelihod vulnerabiilty of five coastal communes of Thua Thien Hue province, Vietnam.
- To determine which factors or sub-indicators of the LVI index influence significantly to the level of vulnerability of communes, in order to suggest the appropriate alternatives for adaptation of policies to climate change.

1.3. Research contribution

This research will expect to close the gap in assessing the vulnerability of livelihoods to climate change and climate variability at the local level. The findings of this research on the influences of sub-indicators of the LVI on the vulnerability of communities' livelihood to climate change impacts will provide understanding of the importance of choosing and adapting each sub-indicator in the LVI. In addition, based on the differences in vulnerabilities between communes as well as disparities in factors affecting the vulnerability of each commune, this research also expects to provide policymakers with valuable contributions for revising and amending the current adaptation strategies in responding to climate change and natural disaster management.

2. LITERATURE REVIEW

2.1. Introduction

This chapter will be a synthesis of the relevant literature in vulnerability to climate change and the evaluation of livelihood vulnerability to climate change in the world and also the study area. The relevant conceptual themes to vulnerability and theoretical framework are also discussed in this chapter via reviewing the varied frameworks of the vulnerability concept as well as assessment of the vulnerability in the circumstance of climate change.

2.2. Climate change and its impacts globally

Climate change is the persistent change in the mean and/or the variability of climate states over the decades or a longer period (IPCC 2007, p. 30). Overall, the change of climate is unprecedented since the 1950s and over decades, with the increased trend in global atmosphere temperature, the decreased amount of snow, an increased amount of ice melting and sea level rise. The report of IPCC (2014c) demonstrates that the period from 1983 to 2012 was recorded as the warmest era of the last 800 years in the Northern Hemisphere. In 2012, the global temperature increased by 0.85°C since 1880. The trend of increased temperature has led to the melting of sea ice and an increase in sea level (IPCC 2014a). Regarding ice melting, the amount of sea ice in the Arctic has declined from 3.5 to 4.1% per decade over the period 1979 to 2012 (IPCC 2014c). In addition, this report also shows that the global mean sea level has risen by 0.19 metre during 1901 to 2010. The world has experienced an increase in climate variability, especially extreme climate events, for example, storms, cyclones, heat waves and heavy rainfall (Bruun 2013; Kreft et al. 2014).

Consequently, climate change has considerably impacted people and ecosystems, which has been researched and demonstrated in a wide range of reports and studies (IPCC 2014c). For example, climate change has significantly affected coastal ecosystems through increased coral bleaching and loss of biodiversity; water through decreased availability of water due to increased drought; food security through loss of arable land, disruption of food production, diseases of plants; as well as affected human health (IPCC 2014a). Kreft, Eckstein and Melchior (2016) report that there were around 11,000 extreme weather events (including storms, floods and heat waves) over the world from 1996 to 2015 that led to more than 528 deaths and the loss of around USD 3.08 trillion. Most significantly, these extreme events will 'become more frequent and severe due to climate change' (Kreft, Eckstein & Melchior 2016, p. 3). Additionally, climate change has had significant impacts on coastal regions over the world, with the effects of climate change on coastal resources having extensive negative influences on the livelihoods of coastal communities (IPCC 2014a; Krishnapillai 2018).

2.3. The importance of coastal zone and impacts of climate change

2.3.1. Coastal zone and its importance

Although the coasts contribute an important role to our planet, there has been a controversy related to the definition of the coastal zone (Harvey 2006; Martínez et al. 2007). According to Carter (1998, p.1), 'the coastal zone is the space in which terrestrial environments influence marine environments and vice versa. Clark (1996 (cited in Hinrichsen (1998), p.2)) defined a coastal zone as 'the part of land most affected by its proximity to the sea, and that part of the ocean most affected by its proximity to the land'. Moreover, the coastal zone is also defined differently by different countries based on a combined perspective of ecological, geographical, socio-economic, historical, political reasons (Harvey 2006; World Bank 2017). In this research, the coastal area is understood as the area in which there is an interaction between terrestrial and aquatic ecosystems.

Around 84% of the world's nations have a shoreline with either open oceans or inland seas or both (Martínez et al. 2007). Globally, there are around 850 million people living within 100km of tropical coastal ecosystems, for instance, coral reefs and mangroves (FAO 2016).

The coastal area offers highly valuable goods and services for humans (Costanza et al. 1997; Martínez et al. 2007). The goods of the coastal system consist of food, salt, oils and mineral resources, materials for construction such as sand, rock and wood, as well as biodiversity. The services include near-shore protection against storms and hurricanes, regulating gas and climate, storage and cycling nutrients, and control biology (Beaumont et al. 2008; Martínez et al. 2007). IPCC (2014b) also cites that the coastal area provides a wide range of benefits for people, for instance, food security, cultural services, and industrial profits (fishing, aquaculture and tourism) (IPCC 2014b). Currently, due to urbanization, the number of populations in coastal regions is likely to rise rapidly. Particularly, there is the fact that a majority of the megacities in the world have developed near the coastline with a higher population density and a greater speed of population growth and urbanization (Harvey 2006; Neumann et al. 2015; Nguyen, Hiroshi & Miguel 2014).

Consequently, the rapid increase of population and the expanded coastal zone together with over-exploitation of resources has been putting more pressure on the coastal ecosystem (Neumann et al. 2015). In fact, coastal areas have been facing a wide range of problems associated with population growth, including habitat destruction, pollution, water scarcity, biodiversity loss and changes in freshwater flows (Neumann et al. 2015; U.S. Agency for International Development (USAID) 2009).

2.3.2. Climate change effects on the coast

Coastal systems are recognized as becoming more vulnerable to climate change (IPCC 2014a) and other risks due to climate change, such as sea level rise, coastal flooding, salinity intrusion and coastal erosion (Camarsa et al. 2012; Leal Filho 2018). The effects of climate change on the coastal area can be categorized into three main areas: social, economic, and environmental impacts (Leal Filho 2018, p. 471).

Social impacts

Climate change may result in displacement of a large proportion of the coastal population, who might need to resettle to become less susceptible (Leal Filho 2018, p. 472). These displacements result in a greater level of unemployment. McLean et al. (2001) cited that some adverse social effects of climate change to the coastal area, include the loss of tourism profits, the negative impacts on recreation functions of the coastal ecosystem as well as the disappearance of cultural values.

Economic impacts

Due to the importance that the coastal areas generate for people as discussed in section 2.3.1, climate change may threaten the infrastructure and important economic activities of the coastal areas, and thereby, reduce the income of coastal communities as well as decrease the contributed GPD for the countries (Leal Filho 2018). According to the European Commission (2016), the estimated annual costs for implementing adaptation and mitigation strategies for climate change will be about €6 billion by the year 2020.

Environmental impacts

Sea level rise is considered as the most significant threat to coastal areas (Boesch, Field & Scavia 2001; IPCC 2014c). The increase in surface temperature of the ocean is expected to speed up the melting of glacier and ice sheets, leading to sea level rise (Burkett & Davidson 2012). Consequently, a large area of coastline and low-lying areas are likely to be inundated more frequently (IPCC 2014c) and beaches will have increased erosion and destruction of wetland systems (Nicholls et al. 2007). Moreover, sea level rise may lead to the interference of sewage systems and wastewater treatment features in the coastal areas (World Bank 2017).

Climate change influences coastal livelihood

Most communities living in and around coastal zones have their main sources of income from the coastal resources, such as agriculture, aquaculture and fishing. Therefore, these means of living are most susceptible to climate change (Füssel & Klein 2006; Tran & Ha 2014). The World Bank (2007) indicates that the productivity of agriculture crops is affected by five primary factors due to climate change, including precipitation, temperature, climate variability and surface water surplus. According to Calzadilla et al. (2013), agriculture crops are directly affected by transformations of rainfall and temperature. This is because these two elements contribute to determining moisture level and freshwater availability of the soil, which is very important for the growth of crops. Notably, sea level rise may result in increasing saltwater intrusion that seriously influences crop productivity (Seggel & De Young 2016; World Bank 2017).

Fishery and aquaculture, which contribute significantly food security and income generation for coastal communities, also are affected considerably from climate change and variability. Nicholls et al. (2007) claim that beyond the pressure from human activities, fishing communities in coastal zones are increasingly at risk from climate change, especially sea level rise, extreme weather events, such as storms and hurricanes. For example, Akaba and Akuamoah-Boateng (2018) assert that storms and hurricanes may cause damage to fishing assets, such as boats and fishing equipment, causing the loss of income and livelihood as well as food security, especially for poor fishing communities. Mohanty et al. (2010) also identify that climate change causes direct and indirect influence on fish production. As an illustration, these authors cite that an increase of temperature may lead to the migration of fish from one region to another region in order to seek more suitable conditions, thereby, changing the distribution and diversity of fish species in the specific coastal area. In addition, climate change may increase the risk to local fish to diseases (Mohanty et al. 2010).

2.4. Understanding the concepts of vulnerability and adaptation to climate change

The various impacts of climate change cited in the previous sections may exacerbate the vulnerability of some regions and people to its effects. This section will define vulnerability and adaptation as well as explain why the assessment of vulnerability is important in responding to climate change effects. Numerous tools and methods of vulnerability assessment to climate change are also presented in this section.

2.4.1. Vulnerability

Understanding the vulnerability and evaluating vulnerabilities across different levels is a necessary step to prepare efficiently for coping with climate change. This section will present the definitions of vulnerability to climate change, in general, and livelihood vulnerability to climate change in particular.

2.4.1.1. Definition of vulnerability

There is no entirely recognized definition of vulnerability (Birkmann 2006; Downing et al. 2005; Kelly & Adger 2000). The literature of vulnerability has been developed over the past decades while the meaning of vulnerability has been interpreted differently by many scholars (Downing et al. 2005; O'Brien et al. 2007). Particularly, vulnerability has been defined as an emerging concept and has been used in different disciplines, including economics and anthropology, psychology and engineering as well as human geography and ecology (Adger 2006; Downing et al. 2005; Füssel & Klein 2006; Joseph 2012; Wang 2012; Wisner 2004). Under the environmentalist perspectives, the term 'vulnerability' has been used in various contexts, such as food security, livelihood, natural disasters and risk management, global health as well as climate change (Bohle, Downing & Watts 1994; Brooks 2003; Downing et al. 2005; Füssel & Klein 2006; Kelly & Adger 2000).

As early as the 1990s, Liverman (1990, cited in Füssel and Klein (2006, p. 305)) noted that 'vulnerability' has been linked or associated to notions of 'resilience, marginality, susceptibility, adaptability, instability, and risk’. In terms of environmental and social-ecological perspective, Bohle, Downing and Watts (1994, p. 37) defined vulnerability ‘as an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of potentially harmful perturbations’. Similarly, as stated by Cardona (2004, p. 37), vulnerability can be defined as ‘an internal risk factor of the system exposes to a hazard, …, or to be susceptible to damages’. Under the perception that vulnerability is a multi-dimensional concept, Blaikie et al. (1994, p. 11) conceptualized vulnerability as ‘the characteristics of an individual or group related to their ability to anticipate, deal with, resist and recover from the effects of natural hazards”. According to Wisner (2004, p. 183), different uses of the ‘vulnerability’ concept refers to the common notion of ‘potential for disruption or harm’.

Within scholars and literature on climate change, generally, vulnerability is a function of three interacting factors: exposure, sensitivity to impacts and adaptive capacity (Adger 2006; Behnassi 2014; Blythe, Flaherty & Murray 2015; Burton 1997; Kelly & Adger 2000; Marshall et al. 2010; McCarthy et al. 2001; Parry et al. 2007). Exposure refers to natural disasters and climate related risks such as floods, drought, and other extreme climate events. The severity of disaster impacts is not only influenced by the exposure but also the sensitivity of the unit exposed such as ecosystems, households, villages or countries, as well as their adaptive capacity (Ford & Smit 2004; Kelly & Adger 2000; Smit & Wandel 2006). However, because different scholars use the vulnerability concept for different outcomes, there is no consensus on its definition and meaning among climate change literature. To illustrate, some scholars conceptualise vulnerability as being constituted by exposure, sensitivity and resilience (such as Turner et al. (2003). Others define vulnerability as a function of exposure and adaptive ability (Gallopín 2006; Smit & Wandel 2006). In other words, these authors claim that exposure and sensitivity are indivisible while resilience is likely a subset of adaptive capacity. In contrast, Turner et al. (2003) argue that adaptation is as the component of a system's resilience.

According to the 2001 report of the Intergovernmental Panel on Climate Change (IPCC) (McCarthy et al. 2001, p. 6), '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'. Specifically, the concept of vulnerability by the IPCC can be understood as a cohesive measure of the adverse effects of climate variation to a system (Füssel and Klein (2006, p. 306).

2.4.1.2. Definition of livelihood and livelihood vulnerability

As mentioned in the previous section, vulnerability concept is used differently by various scholars within diverse contexts and purposes. Under the climate change context, people and their livelihoods have been significantly affected by climate risks and variation. Therefore, regarding a better response to climate change, it is essential to identify the meanings of livelihood as well as livelihood vulnerability, which has been defined by many scholars.

The theory of livelihood has appeared since the late 1980s as an alternative to the idea of 'employment' in order have a better description of the ways people make a living (Scoones 2009). Chambers and Conway (1992, p. 7) then introduced the definitions of livelihood as the following: 'A livelihood comprises people, their capabilities and their means of living, including food, income and assets'. Similarly, Ellis (2000, p. 10) defines livelihood as assets (including natural, physical, human, financial and social capital), and the accessibility to these assets which together determine the living obtained by an individual or the household'. Thus, the concept of livelihood in general is the means and capacities that are essential to robustly sustain the basic needs of living (Gaillard et al. 2009). Indeed, basic needs comprise food, shelter, clothing and social relations. The ability to meet basic demands profoundly relies on the assets of individuals or households. Notably, to meet these basic needs, it is necessary to develop a sophisticated, circumstantial, diverse and dynamic strategy by households (Scoones 2009; Gaillard et al. 2009).

According to Cutter, Mitchell and Scott (2000), acknowledgement of the vulnerability of a community to climate-related stresses can help effectively prepare for adaptation and mitigation plans. Correspondingly, livelihood vulnerability to climate change can be understood as a result of social and biological vulnerability to climate change impacts (Cutter, Mitchell and Scott (2000, p. 715). Social vulnerability refers to the susceptibility of a community to potential damages or losses from climate change effects and the ability of that community to resist and recover from the disasters. Biophysical vulnerability refers to the type of climate risks, their frequency and locational impacts that expose communities and ecosystems. According to Prowse and Scott (2008), climate change variability intensifies the vulnerability of a community, as well as reduce their capacity to cope with shocks and stresses from disasters.

2.4.2. Definition of adaptation

Within the scholars of climate change, understanding the concept of adaptation or adaptive capacity can help to gain knowledge about the linkage between vulnerability and resilience (Engle 2011; Smit et al. 2001; Smit & Wandel 2006). This section presents the concept of adaptation in various literature and climate change scholars.

The concept of adaptation or adaptive capacity has emerged and used in a wide range of earlier works in sociology and business or organizational management (Chakravarthy 1982; Staber & Sydow 2002). From the biological perspective originating from Darwin (2005), adaptation implies the reaction of a system to its surrounding environment (cited in Engle (2011)). Some other adaptation scholars discuss the concepts of biological change in the flow of material, information, and energy, such as Odum (1971) and Holling (1985).

From the physiological perspective, adaptation implies the progress of genetic or behavioural features which allow systems to deal with changes of environment for surviving and reproducing (Smit & Wandel 2006, p. 283). In this definition, adaptive capacity implies learning and modification (Engle 2011).

In the context of climate change, adaptive capacity refers to the resources and assets that individuals or households own to resist, cope with and recover from disaster shocks (Davis, Haghebaert & Peppiatt 2004; Gaillard et al. 2009). According to the IPCC definition, 'adaptive capacity is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences' (McCarthy et al. 2001, p. 6). From this perspective, there is the linkage between vulnerability and adaptation, of which vulnerability is calculated based on the estimates of potential climate change and adaptive responses (Kelly & Adger 2000). The adaptive capacity of a system affects the efficiency of implementing an adaptation response (Engle 2011).

Furthermore, according to Adger et al. (2007), adaptation is different among various systems and contexts. Indeed, Dulal et al. (2010) and McCarthy et al. (2001) argue that adaptive capacity of households varies and may be influenced by their assets and abilities to act (Dulal et al. 2010; McCarthy et al. 2001), as well as external assets such as social capital, trust and organizations (Adger et al. 2009). Hence, it is necessary to determine what shapes the adaptive capacity and what factors affect the adaptation of households or systems (Adger et al. 2009; Füssel & Klein 2006).

2.5. Climate change vulnerability assessment

The previous section defined the concepts of vulnerability, adaptation and the linkage between them within climate change scholars. Understanding these notions is the fundamental step to measure the vulnerability of a system to climate change and increase the efficiency of response strategies to climate change. However, the evaluation of vulnerability differs between scholars and research. This section aims to review the literature of various vulnerability evaluation approaches to gain an understanding of what the differences among them are.

2.5.1. Vulnerability assessment approach evolution and its process

There has been a variety of indicator-based analyses or assessment tools developed and tested under different fields and contexts to evaluate the vulnerability of systems, or society, to the impacts of climate change (Davis, Haghebaert & Peppiatt 2004; Füssel & Klein 2006; Singh & Nair 2014). These differences have been raised due to diverse interpretations of the vulnerability concept based on disparity of scholars outcomes (Downing et al. 2005). According to Eakin and Luers (2006), a few decades ago, the studies on vulnerability were likely to focus on a 'single stressor and single outcome' approach with the emphases on the physical impacts of climate variability and extreme events and the adverse consequences. For example, vulnerability assessment approaches emerged in 1978 in Burton, Kates & White (cited in Tewari and Bhowmick (2014)) seemed to focus only on damage caused by hazards or environmental risks. Subsequently, many scholars have postulated that vulnerability is not only narrowed to physical impacts of disasters or hazards, but also affected by socio-economic and political environments (Bohle, Downing & Watts 1994; Burton 1997).

Recently, based on and developed from the vulnerability definition of the IPCC, the assessment of vulnerability to climate change is a process which begins with the projection of emissions trends, developing climate change scenarios, forward to finding the biophysical impacts and the identification of adaptation options (Kelly & Adger 2000). The vulnerability assessment to climate change requires the integrated perspectives and coordination of disparate disciplines (O'Brien et al. 2007; Williams et al. 2008). Assessing vulnerability to climate change is a vital component in attempts to define the magnitude of climate risks and providing the background information for developing policies and frameworks to deal with the risks and shocks associated with climate change (Downing et al. 2005; Füssel & Klein 2006; Kelly & Adger 2000). Vulnerability assessment needs to address "who and what is vulnerable, to what stresses, in what way and what existing capacity to adapting to climate risks' (Ford & Smit 2004, p. 389). Downing et al. (2005, p.69) state that the assessment of vulnerability can help to address the questions "to what extent are the anticipated benefits from existing development projects sensitive to the risk of climate change, including variability? and how can the considerations of future climate change be integrated in the designing phase of development projects?'. Overall, it could be interpreted that the vulnerability assessment process involves the evaluation of changes of climate, climate variability and its impacts on different sectors and scales and assessing the vulnerability of livelihoods for strategic planning of climate change adaptation practices.

A crucial component in climate change vulnerability assessment is 'Livelihood Vulnerability' measured at regional and local scales to decrease the vulnerability of people and enhance their capacity to deal with climate change impacts and climate variability (Delica-Willison & Willison 2004; Gaillard et al. 2009). A review of frameworks and approaches to assess the vulnerability of community livelihood will be presented in the next section.

2.5.2. Sustainable Livelihood Framework (SLF)

Sustainable livelihoods (SL) can be understood as 'a way of thinking about the objectives, scope and priorities for development' to improve the effectiveness of eliminating poverty (Majale 2002, p. 3). Originating from development and poverty elimination scholars, the sustainable livelihood approach (SLA) or sustainable livelihood framework (SLF) is seen as a holistic approach to seeking and understanding the roots and dimensions of poverty (Kappel, Michelle & Pedersen 2010; Majale 2002; Morse & McNamara 2013a).

Since the 1990s, SLA or SLF to assess the vulnerability of livelihood to shocks and stresses has emerged, developed and widely used by governmental agencies and organizations, especially non-governmental organizations in development projects and plans in both urban and rural areas (Chambers & Conway 1992; Department For International Development (DFID) 1997; Scoones 1998). Generally, according Morse & McNamara (2013a, p. 3), the first stage of SLA or SLF is identifying the critical assets in livelihood, their tendency over time and space, as well as the characters and effects of shocks and stresses (social, economic and environmental) upon these assets. After that, interventions are considered to address the vulnerability and improve livelihoods.

However, the ways they use the SLA were different due to the disparity of institutions' emphases based on their aspects, approaches and purpose of programs, and thereby, each organization adjusted and created their frameworks to assess the livelihood vulnerability (De Satgé & Holloway 2002; Small 2007). The examples and a comparison of three different frameworks of Scoones (1998), Chambers and Conway (1992), and the Department For International Development (DFID) 1997 will be described as follows:

2.5.2.1. Sustainable rural livelihood framework of Chambers and Conway (1992)

Sustainable Livelihood framework as depicted by Chambers and Conway (1992) (see Figure 2.1) is conceived as a function of assets and capabilities of people's living relating to utilizing, maintaining and enhancing under the influence of stress and shocks.

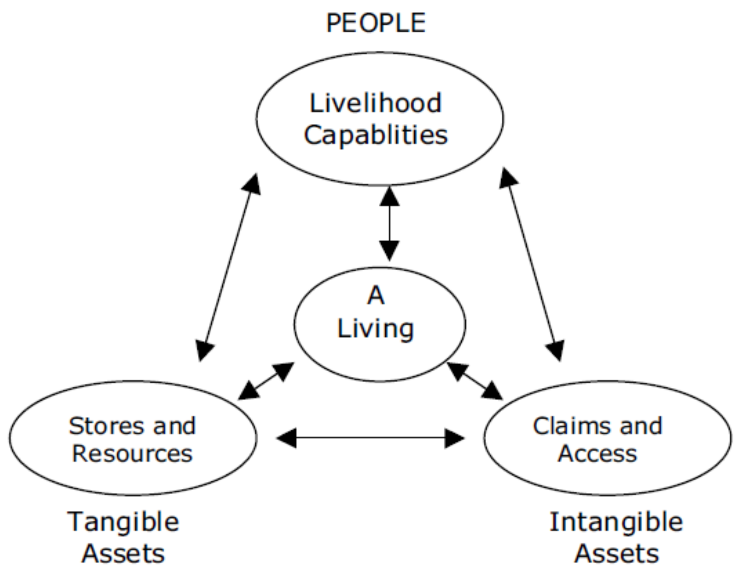


Figure 2.1. Chambers and Conway's sustainable livelihood approaches

(Source: adapted from (Chambers & Conway 1992, p. 7))

Figure 2.1 shows the components and the flow of a livelihood, expressing a living is at the core of a livelihood. Stores and resources, and claims and access, are tangible and intangible assets of a household. Within this framework, the sustainability of a livelihood is seen as 'a function of how assets and capabilities are used, sustained and improved in order to reserve a livelihood' (Chambers & Conway 1992, p. 9).

2.5.2.2. Sustainable rural livelihood framework of Department for International Development (DFID) 1997

The 1997 DFID Sustainable Rural Livelihoods framework (see in Figure 2.2) puts people as the priority concern of assessment, rather than the resources or the institutional factors. This approach has been used in helping poverty elimination.

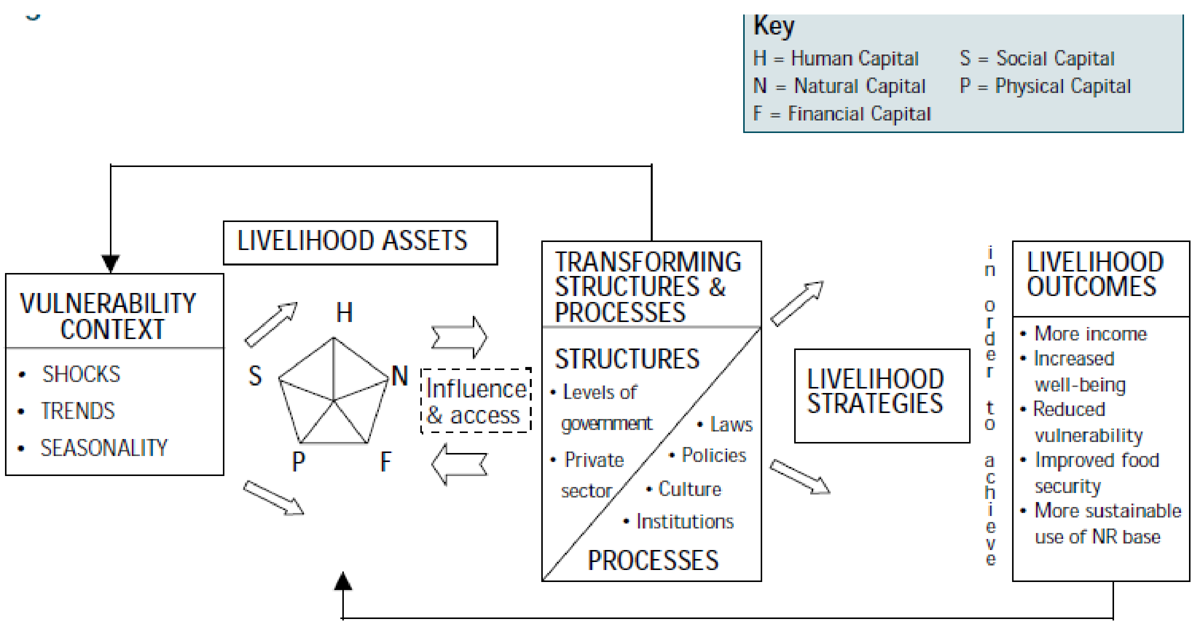


Figure 2.2. The Sustainable Livelihood Framework of DFID

Source: adapted from Department For International Development (DFID) (1997, p. 2)

In this framework, the vulnerability context is identified as the external environment influence, including shocks, trends, and seasonality (DFID 1997, p. 3). The framework illustrates stakeholders as operating in a vulnerability context, within which they have access to certain assets (Kollmair & Gamper 2002). The assets include social, natural, human, physical, and financial capitals, which are influenced by social, institutional and organizational situation (consisting policies, institutions, cultures). This circumstance assertively influences the livelihood strategies of households in order to achieve their livelihood outcomes with increased sustainability.

2.5.2.3. Sustainable rural livelihood framework of Scoones (1998)

The analytical framework of Scoones (1998) for sustainable rural livelihoods is shown in Figure 2.3. Within this framework, a number of different factors affects a livelihood. For example, institutional and organizational processes and structures; livelihood resources such as natural, economic, human and social capital, and livelihood strategies such as livelihood diversifications, agricultural intensification. In other words, the framework emphasizes five interrelating elements, namely: the context, livelihood assets, institutions, livelihood strategies, and livelihood outcomes (Solesbury 2003).

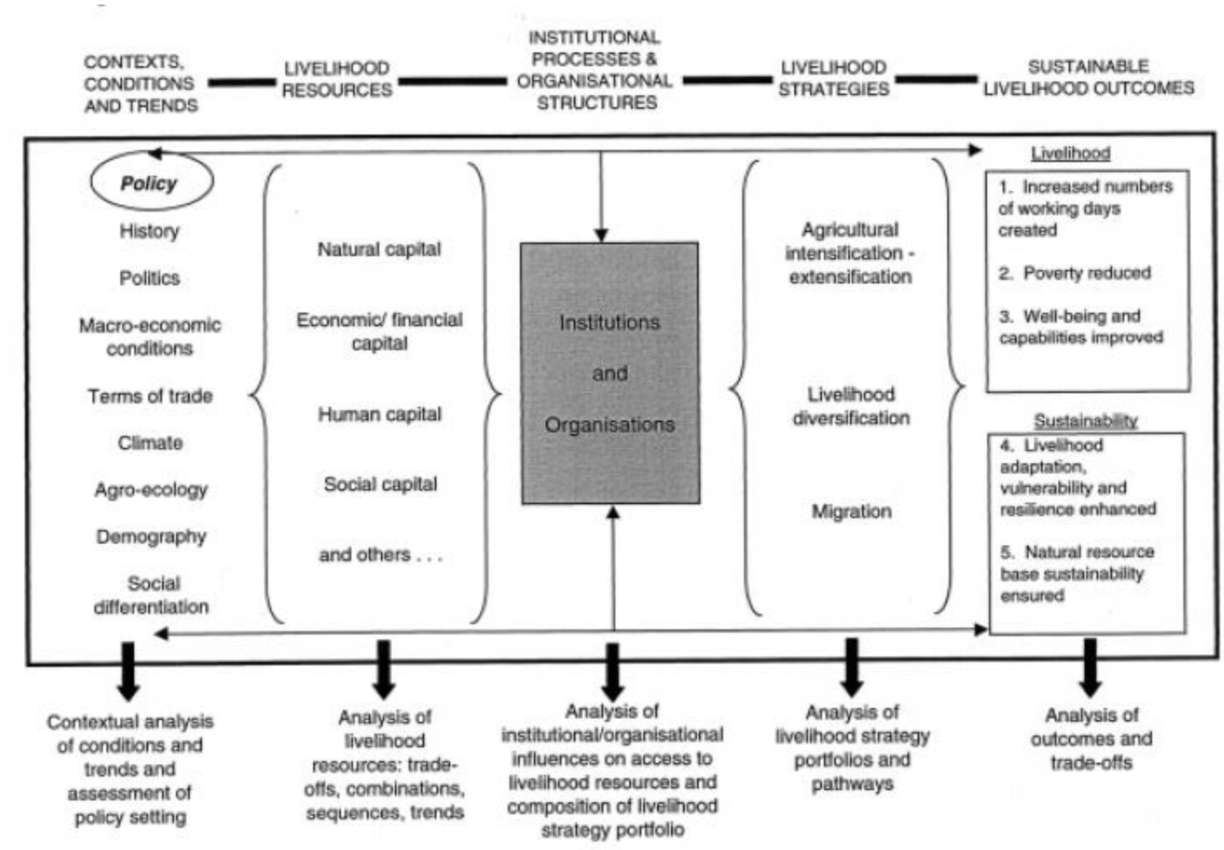


Figure 2.3. A framework for assessing sustainable rural livelihood of Scoones (1998)

(Source: adapted from (Scoones 1998, p. 4))

Overall, the common aims of these three frameworks are eliminating poverty in developing countries (Solesbury 2003) and 'facilitate the planning of concrete projects and programs' (Morse & McNamara 2013b, p. 20). Although these approaches have proven their benefits for measuring the capacity of households to resist shocks, they have some limitations (Hahn, Riederer & Foster 2009; Small 2007). To illustrate, Small (2007, p.32) cites that despite these approaches 'draw together numerous themes from the existing international development principles; they lack the integration of these ideas into a theoretically constant whole'. In addition, Hahn, Riederer and Foster (2009) assert that these SLAs are limited in tackling issues related to the vulnerability and adaptive capacity to climate change, which are considered as two elements contributing more complexity to the livelihood sustainability of households.

According to Kappel, Michelle and Pedersen (2010), the vulnerability context in the SLFs of Chambers and Conway (1992) and DFID (1999) lacks the consideration of climate change vulnerability. In fact, in these two frameworks, the context consists shocks (such as natural disasters, economic inflation, or human health shocks), trends (such as technological trends, economic trends, population trends), and seasonality (such as prices, production, or employment opportunities). Similarly, the framework of Scoones (1998, p. 9) focuses only on three elements, including 'agricultural intensification, livelihood diversification and migration'.

Therefore, under the climate change perspective, it is necessary to develop a livelihood vulnerability approach which involves climate change and climate variability in the local context in order to help communities cope with climate change by appropriate adaptation options at the local scale (Eakin & Bojorquez-Tapia 2008).

2.5.3. Livelihood Vulnerability Index (LVI): the background of forming and developing

Hahn, Riederer and Foster (2009), perceiving the requirement of a new approach to measure livelihood vulnerability which integrates climate exposure and household adaptation practices in the climate change circumstance, developed a Livelihood Vulnerability Index (LVI). They first tested their LVI in two communities of Mozambique. This LVI used multiple indicators, collected from household-level data to assess the sensitivity and adaptive capacity of households to natural disasters and specific vulnerabilities such as water, health, food. This approach may help to avoid the limitation of using secondary data (Hahn, Riederer & Foster 2009), as well as decreasing the reliance on climate models that are usually conducted in large scale and not deliver accurate projections at community levels (Sullivan 2006). Furthermore, instead of forming the vulnerability assessment based on climate projections, the LVI emphasises the evaluation of the strength of existing livelihoods and health systems, together with the capacity of communities to modify the solutions and strategies in responding to climate-related stresses and damages. According to Shah et al. (2013), the structure of the LVI approach provides a realistic framework for the context of the developing countries, where the current issue is the high reliance on natural resources (water and food, for example), especially in rural and coastal communities.

In terms of the expansion of the LVI, there has been a variety of studies apply this index to assess the vulnerability of communities to climate change, especially for coastal community livelihoods. Some scholars have demonstrated using the LVI to assess the vulnerability of communities to climate change impacts in Nepal (Lamichhane 2010; Urothody & Larsen 2010), in Kyoto (Khajuria & Ravindranath 2012), in Trinidad and Tobago (Shah et al. 2013), in Bihar, India (Tewari & Bhowmick 2014), in Ghana (Adu et al. 2017), and in Myanmar (Oo, Van Huylenbroeck & Speelman 2018).

In Vietnam, the LVI has also been applied to assess the sensitivity of communities to climate change impacts in several types of research, such as:

- Assessing risks and vulnerability from flood and climate variability in Mekong Delta (Nguyen, Vo & Chu 2013).
- Investigating the effects of climate change on the livelihood of communities in Dat Mui commune, Ngoc Hien district, Ca Mau province (Le et al. 2014).
- Assessing the vulnerability to climate change impacts on the livelihood of coastal communities in Ca Mau province, Vietnam' (Nguyen 2016).

2.6. Vulnerability assessment to climate change in Vietnam and Thua Thien Hue province

In Vietnam, since the early of the 2000's, there has been a wide range of scholars on theory and assessment vulnerability on different fields and sectors such as social-natural systems, communities and coastal or marine resources at different scales of a region and specific areas. To illustrate, scholars of vulnerability assessment of the coastal zone in Vietnam towards sustainable use of natural resources, protecting the environment and adapting to climate change include (Adger 1999; Mai et al. 2005; Mai et al. 2009; Mai et al. 2011; McElwee et al. 2017; Thai et al. 2009). Correspondingly, there has been some scholars on assessment of the vulnerability to climate change and climate extreme events, such as flooding of households' livelihood and solution options in the Mekong Delta in Vietnam, including McElwee et al. (2017); Vo et al. (2012), and Tran et al. (2013).

Vietnam has been also received the donations from international organizations through several projects and programs regarding vulnerability assessment to climate change. For example, the project 'Climate Change-Induced Water Disaster and Participatory Information System for Vulnerability Reduction in North Central Vietnam (CPIS), funded by the Danish International Development Agency (DANIDA) from 2012 to 2015. One important aspect of this project was assessing the vulnerability of coastal and plain communities in three central provinces of Vietnam, Nghe An, Ha Tinh and Quang Binh, in order to help these communities improve their capacity for disaster preparedness (CPIS Project nd). Within the project 'Asian Cities Climate Change Resilience Network' which was funded by the Rockefeller Foundation from 2008 in three cities, including Can Tho, Da Nang and Quy Nhon, identified the zone, level and group that are most susceptible to climate change (The Rockefeller Foundation 2008).

In Thua Thien Hue province, some projects related to evaluating the vulnerability of communities to climate change have been undertaken with common objectives to evaluate the impacts of climate change on livelihoods of communities who live in coastal areas or rural areas. For example, the project 'Climate Adapted Local Development and Innovation' (as known as VIE/033), jointly funded by the Governments of Vietnam and of the Grand

Duchy of Luxembourg was launched in 2014. The objectives of this project were reducing poverty in the poorest localities, and to mitigate the losses caused by natural disasters and climate change in the most vulnerable areas. This project also aimed to assess the vulnerability and capacity at commune level by using the participatory appraisal (PRA) such as the history of natural disasters, risk map, seasonal calendar and natural disaster season. Another project 'Climate change vulnerability assessment on the Tam Giang - Cau Hai lagoon system, Thua Thien Hue province", which was funded by USAID from 2016 to 2020. The climate change vulnerability is a component of this project which is carried out by GIS and mapping approach.

Overall, these above scholars provide an overview of climate change impacts as well as the vulnerability of socio-economic systems and community livelihoods of Vietnam in general and Thua Thien Hue province in particular. The primary methods that these above research and programs used to assess the vulnerability and adaptive capacity to climate change were the Participatory Rural Appraisal (PRA), community-based approach, climate change scenarios-based method, the top-down approach. Some scholars have built maps for vulnerability to climate change and sea level rise, providing the data and information relating to the impacts of climate change and sea level rise.

However, climate change vulnerability assessment in Vietnam, in general, and in Thua Thien Hue province, in particular, is still fragmented and incoherent as well as lacks the linkage among the projects or research. In addition, the majority of the studies focused on assessing the physical and social impacts of climate change and the vulnerability of natural resources and society at a large scale, such as the national or provincial level. Consequently, these assessments were inadequate, and did not effectively support planning, and provide adaptation strategies at the local level. Therefore, with the aims of assessing the vulnerability and adaptive capacity of communities in the coastal area of Thua Thien Hue province to climate change, this research will apply the Livelihood Vulnerability Index as the central method to analyse the livelihood vulnerability of the communities at the study area.

2.7. Sensitivity analysis

Sensitivity analysis (SA) can be defined as the investigation of potential modifications and errors as well as their influences on the model results (Baird 1989; Pannell 1997). The fact that in all models, parameters are likely more or less uncertain (Baird 1989; Pannell 1997). Thus, there is no doubt that sensitivity analysis is useful for analysing the uncertainty of models contributing to the decision-making process.

There has been a wide range of scholars related to procedures and techniques for SA, such as (Alexander 1989; Baird 1989; Clemson et al. 1995; Hamby 1995; Lomas & Eppel 1992; Pannell 1997). Sensitivity analysis has been used in four main categories; decision support, communication, increased understanding or quantification of the system, and model development (Pannell 1997). The details of using SA is described in Appendix 1.

Within this research, due to the limitation of the LVI and LVI_IPCC of Hahn, Riederer & Foster (2009) is that there was a degree of normative judgement of selecting and adapting the sub-indicators into major components, the results of final scores for major components could be affected. Thus this research applies the sensitivity analysis method to manipulating the changes in the vulnerability of communes based on the change of sub-indicators scores. Based on the results of SA for changes of LVI, this research can discuss what sub-indicators or factors had significant influences to the vulnerability of communes, and hence, recommends some possible solutions for policy-makers in adaptation strategies to climate change for communes.

2.8. Conclusion

The literature synthesized a variety of concepts of the vulnerability with the evolution of this theme in the context of a multi-dimensional perspective. The approach or the framework to assess the vulnerability was also different among scholars. Within the aims of this research, the vulnerability and its assessment in the climate change context is based on the themes of the definition of IPCC. Especially, assessing the vulnerability of community livelihood is the need to increase the ability to cope with climate change and climate variability. Given the importance and the vulnerability of coastal communities to climate change, this research will apply with adjustment of the LVI to assess the vulnerability of coastal livelihoods to natural disasters and climate change. This research targets to make a contribution to policy-makers with a better understanding of the vulnerability of local communities to climate change, and hence, having better strategies or adjustment to help their communities achieve better adaptation to the impacts of climate change.

3. METHODOLOGY

As discussed in Chapter 2, there has been a wide range of frameworks to assess the livelihood vulnerability to climate change. Given the specific context of coastal communities as well as advantages of the Livelihood Vulnerability Index (LVI) discussed in the previous chapter, this research intends to apply LVI method (including LVI and LVI_IPCC models, which was developed from Hahn, Riederer & Foster (2009)) to assess the vulnerability of coastal livelihood at the commune level. The data used in this research is extracted from the large survey data of the Thailand Vietnam Socio Economic Panel project, under the acceptance of the project owners. The detail of data collection, sampling and analysis, as well as the research area, will be presented thoroughly in this chapter.

3.1. Data collection

This research uses mainly the quantitative data from the household survey database which is extracted from the large survey of *'Poverty dynamics and sustainable development: A long-term panel project in Thailand and Vietnam, 2015 - 2024'* under the acceptance of the project management board. This project is the long-term development of the project DFG FOR 756 *“Impact of shocks on the vulnerability to poverty: consequences for the development of emerging Southeast Asian Economies which was implemented from 2007 to 2013”.* The DFG FOR 756 was conducted in Thai Lan and Vietnam, by the Universities of Hanover, Göttingen and Frankfurt which is sponsored by the German Research Foundation (or the Deutsche Forschungsgemeinschaft, DFG). The project has found a unique panel database of 4,400 rural households (mountainous and coastal areas), with 22,000 individuals in 440 villages, distributed over six provinces in Thailand and Vietnam. The data that this research uses is called *‘TVSEP panel wave 6’* (Thailand Vietnam Socio Economic Panel), which was conducted in the period from 1st May 2015 to 30th April 2016. In the database of TVSEP panel wave 6, the data was recorded into 25 main files based on the different sections in the original questionnaire (as shown in Appendix 2). The map of the study area in the TVSEP project is shown in Appendix 3.

In detail, this research extracted the data from the TVSEP panel wave 6 for 5 coastal communes in Thua Thien Hue province, which include Vinh Hien and Loc Binh communes, Phu Loc district, Phu Hai and Phu An communes, Phu Vang district and Huong Phong commune, Huong Tra district (see Figure 3.1).

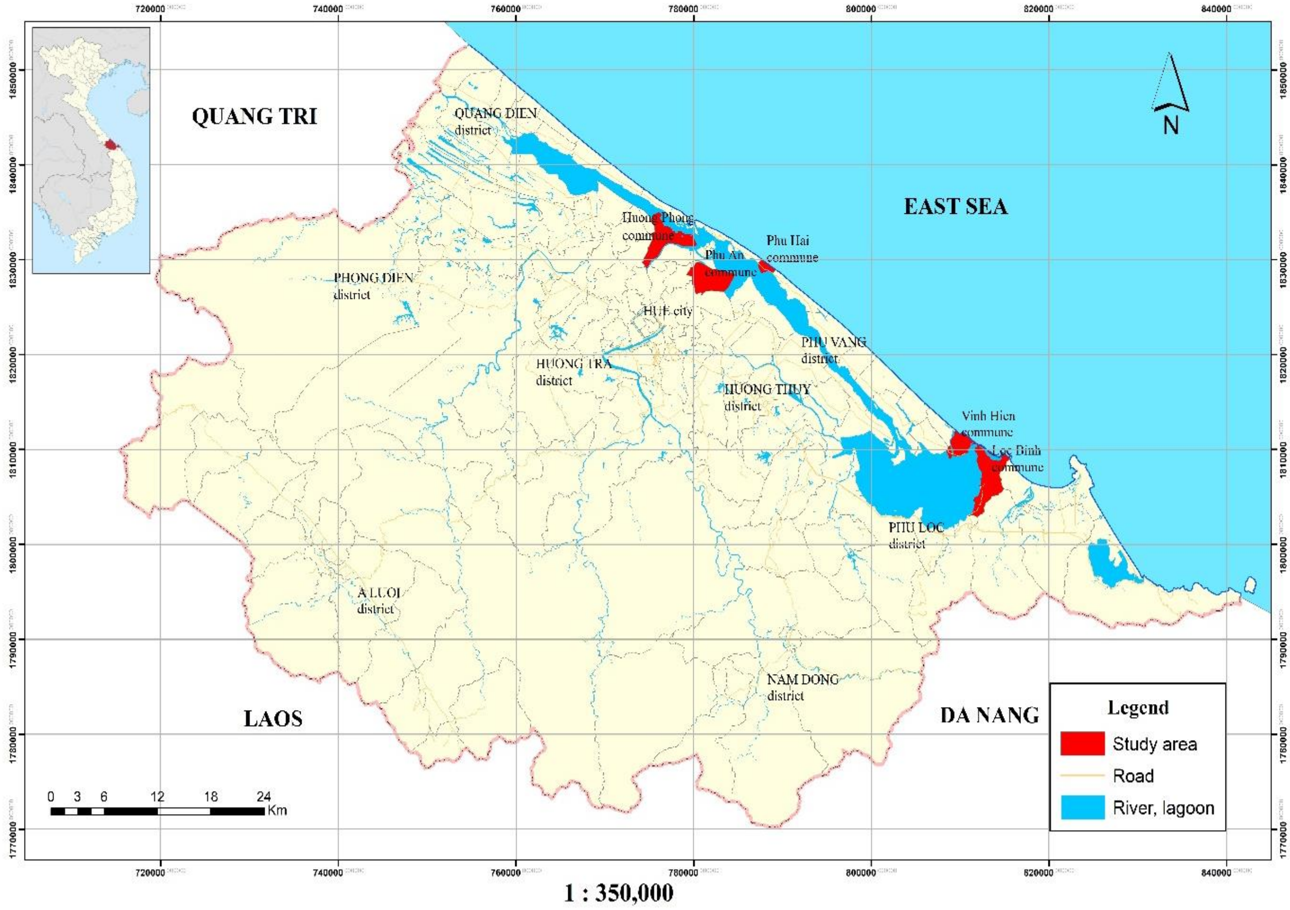


Figure 3.1. Map of research area

3.2. Study area description

All five study communes are highly dependent on agriculture and aquaculture with the majority of land area covered by lagoon and seawater. The socio-economic characteristics of these communes are presented in Table 3.1.

Table 3.1. Social-economic characteristics of five studied communes

Commune	Huong Phong	Phu An	Phu Hai	Loc Binh	Vinh Hien
Areas (ha)	1,567.94	1,135.24	377.72	2,842.23	2,189.78
Population (people)	9,212	9,333	7,233	2,217	7,714
Rate of poor households	7.83%	8.33%	4.99%	19.43%	15.4%
Main livelihoods	Aquaculture, fishing, rice farming	Aquaculture, fishing, rice farming	Aquaculture, fishing	Aquaculture, fishing, rice farming	Aquaculture, fishing,
Geographic location	Bounded by the lagoon	Bounded by the lagoon	Bounded by the lagoon and coastal line	Bounded by the lagoon and coastal line	Bounded by the lagoon and coastal line

Source: Huong Phong Commune People's Committee (CPC) (2016); Phu An Commune People's Committee (CPC) (2016); Loc Binh Commune People's Committee (CPC) (2016); Phu Hai Commune People's Committee (CPC) (2016); (Vinh Hien Commune People's Committee (CPC) 2016); USAID Green Annamites project (2018).

Climate characteristics

The climate of the five communes is characterized by a tropical monsoon climate. The average annual rainfall is 2,500 to 3,000 mm, falling mostly in September, October and November (Thua Thien Hue Department of Natural Resources and Environment 2013). Significantly, during the rainy season, flooding and heavy rainfall might decrease the salinity of aquaculture pond waters which leads to reducing the fishing quantity and aquaculture production. Conversely, in the dry season, prolonged low rainfall, as well as drought may result in water scarcity and reduce agricultural output due to salinization of croplands. In addition, the ecosystem of the lagoon and aquatic resources are also affected by increased salinity during the dry season.

Sea level rise

According to the Vietnam Ministry of Natural Resources and Environment (2016), Thua Thien Hue province is likely to face the highest inundation risk of any of the Central Coast provinces. Table 3.2 shows the risk of inundation with a scenario of 100 cm sea level rise of coastal districts where the five research communes are located.

Table 3.2. Areas at risk of inundation in coastal districts of Thua Thien Hue province with a 100 cm rise in sea level

District	Area (ha)	% of Total Area at Risk of Inundation
Huong Tra	519	7.92
Phu Loc	716	11.19
Phu Vang	278	42.58

Source: Vietnam Ministry of Natural Resources and Environment (2016).

3.3. Data sampling

Within the study area, the data extracted was from 83 households for the five communes. Table 3.3 presents the number of households that this research obtained from the original database.

Table 3.3. Data of extracted sampled households

No.	Communes	Sampled households
1	Loc Binh	20
2	Vinh Hien	15
3	Phu An	18
4	Phu Hai	13
5	Huong Phong	17
Total		**83**

To address the aims of this research, the data was selected and extracted for 7 major indicators: socio-demographic profile, livelihood strategies; health status, social networks, food security, water access, and natural disasters and climate variability. These seven major indicators are used in the Livelihood Vulnerability Index (LVI) which were developed by Hahn, Riederer and Foster (2009) to calculate the level of vulnerability of households to climate change variability. Based on the availability of information groups in the existing database, as well as to adapt to the local context of the research area, this research adjusted and revised the original sub-indicators in the LVI and is presented in Table 3.4. In this research, LVI is designed with a total of 7 major indicators and 29 sub-indicators (Table 3.4). Data was filled and recorded using SPSS software, data analysis was carried out using Microsoft Excel software to apply the equations for the LVI calculation. Table 3.4 also explains how each sub-indicator was quantified and recorded with the relevant survey questions from the TVSEP database.

Table 3.4. Design of Livelihood Vulnerability Index for five coastal communes with the household survey data extracted from the TVSEP panel wave 6 database

Major indicators	No of sub-indicators	Sub-indicators	Assumed explanation to the LVI reflection and sources	Survey question extracted from TVSEP Wave 6	TVSEP Code	Units	Note of data source and recording method
Socio-Demographic Profile	1.1	Percent of dependency (households' members who are over employment age (under 15 and over 60 years old) (is issued in Vietnam Labor Laws (APAC 2017)	High dependency percentage implies less capacity to adapt to climate change	Please list the household members with the ages	Section 2.1 (4)	%	Filter and extract data from the original database for head of each household, with data file name "mem", code "@__21004". The data for household member under 18 and over 60-year-old will be counted and recorded for each household.
	1.2	Percent of households where the head are female	Women are usually more vulnerable than men (Brody, Demetriades & Esplen 2008)	Please list the household members with gender	Section 2.1 (3)	%	Filter and extract data from the original database for head of each household, with data file name "2.2. HH member, education and health", code "@__21004"
	1.3	Percent of households where household heads did not attend school	High education level help people be more conscious and better cope with the changes of environmental conditions (Hess & Collins 2018; Panthi et al. 2015)	Has your family's member ever been to school?	Section 2.2 (6)	%	Filter and extract data from the original database for head of each household, with data file name "mem", code "@__22006"
Livelihood Strategies	2.1	Percent of households have main income source from agriculture and aquaculture	Dependency on agriculture faces high risk from climate change impacts (Organization for economic cooperation and development (OECD) 2015; Wreford, Moran & Adger 2010))	Main occupation of family is engaged in own agriculture (including livestock and aquaculture) in last 1 year (5/15 - 4/16)	Section 2.1 (14)	%	Extract from the original database for households, include household members, "with data file name "mem", code "@__21014". The data will be recorded as "Yes" or "No" according to each variable.
	2.2	Percent of households without second main occupation	Income diversification increases adaptive capacity (Swanson et al. 2007)	Second occupation of family member in last 1 year (5/15 - 4/16)	Section 2.1 (15)	%	Extract from the original database for households, include household members, "with data file name "mem", code "@__21015". The data will be recorded as "Yes" or "No" according to each variable.

Table 3.4 (continued)

Major indicators	No of sub-indicators	Sub-indicators	Assumed explanation to the LVI reflection and sources	Survey question extracted from TVSEP Wave 6	TVSEP Code	Units	Note of data source and recording method
	2.3	Percent of households have unemployed member	High percentage means less adaptive capacity to climate variability (Cutter et al. 2008)	Main occupation of family in last 1 year	Section 2.1 (14)	%	Extract from the original database for households, include household members, "with data file name "mem", code "@__21014". The data with code of 12 will be recorded as "yes" and otherwise is "No"
	2.4	Percent of households without saving a part of income	Saving helps strengthen adaptive capacity when disasters happen (Cutter et al. 2008)	Do you or your family have any saving?	Section 71 E (1)	%	Extract from the original database (data file name "hh", code "@_x71501"
Social Networks	3.1	Percent of households who lent or borrowed money or goods	Large amount of borrowed money shows the financial stress, and thereby, less ability to adapt to changes and stresses (Abdul-Razak & Kruse 2017)	Did you ever borrow cash or goods (rice, fertilizer etc.?)	Section 7.1A (1)	%	Extract from the original database (data file name "hh", code "@_x71101"
	3.2	Percent of households who did not receive money from family member or others	High amount of receiving strengthens adaptive capacity to financial stress caused by climate change (Adger et al. 2009)	Amount of money/value of gifts the household received from family member (section 2.1) and relatives (2.4) between 5/15 - 4/16	Section 2.1 (20) and 2.4 (12)	%	Extract and record from the original database, with the data file name "mem", code "@__21020". The data for a certain amount of money will be recorded as "Yes" and No for the total of money is "0" or no recorded data
	3.3	Percent of households who did not receive advice on farming activities	Reducing the risk of farming related to techniques and extreme climate events and thereby, less vulnerability to climate change (Abdul-Razak & Kruse 2017)	Did you receive regularly advice on farming activities by extension services last year?	Section 4.4 (20)	%	Extract from the original data for household, with data file name "hh", code "@__44020"
Health Status	4.1	Average distance to go to health facilities	The shorter distance, the less vulnerability (Adu et al. 2017)	Where is the facility where your family got main treatment?	Section 2.3 (13a)	km	Record from the original data. The location of health facility will be recorded as estimated distance. Then, the ranges of distance will be recorded as "1": <5km; "2": 5-10km; "3": 10-15km; "4": 20-25km; and "5" >30km

Table 3.4 (continued)

Major indicators	No of sub-indicators	Sub-indicators	Assumed explanation to the LVI reflection and sources	Survey question extracted from TVSEP Wave 6	TVSEP Code	Units	Note of data source and recording method
	4.2	Percent of households with members having chronic illness (get sick very often)	Family members who have chronic illness and disability are likely more vulnerable (Levy & Patz 2015)	How healthy is each household member?	Section 2.3 (3)	%	Extract and record from the original database, with the data file name "mem", code "@__23003". The answer of "1. Healthy" and "2. Can manage" will be recorded as "No" and the answer of "3.Sick" will be recorded as "Yes"
Food Security	5.1	Percent of households who have inadequate food for the whole year	Limited source of food leads to more sensitivity to climate change impacts (World Bank 2010)	During the past 12 months, did your family borrow food (rices etc.)?	Section 7.1A (4) - Code 4	%	Extract and record from the original database, with the data file name "borr", code "@_x71104". The answer of code 4 (Food (rice, etc.) will be recorded as "Yes", and other answers and no data will be recorded as "No"
	5.2	Percent of households who did not save seeds	Lower percentage implies more adaptive capacity to disasters and climate change impacts	Did your family reserve seeds for growing crops?	Section 4.2 (13a)	%	Extract from the original data, with the data file name “Crops", code "@_x42013a". The data with number of quantities will be recorded as "Yes", and otherwise will be recoded as "No
	5.3	Percent of households who did not reserve a part of agriculture production	Lower percentage implies more adaptive capacity to disasters and climate change impacts (Ali et al. 2017)	Do your family usually store part of your agricultural production?	Section 4.2 (30)	%	Extract from the original data, with the data file name "hh", code "@__42030"
Water Access	6.1	Percent of households who used natural sources of water for drinking	Higher percentage implies higher the sensitivity to disasters (Etwire et al. 2013)	What is the main source of drinking water?	Section 9.2 (12)	%	Extract and record from the original data, with the data file name "house", code "@__92012". The answer will be recorded as "Yes" for code 4, 5, 6 (well, rain water and river, lake, pond), and others will be recorded as "No"
	6.2	Percent of households who did not have tap water inside house	Limitation the risk of water shortage or conflict of using water	What is the main source of drinking water?	Section 9.2 (12)	%	Extract and record from the original data, with the data file name "house", code "@__92012". The answer will be recorded as "Yes" for code1 - Tap inside house and others will be recorded as "No"

Table 3.4 (continued)

Major indicators	No of sub-indicators	Sub-indicators	Assumed explanation to the LVI reflection and sources	Survey question extracted from TVSEP Wave 6	TVSEP Code	Units	Note of data source and recording method
	6.3	Percent of households who used natural source of water for agriculture land (rainfed, well)	Higher percentage implies higher the sensitivity	What is the main source of water supply for your agriculture, aquaculture and gardening land?	Section 4.1 (14)	%	Extract from the original data, with the data file name "land", code "@__41014". The answer with code 1 - rainfed, and 3 - irrigated (well) will recorded as "Yes", and other answers will be recorded as "No"
Natural Disasters and Climate Variability	7.1	Percent of households affected by flooding of agriculture land in last three years (2013 - 2016)	High percentage reflects higher exposure to climate change impacts	Was your household affected by flooding of agriculture land between 5/13 - 4/16?	Section 3.1 (2) - Code 10	%	Extract from original data, with the data file name "shock", code "@_x31002". The answer of code 10-Agriculture flooding" will be recorded as "Yes", and otherwise answered and no data will be recorded as "No".
	7.2	Percent of households affected by drought in last three years (2013 - 2016)	High percentage reflects higher exposure to climate change impacts	Was your household affected by drought between 5/13 - 4/16?	Section 3.1 (2) - Code 11	%	Extract from the original data, with the data file name "shock", code "@_x31002". The answer of code 11-Drought" will be recorded as "Yes", and otherwise answered and no data will be recorded as "No".
	7.3	Percent of households affected by storm in last three years (2013 - 2016)	High percentage reflects higher exposure to climate change impacts	Was your household affected by storm between 5/13 - 4/16?	Section 3.1 (2) - Code 55	%	Extract from original data, with the data file name "shock", code "@_x31002". The answer of code 55-Storm" will be recorded as "Yes", and otherwise answered and no data will be recorded as "No".
	7.4	Percent of households affected by pest and livestock diseases in last three years (2013 - 2016)	High percentage reflects higher exposure to climate change impacts	Was your household affected by pest and livestock diseases between 5/13 - 4/16?	Section 3.1 (2) - Code 63	%	Extract from original data, with the data file name "shock", code "@_x31002". The answer of code 63-Pest and livestock diseases" will be recorded as "Yes", and otherwise answered and no data will be recorded as "No".
	7.5	Percent of households who did not perceive the change of the climate in general	High level of perception of climate change helps to increase the success of preventing and mitigate climate change impacts (Toan et al. (2014)	Do you think the climate in general has been changing since the time you lived in this place?	Section 3.2 (24)	%	Extract from the original household data, with the data file name "Questions at household level", code "@__32024"

Table 3.4 (continued)

Major indicators	No of sub-indicators	Sub-indicators	Assumed explanation to the LVI reflection and sources	Survey question extracted from TVSEP Wave 6	TVSEP Code	Units	Note of data source and recording method
	7.6	Percent of household members affected by these above events	High percentage reflects higher exposure to climate change impacts	How many members in your household affected by flooding/drought/storms?	Section 3.1b (2a) (Code 10,11,55)	%	Extract from original data, with the data file name "shock", code "@_x31002a". The answer of code 10; 11; and 55 will be recorded as "Yes" and otherwise will be recorded as "No"
	7.7	Percent of households that have loss of income and assets because of those events	High percentage reflects higher exposure to climate change impacts	Estimated total loss of income and assets of your household due to the events (flooding, storm, drought, pests and livestock diseases)	Section 3.1b (5a & 6a))	%	Extract from original data, with the data file name "shock", code "@_x31005a and @_x31006a". The data for a certain amount of money will be recorded as "Yes" and No for the total of money is "0" or no recorded data
	7.8	Percent of households who did not have a plan for applying mitigation/prevention strategies	Mitigation and prevention plans help to increase the resilience to the shocks and stresses (Paton & Johnston 2001)	Do you do anything to prevent [event] from happening OR to mitigate its impact on your household's income and assets?	Section 3.2 (13)	%	Extract from the original household data, with the data file name "Risks", code "@__32013". The data for answer with codes are 10,11,55,63 will be recorded as "Yes", and otherwise will be recorded as "No".
	7.9	Percent of households who did not adjust their agricultural activities	This helps to increase the resilience of livelihoods to disasters and climate risks (Smit & Wandel 2006)	"How have you adjusted your agricultural activities?"	Section 3.2 (30)	%	Extract from the original data with the data file name "hh", code "@__32030". With the recorded answer is 20 - No adjustment, the data will be recorded to "No" and otherwise is "Yes"

3.4. Missing data

During the extraction step for LVI data from the original database of the TVSEP panel wave 6, there are some missing data in terms of collecting data for sub-indicators for LVI (as presented in Table 3.4) which are shown in Table 3.5.

Table 3.5. Missing data regarding sub-indicators collection for LVI calculation

No. of sub-indicators	Sub-indicators	Missing data/total of samples				
		Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong
7.1	Percentage of households affected by flooding of agriculture land in last three years (2013 - 2016)	0/20	1/15	1/18	3/13	2/17
7.2	Percentage of households affected by drought in last three years (2013 - 2016)	0/20	1/15	1/18	3/13	2/17
7.3	Percentage of households affected by storm in last three years (2013 - 2016)	0/20	1/15	1/18	3/13	2/17
7.4	Percentage of households affected by pest and livestock diseases in last three years (2013 - 2016)	0/20	1/15	1/18	3/13	2/17
7.6	Percent of household members affected by these above events	0/20	1/15	1/18	3/13	2/17
7.7	Percent of households that have loss of income and assets because of those events	0/20	1/15	1/18	3/13	2/17
4.1	Average distance to go to health facilities	7/20	5/15	8/18	4/13	6/17

The frequency of missing data for sub-indicators from 7.1 to 7.4 is the same for each commune because the data was extracted from one question for different codes of responded data as presented in Table 3.4. Similarly, there is the same figure for missing data of sub-indicators 7.6 and 7.7 compared to 7.1 to 7.4 because the responded data for these sub-indicators were linked together. To deal with these missing data in the analysis, the calculation of the percentages of these sub-indicators were based on the number of respondents for those questions excluding missing data. For example, for Vinh Hien, Phu

An, Phu Hai and Huong Phong communes, the percentages will be calculated by actual values per the total of 14, 17, 10, and 15 respondents respectively.

In terms of missing data for the distance from home to the health facilities, although the percentage of missing data is significant, this did not affect the result because it was calculated by "average" function.

3.5. Data analysis and calculation

The extracted data from the TVSEP panel wave 6 were imported to Excel for analysing and calculating the LVI and the LVI_IPCC by 5 specific equations below. All these equations were adapted from Hahn, Riederer & Foster (2009).

3.5.1. Composite Livelihood vulnerability index (LVI) calculation (Model 1)

Step 1: Because each indicator is quantified on various scales, it will be normalized as an index by the following equation:

$$\text{Index } S_c = \frac{S_c - S_{min}}{S_{max} - S_{min}} \qquad \textit{(Equation 1)}$$

In this equation, S_c is the actual value of sub-indicators for commune *c*; S_{min} and S_{max} are the minimum and maximum values of each sub-indicator that are collected from the extracted survey data for the 5 communes.

Step 2: After standardization, each major indicator is averaged from the standardized sub-indicators, using equation 2:

$$M_c = \frac{\sum_{i=1}^{n} index_{Sci}}{n} \qquad \textit{(Equation 2)}$$

M_c represents each of the seven major indicators, in turn, for commune *c* (including Socio-demographics, Livelihood strategies, Social networks, Health status, Food security, Water access, or Natural disasters and climate variability); $index_{Sci}$ is the sub-indicators, indexed by i, that structure each major indicator; and n is the quantity of sub-indicators in each major indicator.

Step 3: The composite LVI value of each commune is calculated by averaged seven major indicators, using Equation (3):

$$LVI_c = \frac{\sum_{i=1}^{7} W_{Mi} M_{ci}}{\sum_{i=1}^{7} W_{Mi}} \qquad \textit{(Equation 3)}$$

In this formula, LVI_c is the Livelihood Vulnerability Index for commune c; W_{Mi} is the number of sub-components for each major indicator; M_{ci} is the value of each major indicator which was calculated from Equation 2. In this research, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable).

The example for calculating the Socio-demographic component for the LVI and the composite LVI value of one commune (Loc Binh) is illustrated in Appendix 4.

3.5.2. LVI_IPCC (LVI takes into consideration IPCC definition) (Model 2)

Based on the definition of the IPCC, vulnerability is a function of exposure, sensitivity and adaptive capacity of the system. In this model, the same seven major indicators of the composite LVI model were grouped for measuring the three contributing factors (exposure, sensitivity and adaptive capacity) to the vulnerability. Three steps: inverse of sub-indicators for adaptive capacity; grouping of indicators; and calculation of LVI_IPCC are detailed below.

The contribution of the seven major indicators in the LVI to the level of vulnerability of communities as IPCC define is presented in Table 3.6.

Table 3.6. The relationship between LVI major indicators and the IPCC definition

LVI major components	IPCC definition of vulnerability
Natural disasters and climate variability	Exposure (E)
Socio-demographic profile	Adaptive Capacity (A)
Livelihood strategies	
Social networks	
Health status	Sensitivity (S)
Food security	
Water access	

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

Step 1: The same sub-indicators (see Table 3.4) are used in this model. However, for adaptive capacity, the inverse of all sub-indicators for adaptive capacity are taken before averaging them into respective major indicators to fit the LVI_IPCC framework. For example, the sub-indicators 'Percent of households where the head are male' will be used for this method instead of 'Percent of households where the head are female'. The reason for taking that inverse is that the high percentage of the female head may increase the vulnerability of households as well as communities, and hence, reducing their adaptive capacity.

Step 2: The major indicators are grouped into three categories; exposure, adaptation capacity and sensitivity by using the equation 4:

$$CF_c = \frac{\sum_{i=1}^{n} W_{Mi} M_{ci}}{\sum_{i=1}^{n} W_{Mi}} \qquad \textit{(Equation 4)}$$

of which: CF_c represents a contributing factor according to the IPCC definition (including exposure, sensitivity, and adaptation capacity) for commune *c*; M_{ci} represent the major components for commune *c* which indexed by i, W_{Mi} represents the weight of each major sub-indicator; and n is the number of major indicators in each contributing factor.

Step 3: Calculating the overall LVI_IPCC values by combining the three contributing factors, using the equation 5:

$$LVI\_IPCC_c = (E_c - A_c) \times S_c \qquad \textit{(Equation 5)}$$

In this equation:

- LVI_IPCCc is the LVI value for commune c;
- E is the calculated exposure value for commune *c*;
- A is the calculated adaptive capacity value for commune *c*; and
- S is the calculated sensitivity value for commune *c*

In this research, the LVI_IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable). An example of calculating contributing factors and overall LVI_IPCC value of the LVI_IPCC model for Loc Binh commune is presented in Appendix 5.

3.6. ANOVA analysis

After calculating the vulnerability of each commune based on the LVI and LVI_IPCC models, this research used a one-way ANOVA analysis, using IBM SPSS Statistics 25 software to investigate the statistically significant differences in means of each major indicator of LVI as well as LVI_IPCC between communes. The significant differences in mean LVI and LVI_IPCC models also was examined using this method.

In one-way ANOVA analysis, each major indicator variable was the input for the 'dependent list' and the commune variable was the input for 'factor'. If there were significant differences between the means (sig. (*p_value*) of one-way ANOVA ≤ 0.5), the post-hoc test was used analysed to compare the details of significantly differences among communes.

3.7. Sensitivity analysis

The sensitivity analysis (SA) method is used in this research to identify the influences of major indicators and sub-indicators to the vulnerability of communes. The results of the sensitivity analysis also suggest what factors may affect decision-making in terms of adaptation strategies for the communes.

By using this method, this research will examine the changes to LVI of communes based on sub-indicators by re-calculating LVI scores by increasing by 20 percent each of the 27 sub-indicators and then comparing to the original calculated scores.

3.8. Summary

This chapter presents the research methodology with the detailed techniques and approaches to collect and analyse data to achieve the research objectives. The source of data obtained from the TVSEP panel wave 6 to apply the LVI and LVI_IPCC models of Hahn, Riederer & Foster (2009) for calculating the vulnerability of the 5 coastal communes of Thua Thien Hue province, Vietnam.

4. RESULTS

This chapter presents the results of analysing the Livelihood Vulnerability Index (LVI) for five coastal communes. The results indicate the vulnerability of each commune along with the comparison of the level of vulnerability among these five communes based on each major indicator. This chapter also presents the result of the LVI calculation based on the IPCC definition (LVI_IPCC) as well as the results of ANOVA analysis for examining the statistical differences in means of major indicators of the LVI and LVI_IPCC models. The sensitivity analysis results also are presented in this chapter.

Livelihood Vulnerability Index (LVI) sub-indicator original values for each commune and the minimum and maximum values for the five communes are presented in Table 4.1. In this table, a majority of sub-indications was valued by percentage, the minimum and maximum values of them are 0 and 100 respectively. In terms of the sub-indicators for the distance from the household to go to health facilities, it was measured by kilometre.

The major indicators and the overall LVI value for each commune are presented in Table 4.2.

4.1. Commune's livelihood vulnerability index (LVI)

This section will present the results of the vulnerability calculation based on the LVI model outlined in subsection 3.5.1 of Chapter 3 (Methodology). The vulnerability of five communes in terms of each of the seven major indicators; socio-demographics, livelihood strategies, social networks, health status, food security, water access, and natural disasters and climate variability will be presented in section 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5, 4.1.6, and 4.1.7 in order. Section 4.1.8 will present the overall score of LVI calculation for the five communes.

4.1.1. Socio-demographic profile vulnerability

Socio-demographic profile vulnerability indicators in this research uses three sub-indicators to analyse and calculate the vulnerability for each commune as shown in Table 4.1. Table 4.2 shows that the highest vulnerability in terms of socio-demographic profile was found in Loc Binh commune (0.303) and the lowest vulnerability was in Phu An commune (0.148).

Dependency percentage

The dependency percentage (percent of household members who are under 18-years-old and over 65-years-old) was highest for Huong Phong commune (0.325) and lowest for Vinh Hien commune (0.221). In Phu Hai commune, the dependency proportion was fairly high (0.316), with a small difference compared to Huong Phong commune. Meanwhile, the value of dependant family members in Loc Binh and Phu An commune were 0.260 and 0.277 respectively.

Percentage of households with female heads and percentage of households where household heads did not attend school sub-indicators

The results as shown in Table 4.2 indicate that Loc Binh commune, where the majority of household-heads are female (0.300) has higher vulnerability. Loc Binh also had the highest score of household heads who have not attended school with 0.350. The education level of household-head of Loc Binh commune was the lowest, leading to higher vulnerability.

In contrast, Table 4.2 shows Phu An commune has the lowest number of female household-heads (0.111) and the lowest rate of household head who has not attended school (0.056), indicating a high education level, and thus lowest vulnerability. The figures for female household-heads and household-heads who has not attended school were recorded for Vinh Hien (0.200 vs 0.267), Phu Hai (0.231 vs 0.308) and Huong Phong (0.176 vs 0.059) respectively.

Table 4.1. The original, standardized, minimum and maximum values of sub-indicators of Livelihood Vulnerability Index (LVI) for five communes

Major indicators	Sub-indicators	Unit	Original values and standardized for 5 communes (Sc)					Maximum value in 5 communes (Smax)	Minimum value in 5 communes (Smin)
			Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong		
Socio-Demographic Profile	*Dependency percentage*	%	25.98	22.11	27.68	31.58	32.46	100	0
	Percent of households where the head are female	%	30.00	20.00	11.11	23.08	17.65	100	0
	Percent of households where household head has not attended school	%	35.00	26.67	5.56	30.77	5.88	100	0
Livelihood strategies	*Percent of households who have main income source from agriculture and aquaculture*	%	70.00	60.00	77.78	30.77	88.24	100	0
	Percent of households without second main occupation	%	50.00	60.00	44.44	38.46	17.65	100	0
	Percent of households who have unemployed member	%	5.00	33.33	11.11	23.08	11.76	100	0
	Percent of households without saving part of income	%	65.00	26.67	50.00	38.46	64.71	100	0
Social Networks	*Percent of households who borrowed money or goods*	%	75.00	73.33	83.33	69.23	94.12	100	0
	Percent of households who did not receive money from family member or others	%	70.00	66.67	72.22	69.23	70.59	100	0
	Percent of households who did not receive advice on farming activities	%	100.00	93.33	83.33	100.00	76.47	100	0
Health status	*Average distance to go to health facilities*	km	4.00	3.40	2.60	3.33	2.64	5	1
	Percent of households with members having chronic illness (get sick very often)	%	25.00	46.67	44.44	46.15	58.82	100	0
Food security	*Percent of households who have inadequate food for whole year*	%	0.00	0.00	0.00	15.38	0.00	100	0
	Percent of households without saving seeds	%	95.00	100.00	88.89	100.00	94.12	100	0
	Percent of households without reserving a part of agriculture production	%	45.00	80.00	33.33	84.62	35.29	100	0

Table 4.1 (continued)

Major indicators	Sub-indicators	Unit	Original values and standardized for 5 communes (Sc)					Maximum value in 5 communes (Smax)	Minimum value in 5 communes (Smin)
			Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong		
Water access	*Percent of households who used natural source of water for drinking*	%	25.00	26.67	0.00	7.69	0.00	100	0
	Percent of households who did not have tap water inside house	%	20.00	40.00	0.00	7.69	5.88	100	0
	Percent of households who used natural sources of water for agriculture land (rainfed, well)	%	55.00	26.67	16.67	30.77	11.76	100	0
Natural Disasters and Climate Variability	*Percent of households affected by flooding of agriculture land in last three years (2013 - 2016)*	%	5.00	7.14	11.76	0.00	6.67	100	0
	Percent of households affected by drought in last three years (2013 - 2016)	%	15.00	14.29	0.00	0.00	26.67	100	0
	Percent of households affected by storm in last three years (2013 - 2016)	%	5.00	14.29	0.00	0.00	0.00	100	0
	Percent of households affected by pest and livestock diseases in last three years (2013 - 2016)	%	35.00	35.71	23.53	20.00	46.67	100	0
	Percent of households who did not perceive the change of the climate in general	%	10.00	6.67	22.22	23.08	0.00	100	0
	Percent of household members affected by the above events	%	35.00	50.00	35.29	20.00	66.67	100	0
	Percent of households that have loss of income and assets because of those events	%	40.00	50.00	35.29	30.00	66.67	100	0
	Percent of households without mitigation/prevention strategies	%	35.00	40.00	27.78	61.54	41.18	100	0
	Percent of households without adjustment in their agricultural activities	%	50.00	86.67	66.67	100.00	29.41	100	0

Table 4.2. Major indicators and overall LVI for five communes

No	Sub-indicators	Standardized values of sub-indicators for 5 communes (Index Sc = $\frac{S_c - S_{min}}{S_{max} - S_{min}}$)					Major indicators	Major indicators for 5 communes (Mc = $\frac{\sum_{i=1}^{n} index_{Sci}}{n}$)				
		Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong		Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong
1.1	*Dependency percentage*	0.260	0.221	0.277	0.316	0.325	**Socio-Demographic Profile (M1)**	**0.303**	**0.229**	**0.148**	**0.285**	**0.187**
1.2	*Percent of households where the head are female*	0.300	0.200	0.111	0.231	0.176						
1.3	*Percent of households where household head has not attended school*	0.350	0.267	0.056	0.308	0.059						
2.1	*Percent of households who have main income source from agriculture and aquaculture*	0.700	0.600	0.778	0.308	0.882	**Livelihood Strategies (M2)**	**0.475**	**0.450**	**0.458**	**0.327**	**0.456**
2.2	*Percent of households without second main occupation*	0.500	0.600	0.444	0.385	0.176						
2.3	*Percent of households who have unemployed member*	0.050	0.333	0.111	0.231	0.118						
2.4	*Percent of households without saving part of income*	0.650	0.267	0.500	0.385	0.647						
3.1	*Percent of households who borrowed money or goods*	0.750	0.733	0.833	0.692	0.941	**Social Networks (M3)**	**0.817**	**0.778**	**0.796**	**0.795**	**0.804**
3.2	*Percent of households who did not receive money from family member or others*	0.700	0.667	0.722	0.692	0.706						
3.3	*Percent of households who did not receive advice on farming activities*	1.000	0.933	0.833	1.000	0.765						
4.1	*Average distance to go to health facilities*	0.750	0.600	0.400	0.583	0.409	**Health status (M4)**	**0.500**	**0.533**	**0.422**	**0.522**	**0.499**
4.2	*Percent of households with members having chronic illness (get sick very often)*	0.250	0.467	0.444	0.462	0.588						
5.1	*Percent of households who have inadequate food for whole year*	0.000	0.000	0.000	0.154	0.000	**Food security (M5)**	**0.467**	**0.600**	**0.407**	**0.667**	**0.431**
5.2	*Percent of households without saving seeds*	0.950	1.000	0.889	1.000	0.941						

Table 4.2 (continued)

No	Sub-indicators	Standardized values of sub-indicators for 5 communes (Index Sc = $\frac{S_c - S_{min}}{S_{max} - S_{min}}$)					Major indicators	Major indicators for 5 communes (Mc = $\frac{\sum_{i=1}^{n} index_{Sci}}{n}$)				
		Loc Binh	**Vinh Hien**	**Phu An**	**Phu Hai**	**Huong Phong**		**Loc Binh**	**Vinh Hien**	**Phu An**	**Phu Hai**	**Huong Phong**
5.3	*Percent of households without reserving a part of agriculture production*	0.450	0.800	0.333	0.846	0.353						
6.1	*Percent of households who used natural source of water for drinking*	0.250	0.267	0.000	0.077	0.000						
6.2	*Percent of households who did not have tap water inside house*	0.200	0.400	0.000	0.077	0.059	**Water stress (M6)**	**0.333**	**0.311**	**0.056**	**0.154**	**0.059**
6.3	*Percent of households who used natural sources of water for agriculture land (rainfed, well)*	0.550	0.267	0.167	0.308	0.118						
7.1	*Percent of households affected by flooding of agriculture land in last three years (2013 - 2016)*	0.050	0.071	0.118	0.000	0.067						
7.2	*Percent of households affected by drought in last three years (2013 - 2016)*	0.150	0.143	0.000	0.000	0.267						
7.3	*Percent of households affected by storm in last three years (2013 - 2016)*	0.050	0.143	0.000	0.000	0.000						
7.4	*Percent of households affected by pest and livestock diseases in last three years (2013 - 2016)*	0.350	0.357	0.235	0.200	0.467						
7.5	*Percent of households who did not perceive the change of the climate in general*	0.100	0.067	0.222	0.231	0.000	**Natural Disasters and Climate Variability (M7)**	**0.256**	**0.339**	**0.247**	**0.283**	**0.315**
7.6	*Percent of household members affected by the above events*	0.350	0.500	0.353	0.200	0.667						
7.7	*Percent of households that have loss of income and assets because of those events*	0.400	0.500	0.353	0.300	0.667						
7.8	*Percent of households without mitigation/prevention strategies*	0.350	0.400	0.278	0.615	0.412						
7.9	*Percent of households without adjustment in their agricultural activities*	0.500	0.867	0.667	1.000	0.294						
	Overall LVI = ($\frac{\sum_{i=1}^{7} W_{Mi} M_{ci}}{\sum_{i=1}^{7} W_{Mi}}$)							**0.406**	**0.432**	**0.338**	**0.393**	**0.374**

4.1.2. Livelihood strategies vulnerability

Four sub-indicators were used to measure the vulnerability of households in terms of livelihood strategies (see Table 4.1). Table 4.2 shows that the Loc Binh commune had the highest value, indicating a high vulnerability in terms of livelihood strategies indicator (0.475). The figure was followed by 0.458 (Phu An commune) and 0.456 (Huong Phong commune), 0.450 (Vinh Hien commune). Phu Hai commune had the lowest level of livelihood strategies vulnerability with a value of 0.327.

Main sources of income and second income sub-indicators

The results indicate that both sub-indicators contribute considerably to the vulnerability. Table 4.2 shows that all of the five communes are highly dependent on agriculture and aquaculture, of which Huong Phong had the highest dependence (0.882), and Phu Hai valued the lowest reliant (0.308). Phu An, Loc Binh and Vinh Hien commune were also highly reliant on agriculture and aquaculture, with 0.778; 0.700; and 0.600 respectively. In Huong Phong commune, the percentage of households without a second income was the lowest (0.176), whereas Vinh Hien commune had the highest percentage of households without a second income (0.600). The figures for Loc Binh, Phu An, and Phu Hai communes were 0.500; 0.444; and 0.385 in turn.

Unemployed family member sub-indicator

Table 4.2 indicates that Vinh Hien has the highest value (0.333) and Loc Binh commune was the lowest figure (0.050). The proportions of unemployed family members in Phu An, Huong Phong and Phu Hai were found to be lower, with 0.111; 0.118; and 0.231.

Saving part of income sub-indicator

Vinh Hien commune had the lowest value for households without saving part of household income (0.267) while Loc Binh recorded the highest value (0.650). In Phu An and Huong

Phong commune, the values for saving part of household income were high, 0.500 was recorded for Phu An commune and 0.647 for Huong Phong commune. Phu Hai commune was lower, with the value for saving part of their income 0.385.

4.1.3. Social networks vulnerability

The vulnerability of social networks indicators for each of the five communes range from 0.778 to 0.817 (Table 4.2). Three sub-indicators measured the vulnerability of social networks were presented in Table 4.1. Almost all sub-indicators were high for all the five communes. Loc Binh had the highest level of vulnerability (0.817) and Vinh Hien was the lowest (0.778). The figures for Huong Phong, Phu An and Phu Hai communes were 0.804; 0.796; and 0.795 respectively.

Borrowed money or goods sub-indicators

The majority of households in each of the five communes had borrowed money or food from their friends or relatives (Table 4.2). Huong Phong commune had the highest value for households that borrowed money or food (0.941). Phu Hai commune had the lowest value (0.692). Loc Binh, Vinh Hien and Phu An communes reporteds figures for households borrowing cash and good of 0.750; 0.733; and 0.833 respectively.

Receiving money from their family members or relatives sub-indicator

There was little difference among the five communes in the value of household that received money from family members or relatives (Table 4.2), with the range from 0.667 (Vinh Hien commune) to 0.722 (Phu An commune). The values for Phu Hai, Loc Binh, and Huong Phong commune were 0.692; 0.700; and 0.706 respectively.

Receiving advice on farming activities sub-indicator

Table 4.2 shows that two of the five communes, Loc Binh and Phu Hai, reported that none of the surveyed households had received advice on farming activities from the local government (1.000). Meaning that 100% of responding households in both Loc Binh and Phu Hai communes did not receive advice. The remaining communes responded that only a minority of families received advice from local governments. Vinh Hien, Phu An and Huong Phong communes where the households did not receive agricultural advice were 0.933; 0.833; and 0.765 respectively.

4.1.4. Health status vulnerability

Health status indicator consisted of two sub-indicators as shown in Table 4.1. In general, Vinh Hien commune was the most vulnerable in terms of health (0.533) whereas Phu An commune was least vulnerable (0.422) among the five communes. Phu Hai, Loc Binh and Huong Phong communes had a health vulnerability of 0.522; 0.500; and 0.499 respectively (see Table 4.2).

Average distance from household to health facilities sub-indicator

Table 4.2 indicates the standardized values of average distance from households to health facilities where they usually get health treatment for each of the five communes. There was a range from 0.400 (Phu An commune) to 0.750 (Loc Binh commune). The values for average distance from households to health facilities of Huong Phong, Phu Hai, and Vinh Hien commune were 0.409; 0.583; and 0.600 respectively.

Households with members having chronic illness sub-indicator

Table 4.2 shows that the index for households who have members that get sick very often in Huong Phong commune was the highest (0.588). Loc Binh commune recorded the lowest figure for chronic illness of family members (0.250). Meanwhile, Vinh Hien, Phu An and Phu Hai communes reported minor differences in terms of chronic illness of family members, with 0.467; 0.444; and 0.462 respectively.

4.1.5. Food security vulnerability

The food security indicator contains three sub-indicators (Table 4.1). Table 4.2 shows that the overall food vulnerability index ranges from 0.407 (least vulnerable for Phu An commune) to 0.667 (most vulnerable for Phu Hai commune). The score for food vulnerability of Huong Phong, Loc Binh and Vinh Hien commune were 0.431; 0.467; and 0.600 respectively.

Having inadequate food for whole year sub-indicator

Only Phu Hai commune reported there were a number of households who struggled in providing adequate food for their families (0.154) whereas none of the families in the four other communes indicated that they lacked sufficient food for the whole year (see Table 4.2).

Saving seeds sub-indicator

A majority of all households in each of the five communes responded that they did not save seeds for next crop (see Table 4.2). None of the households in Vinh Hien and Phu Hai communes saved any seeds from their crops for planting in succeeding crop seasons (100% of households responded they did not reserve seeds). There were some minor saving seeds recorded for Phu An, Huong Phong and Loc Binh communes (0.899; 0.941; and 0.950 respectively).

Reserving part of agriculture production sub-indicator

Phu Hai commune had the highest number of households that did not reserve agriculture products (0.846). This was followed by Vinh Hien commune with 0.800. Loc Binh and Huong Phong communes were much lower, with 0.450 and 0.353 respectively. Phu An households reported the lowest value (0.333), which can be interpreted that this commune had the highest percentage of households who reserved agriculture products.

4.1.6. Water access vulnerability

Water vulnerability indicator consists of three sub-indicators (see Table 4.1). Overall, Phu An commune had the lowest vulnerability score for water access compared to others, with 0.056 (Table 4.2). The value for Huong Phong commune was 0.059, followed by Phu Hai commune with a vulnerability score of 0.154. Vinh Hien commune had a score of 0.311 and Loc Binh commune had the highest value of water access vulnerability (0.333).

Using natural sources of water for drinking sub-indicator

Comparing the five communes, Table 4.2 indicates that in both Phu An and Huong Phong communes, none of the families used natural sources of water for drinking. Loc Binh and Vinh Hien communes reported that around a quarter of households used natural sources of water for drinking such as from rain or well water, with 0.250 and 0.267 respectively. The figure for Phu Hai commune was 0.077, meaning that few households in this commune used drinking water from natural sources.

Households without tap water inside house sub-indicator

Table 4.2 shows that Phu An commune reported that all households had tap water inside their houses (0.000 for proportion of households without tap water inside houses). Vinh Hien recorded the highest score of the surveyed households without tap water inside their houses (0.400). The score for Loc Binh commune was 0.200. Phu Hai and Huong Phong communes recorded the lower number of households without tap water inside the house, 0.077 and 0.059 respectively.

Using natural sources of water for agriculture land sub-indicator

The commune with the highest score for this sub-indicator was Loc Binh commune (0.550) while Huong Phong commune had the lowest value (0.118). For Phu An, Vinh Hien and Phu Hai commune, the scores of households using rain and well water to irrigate their agriculture land were 0.167; 0.267; 0.308 respectively.

4.1.7. Natural disasters and climate variability vulnerability

The natural disasters and climate variability index consists of nine sub-indicators as shown in Table 4.1.

Table 4.2 indicators Vinh Hien commune had the highest vulnerability (0.339) to natural disasters and climate variability whereas Phu An commune had the lowest vulnerability (0.247). The vulnerability score for Huong Phong commune was also high (0.315). Phu Hai and Loc Binh communes reported lower vulnerability levels, with 0.283 and 0.256 respectively.

Percentage of households affected by natural disasters (flooding, drought, storm, and pest and livestock diseases) sub-indicator

Among the four types of natural disasters, Phu An commune showed the highest vulnerability to flooding of agriculture land (0.118) while Phu Hai households reported that none of the households in this commune were affected by flooding during the period 2013 to 2016. The number of households affected by flooding of agriculture land in Loc Binh, Vinh Hien and Huong Phong commune were 0.050; 0.071; and 0.067 respectively.

In terms of drought and storm disasters, Vinh Hien, Phu An and Phu Hai communes reported the same values for households affected by these two disasters, with score of 0.143 for Vinh Hien households affected by droughts and storms from 2013 to 2016. No households were affected in Phu Hai and Phu An communes. Huong Phong commune reported the highest score of households affected by droughts in the same period (0.267) and Vinh Hien commune had the most households affected by storms (0.143). None of the Huong Phong households affected by storms during the period 2013 to 2016. Loc Binh commune had 0.150 households affected by droughts and 0.050 households affected by storms in the same period.

All five communes suffered from pest and livestock diseases influenced by climate change. Huong Phong commune had highest value (0.467) of households affected by pest and livestock diseases. Loc Binh and Vinh Hien communes recorded the number of households who suffered from pest and livestock disease were 0.350 and 0.357 respectively. Phu An and Phu Hai communes reported lower numbers, with 0.235 and 0.200.

Percentage of household without perception of climate change sub-indicator

Table 4.2 displays Huong Phong commune reported the lowest figure for households without perception of climate change (0.000) whereas the value for each of the remaining communes range from 0.067 (Vinh Hien commune) to 0.231 (Phu Hai commune). The scores for households without perception of climate change in Loc Binh and Phu An communes were 0.100 and 0.222 respectively.

Sub-indicators of household members affected by flooding, drought, storms sub-indicator, and income and assets loss caused by these disasters

Huong Phong commune showed the highest percentage of households who have family members affected by disasters as well as income and assets loss caused by the four types of listed disasters, with the figure of 0.667. In contrast, Phu Hai commune had lowest number of households who had family members affected by disasters (0.200) as well as income and assets loss influenced by disasters (0.300). Vinh Hien and Phu An communes had the same values of vulnerability in terms of family members affected by disasters (0.500) and income and properties loss due to natural disaster (0.353). The values for Loc Binh commune were 0.350 (family members affected), and 0.400 (income and assets loss).

Households without applying mitigation/prevention strategies sub-indicator

Table 4.2 shows that Phu Hai commune reported the highest score of households without application of mitigation strategies (0.615) while Phu An commune had the lowest score (0.278). The figure for Phu An commune reflects that there was a majority of households in this commune that had applied options to prevent disasters as well as mitigate the impacts of disasters. In Loc Binh, Vinh Hien and Huong Phong communes, the values of households without application of mitigation strategies were 0.350; 0.400; and 0.412 respectively.

Households without adjustment in agricultural activities sub-indicator

None of the households in Phu Hai commune had adjusted their agricultural activities (percent of households without adjustment in agriculture activities was 1.000) (see Table 4.2). The value of households without adjustment in agricultural activities in Vinh Hien commune was also high (0.867). Huong Phong commune reported the lowest value (0.294) reflected by the highest number of households that had adjustment in their agricultural activities. The scores for Loc Binh and Phu An communes were 0.500 and 0.667 respectively.

4.1.8. The overall LVI

The overall LVI score presented in Table 4.2 shows that Vinh Hien commune had the highest LVI of 0.432, which refers to the highest vulnerability of livelihood to climate change impacts. Phu An commune had the lowest level of vulnerability of 0.338. The vulnerability index for Loc Binh commune was also high (0.406), which was the second most vulnerable to climate change impacts. Huong Phong and Phu Hai communes had a lower LVI, with 0.374 and 0.393 respectively.

Figure 4.1 is the spider diagram, which presents the results of the seven major indicators for each commune.

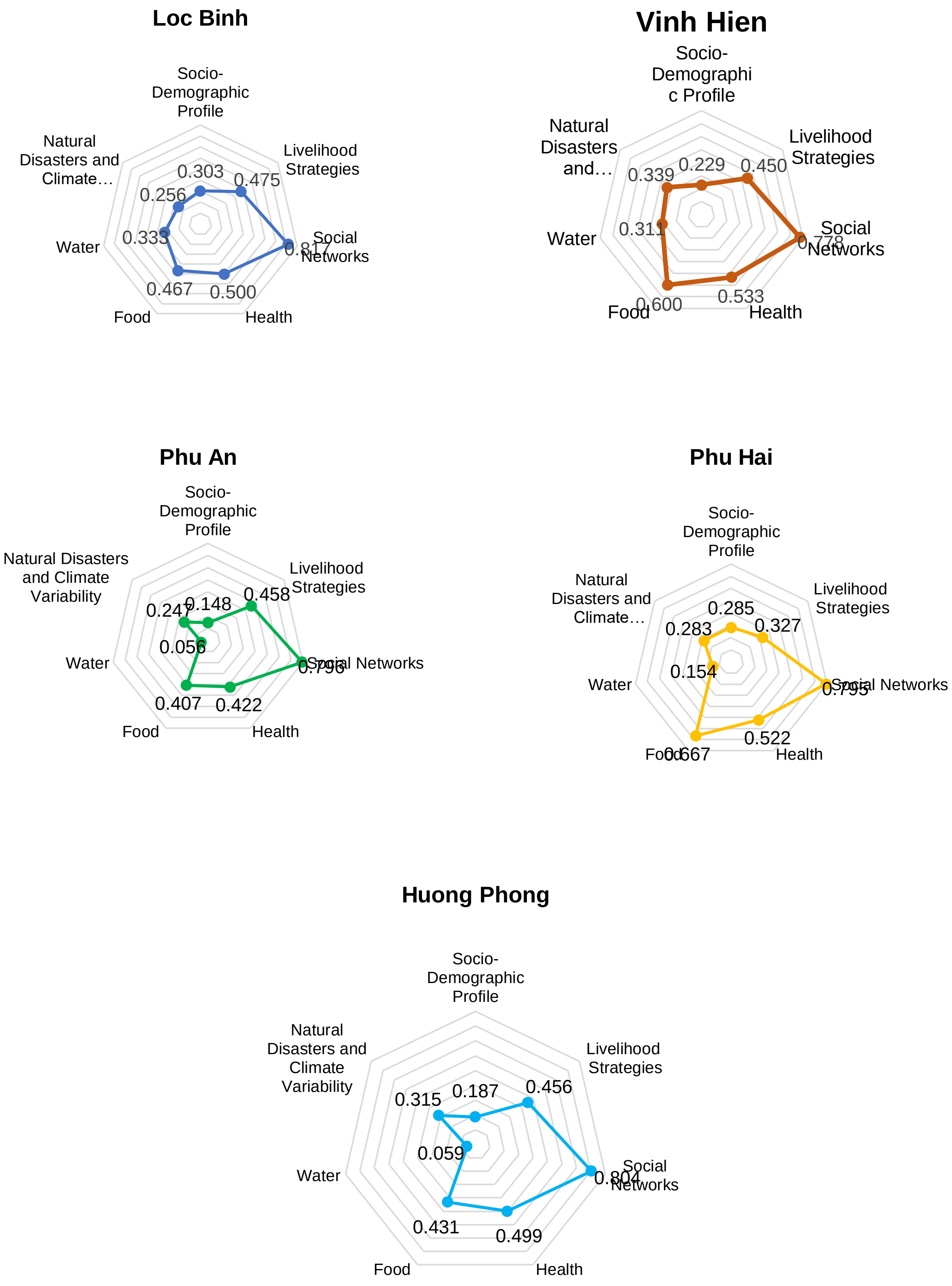


Figure 4.1. Vulnerability spider diagram of the major indicators of the LVI for 5 study communes

The ranking of vulnerability of the five communes in terms of seven major indicators is presented in Table 4.3.

Table 4.3. The vulnerability ranking of five communes in term of each major indicator (1 (lowest vulnerability) to 5 (highest vulnerability))

Commune \ Major Indicators	Socio-Demographic profile	Livelihood Strategies	Social networks	Health status	Food security	Water access	Natural Disasters and Climate Variability
Loc Binh	5	5	5	3	3	5	2
Vinh Hien	3	2	1	5	4	4	5
Phu An	1	4	3	1	1	1	1
Phu Hai	4	1	2	4	5	3	3
Huong Phong	2	3	4	2	2	2	4

Table 4.3 shows that Loc Binh commune was the most vulnerable in terms of Socio-demographics, livelihood strategies, social networks and water. Vinh Hien commune was most vulnerable in terms of health and natural disaster and climate variability. Phu Hai commune was the most vulnerable regarding food indicators.

4.2. Livelihood vulnerability: IPCC definition

This section presents the overall LVI calculation for the five communes based on the LVI_IPCC model outlined in subsection 3.5.2.

In this model, the major indicators of socio-demographics, livelihood strategies and social networks are considered as contributing to an adaptive capacity factor according to the IPCC vulnerability definition. The scores for the three major indicators of socio-demographics, livelihood strategies and social networks were calculated by taking the inverse of their sub-indicators in the LVI calculation as shown in Table 4.4.

Table 4.4. A change of sub-indicators for three major indicators (Socio-demographics, livelihood strategies and social networks) for LVI_IPCC calculation

Major indicators	Sub-indicators for LVI calculation	Sub-indicators for LVI_IPCC calculation
Socio-Demographic Profile	Dependency percentage (Percentage of household members who are under 18 and over 65-year-old)	Inverse Dependency percentage (Percentage of household members with age from 18-65 years old)
	Percent of households where the head are female	Percent of households where the head are male
	Percent of households where the household head did not attend school	Percent of households where the household head attended school
Livelihood Strategies	Percent of households who have the main income source from agriculture and aquaculture	Percent of households who have main income source not only from agriculture and aquaculture
	Percent of households without second main income	Percent of households have second main income
	Percent of households who have unemployed member	Percent of households without unemployed member
	Percent of households who did not save a part of income	Percent of households who saved a part of income
Social Networks	Percent of households who borrowed money or goods	Percent of households who did not borrow money or goods
	Percent of households who did not receive money from family member or others	Percent of households who received money from family member or others
	Percent of households who did not receive advice on farming activities	Percent of households who received advice on farming activities

The LVI_IPCC value was calculated by grouping the seven major indicators of the Livelihood Vulnerability Index (LVI) into three categories of vulnerability under the framework of the IPCC as shown in Table 4.5.

Table 4.5. Results of calculated LVI for contributing factors into the IPCC-definition

(LVI_IPCC vulnerability scale: -1 (least vulnerability) to 1 (most vulnerability))

Major component	Communes					IPCC contributing factors	Communes				
	Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong		Loc Binh	Vinh Hien	Phu An	Phu Hai	Huong Phong
Socio-demographic profile	0.697	0.771	0.852	0.715	0.813	Adaptive Capacity (A)	0.474	0.518	0.533	0.545	0.520
Livelihood strategies	0.525	0.550	0.542	0.673	0.544						
Social networks	0.183	0.222	0.204	0.205	0.196						
Health status	0.500	0.533	0.422	0.522	0.499	Sensitivity (S)	0.425	0.475	0.279	0.438	0.308
Food security	0.467	0.600	0.407	0.667	0.431						
Water access	0.333	0.311	0.056	0.154	0.059						
Natural disaster and climate variability	0.256	0.339	0.247	0.283	0.315	Exposure (E)	0.256	0.339	0.247	0.283	0.315
LVI-IPCC = $(E_c - A_c) \times S_c$							**-0.093**	**-0.085**	**-0.080**	**-0.115**	**-0.063**

The results in Table 4.5 show that overall, according to LVI_IPCC calculation, Huong Phong commune had the highest vulnerability level (-0.063) and Phu Hai had the lowest vulnerability level (-0.115). The value for the vulnerability level of Phu An, Vinh Hien, and Loc Binh communes under the IPCC definition were -0.080; -0.085; and -0.093 respectively.

The different scores of adaptive strategies, sensitivity and exposure for each of the five communes are presented in the vulnerability triangle diagram (Figure 4.2).

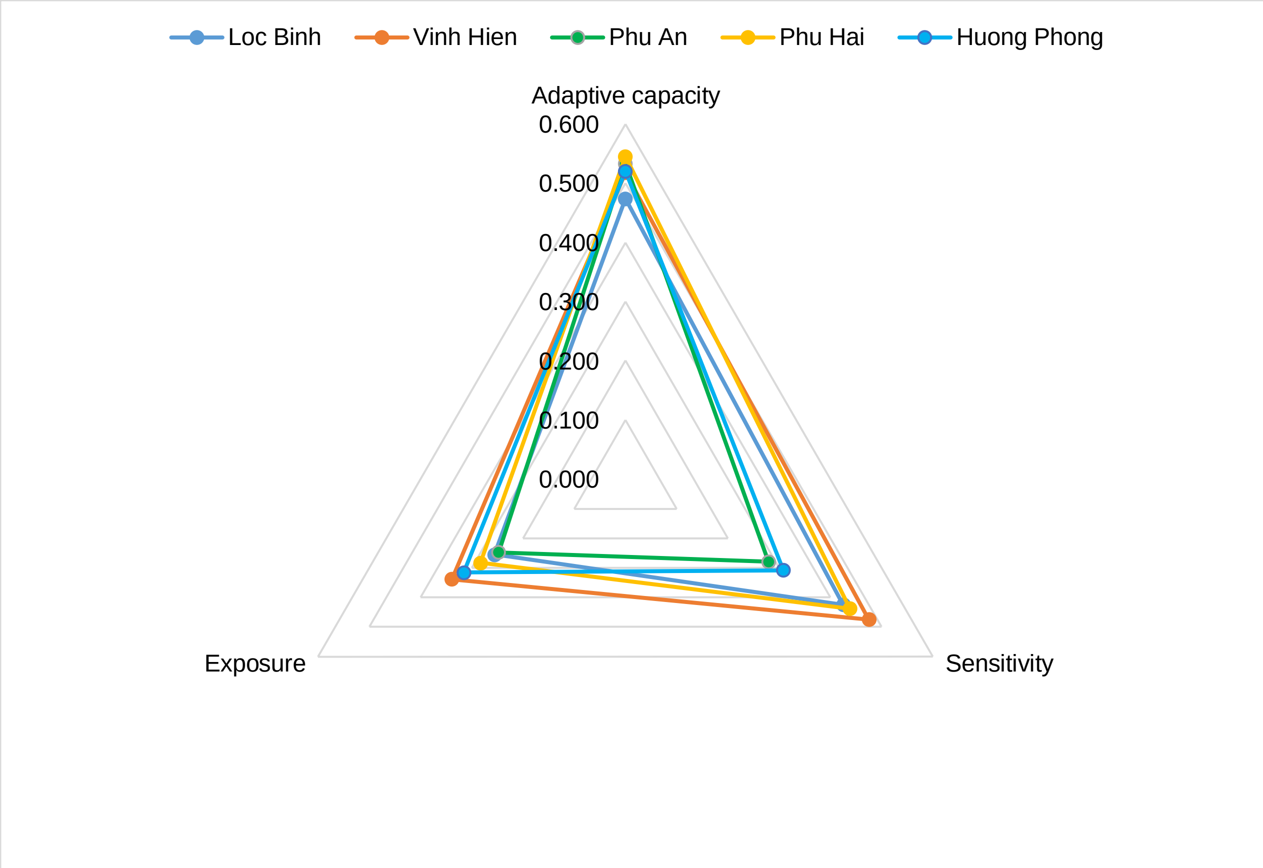


Figure 4.2. Vulnerability triangle diagram of the contributing factors of the LVI_IPCC for five study communes

Taking the comparison based on three categories of the IPCC definition (adaptive capacity, exposure and sensitivity), the results for vulnerability levels differed from the overall results of five communes when three contributing factors scores were computed using the IPCC equation (Equation 5). In detail, it can also be seen in Figure 4.2 and Table 4.5, that Vinh Hien commune had higher exposure level to natural disasters and climate change impacts than the four other communes, with an exposure score of 0.339. In addition, Vinh Hien commune also showed the most sensitivity regarding health status, food security and water access than others, with sensitivity score was 0.475. Regarding socio-demographics, livelihoods strategies and social networks, Phu Hai commune had a higher adaptive capacity score compared to the four other communes (0.545). In this model, Phu Hai commune had the highest score of livelihood strategies indicator (0.673), contributing significantly to its adaptive capacity.

4.3. Differences in mean LVI for major indicators between communes

This section discusses the differences in the vulnerability of each of the five communes based on each major indicator of the LVI model.

4.3.1. Socio-demographic differences

A one-way analysis of variables compared the mean of the socio-demographics score between the communes. The results of this analysis (Table 4.6) show that there were no statistically significant differences between the communes related to socio-demographics profile indicators (F=0.297, *p_value*=0.879).

Table 4.6. Summary of one-way ANOVA analyses of differences in socio-demographics, livelihood strategies, social networks, health status and food security indicators between communes

Variables	Sig. (Levene Statistic)	Sum of Squares	df	Mean Square	F	Sig. (*p_value*)
Socio-Demographic profile	.096	.033	4	.008	.297	.879
Livelihood Strategies	.767	.203	4	.051	1.438	.229
Social Networks	.794	.014	4	.003	.058	.994
Health status	.230	.142	4	.035	.220	.927
Food security	.141	.769	4	.192	5.650	.000

(p_value of Levene Statistic ≥ 0.05, null hypothesis for equal variances is accepted; p_value of Levene Statistic <0.05, the variances are not equal)

4.3.2. Livelihood strategies differences

Considering statistical meaning, the results of the one-way ANOVA statistics as shown in Table 4.6 indicate that there were no statistically significant disparities in livelihood strategies indicators between the communes (F=1.438, *p_value*=0.229).

4.3.3. Social networks differences

Table 4.6 points out that the statistical differences in overall social networks vulnerability between the communes were not significant, with F=0.058 and *p_value* =0.994. This reflects that although the results in Table 4.2 indicate the scores of vulnerability levels of the five communes were dissimilar, there was still the absence of data to point out the statistical variances.

4.3.4. Health status differences

The results of one-way ANOVA analyses show that the difference in mean of health status indicator between the five communes was not significant (F=0.220, *p_value*=0.927) (see Table 4.6).

4.3.5. Food security differences

The results of the one-way ANOVA analysis shown in Table 4.6 indicate that there were statistically significant differences in food security indicators between the five communes (F=5.650, *p_value*=0.000). The details of the differences between communes are presented in Table 4.7.

Table 4.7 shows that there were statistically significant differences in food security between four pairs of communes, namely Loc Binh and Phu Hai commune (*p_value*= 0.026), Vinh Hien and Phu An commune (*p_value* = 0.030), Phu An and Phu Hai commune (*p_value* = 0.002), and Phu Hai and Huong Phong commune (*p_value* = 0.008). There were no significant differences between the remaining groups of communes.

Table 4.7. Summary of post hoc test (by Tukey) for multiple comparisons in means of food security between communes

(I) Commune	(J) Commune	Mean Difference (I-J)	Std. Error	Significant (*p* value)	95% Confidence Interval	
					Lower Bound	Upper Bound
Loc Binh	Vinh Hien	-.133550	.063024	.223	-.30955	.04245
	Phu An	.059372	.059948	.859	-.10804	.22678
	Phu Hai	-.200196*	.065736	**.026**	-.38377	-.01662
	Huong Phong	.035356	.060869	.978	-.13463	.20534
Vinh Hien	Loc Binh	.133550	.063024	.223	-.04245	.30955
	Phu An	.192922*	.064507	**.030**	.01278	.37307
	Phu Hai	-.066646	.069919	.875	-.26190	.12861
	Huong Phong	.168906	.065364	.083	-.01363	.35144
Phu An	Loc Binh	-.059372	.059948	.859	-.22678	.10804
	Vinh Hien	-.192922*	.064507	**.030**	-.37307	-.01278
	Phu Hai	-.259568*	.067159	**.002**	-.44712	-.07202
	Huong Phong	-.024016	.062403	.995	-.19828	.15025
Phu Hai	Loc Binh	.200196*	.065736	**.026**	.01662	.38377
	Vinh Hien	.066646	.069919	.875	-.12861	.26190
	Phu An	.259568*	.067159	**.002**	.07202	.44712
	Huong Phong	.235552*	.067983	**.008**	.04570	.42540
Huong Phong	Loc Binh	-.035356	.060869	.978	-.20534	.13463
	Vinh Hien	-.168906	.065364	.083	-.35144	.01363
	Phu An	.024016	.062403	.995	-.15025	.19828
	Phu Hai	-.235552*	.067983	**.008**	-.42540	-.04570
*. The mean difference is significant at the 0.05 level.						

4.3.6. Water access differences

The Levene's test in one-way ANOVA analysis for the differences in mean of water indicators between communes shows that the significant value (*p_value*) was less than 0.05 (*p_value*=0.001), the assumption that equality of variances was violated, or the variances are significantly different (Table 4.8). Therefore, to analyse the differences in water indicators between each commune, this research uses an adjusted F statistic by Robust test (Welch statistic). This statistic is available within one-way ANOVA in comparison of means (Field 2013).

Table 4.8. Summary of Welch analysis for differences in water access and natural disasters and climate variability indicators between the communes

Variables	Levene test	Welch analyses result			
	Sig. (p_value)	Statistic[a]	df1	Df2	Sig. (*p_value*)
Water access	.001	4.683	4	35.891	.004
Natural disasters and climate variability	.046	.636	4	37.516	.640

a. Asymptotically F distributed.

The results of the Welch statistic as shown in Table 4.8 indicate that there were statistically significant differences between the five communes in terms of water access indicators (*p_value*=0.004). The detail of disparities between communes was shown in Table 4.9.

Table 4.9. Summary of post hoc test (by Tamhane) for multiple comparisons in means of water access between communes

(I) Commune	(J) Commune	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Loc Binh	Vinh Hien	.022117	.114763	1.000	-.32521	.36944
	Phu An	.277750*	.078555	**.016**	.03693	.51857
	Phu Hai	.179481	.094814	.504	-.10627	.46523
	Huong Phong	.274426*	.084214	**.027**	.02015	.52870
Vinh Hien	Loc Binh	-.022117	.114763	1.000	-.36944	.32521
	Phu An	.255633	.093870	.135	-.04533	.55660
	Phu Hai	.157364	.107844	.820	-.17480	.48953
	Huong Phong	.252310	.098654	.172	-.05729	.56191
Phu An	Loc Binh	-.277750*	.078555	**.016**	-.51857	-.03693
	Vinh Hien	-.255633	.093870	.135	-.55660	.04533
	Phu Hai	-.098269	.068049	.837	-.31541	.11887
	Huong Phong	-.003324	.052278	1.000	-.16163	.15499
Phu Hai	Loc Binh	-.179481	.094814	.504	-.46523	.10627
	Vinh Hien	-.157364	.107844	.820	-.48953	.17480
	Phu An	.098269	.068049	.837	-.11887	.31541
	Huong Phong	.094946	.074510	.912	-.13605	.32595
Huong Phong	Loc Binh	-.274426*	.084214	**.027**	-.52870	-.02015
	Vinh Hien	-.252310	.098654	.172	-.56191	.05729
	Phu An	.003324	.052278	1.000	-.15499	.16163
	Phu Hai	-.094946	.074510	.912	-.32595	.13605

*. The mean difference is significant at the 0.05 level.

Table 4.9 shows that there were statistically significant differences in water access indicators between Loc Binh and Phu An communes (p_value=0.016) and Loc Binh and Huong Phong communes (*p_value*=0.027). There were no significant variances between the remaining communes.

4.3.7. Natural disasters and climate variability differences

Similar to water access indicator, the result of Levene's statistic test identifies the significant (*p_value*) for differences in means of natural disasters and climate variability indicators was less than 0.05 (*p_value*=0.046) (Table 4.8). Thus, the Welch statistic was applied to analyse the differences between each commune in terms of natural disaster indicator. The results in Table 4.8 point out the significance of the Welch test was greater than 0.05 (*p_value*=0.640), reflecting the differences in natural disasters and climate variability between communes was not significant in terms of the statistical perspective.

4.4. Differences in mean LVI_IPCC for adaptive capacity, sensitivity and exposure factors between communes

Similar to the previous section, a one-way ANOVA analysis was also used to examine the statistical differences between the communes based on the three factors of vulnerability according to the IPCC definition, including adaptive capacity, sensitivity and exposure.

The differences in mean adaptive capacity and exposure variables between the communes are presented in Table 4.10. The result of the significant value in the Levene's test was less than 0.05, as such the Welch statistic was used to analyse the differences in adaptive capacity and exposure between communes (Table 4.10).

Table 4.10. Summary of one-way ANOVA analyses for the differences in mean adaptive capacity and exposure between the communes

Variables	Levene test	Welch analyses result			
	Sig. (p_value)	Statistic[a]	df1	df2	Sig. (*p_value*)
Adaptive capacity	.004	.630	4	36.551	.644
Exposure	.046	.636	4	37.516	.640

a. Asymptotically F distributed.

4.4.1. Adaptive capacity (AC)

The results in Table 4.10 shows that there were no statistically significant differences in adaptive capacity between the five communes because the significant value is greater than 0.05 (*p_value*=0.644).

4.4.2. Exposure (E)

The results in Table 4.10 also show that there were no statistically significant differences in mean exposure variable between the communes, (*p_value*=0.640).

4.4.3. Sensitivity (S)

The result of one-way ANOVA statistical analysis for the differences in sensitivity between the communes is described in Table 4.11.

Table 4.11. Summary of one-way ANOVA analysis of differences in mean sensitivity between communes

Variables	Sig. (Levene Statistic)	Sum of Squares	df	Mean Square	F	Sig. (*p_value*)
Sensitivity	.052	.407	4	.102	3.996	.005

(p_value of Levene Statistic ≥ 0.05, null hypothesis for equal variances is accepted; p_value of Levene Statistic < 0.05, the variances are not equal)

The result in Table 4.11 indicates that there were statistically significant differences in mean sensitivity between the communes (F=3.996, *p_value*=0.005). The details of those differences are presented in Table 4.12.

Table 4.12. Summary of post hoc test (by Tukey) for multiple comparisons in mean of sensitivity between communes

(I) Commune	(J) Commune	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Loc Binh	Vinh Hien	-.068267	.054493	.721	-.22044	.08391
	Phu An	.120400	.051833	.149	-.02435	.26515
	Phu Hai	-.017600	.056838	.998	-.17633	.14113
	Huong Phong	.092988	.052629	.400	-.05399	.23996
Vinh Hien	Loc Binh	.068267	.054493	.721	-.08391	.22044
	Phu An	.188667*	.055775	**.010**	.03291	.34443
	Phu Hai	.050667	.060454	.918	-.11816	.21949
	Huong Phong	.161255*	.056516	**.043**	.00343	.31908
Phu An	Loc Binh	-.120400	.051833	.149	-.26515	.02435
	Vinh Hien	-.188667*	.055775	**.010**	-.34443	-.03291
	Phu Hai	-.138000	.058068	.133	-.30016	.02416
	Huong Phong	-.027412	.053956	.986	-.17809	.12327
Phu Hai	Loc Binh	.017600	.056838	.998	-.14113	.17633
	Vinh Hien	-.050667	.060454	.918	-.21949	.11816
	Phu An	.138000	.058068	.133	-.02416	.30016
	Huong Phong	.110588	.058780	.336	-.05356	.27474
Huong Phong	Loc Binh	-.092988	.052629	.400	-.23996	.05399
	Vinh Hien	-.161255*	.056516	**.043**	-.31908	-.00343
	Phu An	.027412	.053956	.986	-.12327	.17809
	Phu Hai	-.110588	.058780	.336	-.27474	.05356

*. The mean difference is significant at the 0.05 level.

The results in Table 4.12 indicate that there were statistically significant differences in mean sensitivity between two pairs of communes, including Vinh Hien and Phu An communes (*p_value*=0.010), and Vinh Hien and Huong Phong communes (*p_value*=0.043). The statistical difference between other pairs of communes were not significant.

4.5. Differences of vulnerability of communes based on LVI and LVI_IPCC models

This section will present the statistical differences in means of the LVI and LVI_IPCC score between communes. Additionally, this section aims to examine the reasons for disparities of vulnerability level of each communes based on two models, LVI and LVI_IPCC.

Table 4.13. Summary of one-way ANOVA analyses for the differences in mean LVI and LVI_IPCC between the communes

Variables	Sig. (Levene Statistic)	Sum of Squares	df	Mean Square	F	Sig. (*p_value*)
LVI	.342	.068	4	.017	2.065	.093
LVI_IPCC	.182	.005	4	.001	.119	.975

(p_value of Levene Statistic ≥ 0.05, null hypothesis for equal variances is accepted; p_value of Levene Statistic < 0.05, the variances are not equal)

The results of the one-way ANOVA analyses in Table 4.13 indicate that there were no statistically significant differences in mean LVI (F=2.065, *p_value*=0.093) as well as mean LVI_IPCC (F=0.119, *p_value*=0.975) between communes. In other words, the one-way ANOVA analyses suggest that there was a lack of data to investigate the differences in vulnerability between the communes based on the LVI and LVI_IPCC models in a statistical perspective.

4.6. Sensitivity of each commune based on each sub-indicator and the policy implications

The LVI and LVI_IPCC models were designed with the aims of providing to policymakers and practitioners a useful tool to assess various indicators contributing to the vulnerability of community livelihoods to climate change variability, as well as to evaluate the impact of a program or policy (Hahn, Riederer & Foster 2009; Singh & Nair 2014). However, the findings of this research indicate there was a lack of data to conclude that there were significant differences in means of the LVI and LVI_IPCC between communes. Additionally, the results of LVI and LVI_IPCC calculations did not show which factors of livelihood assets contribute to the vulnerability of communes. Therefore, a sensitivity analysis is very useful in this research to discuss the influences of major indicators and sub-indicators to the level of vulnerability of the five communes. The results of simulated LVI based on the various sub-indicators for each commune is presented in Table 4.14 and Figure 4.3.

Table 4.14. Simulated LVI to changes of sub-indicators for communes

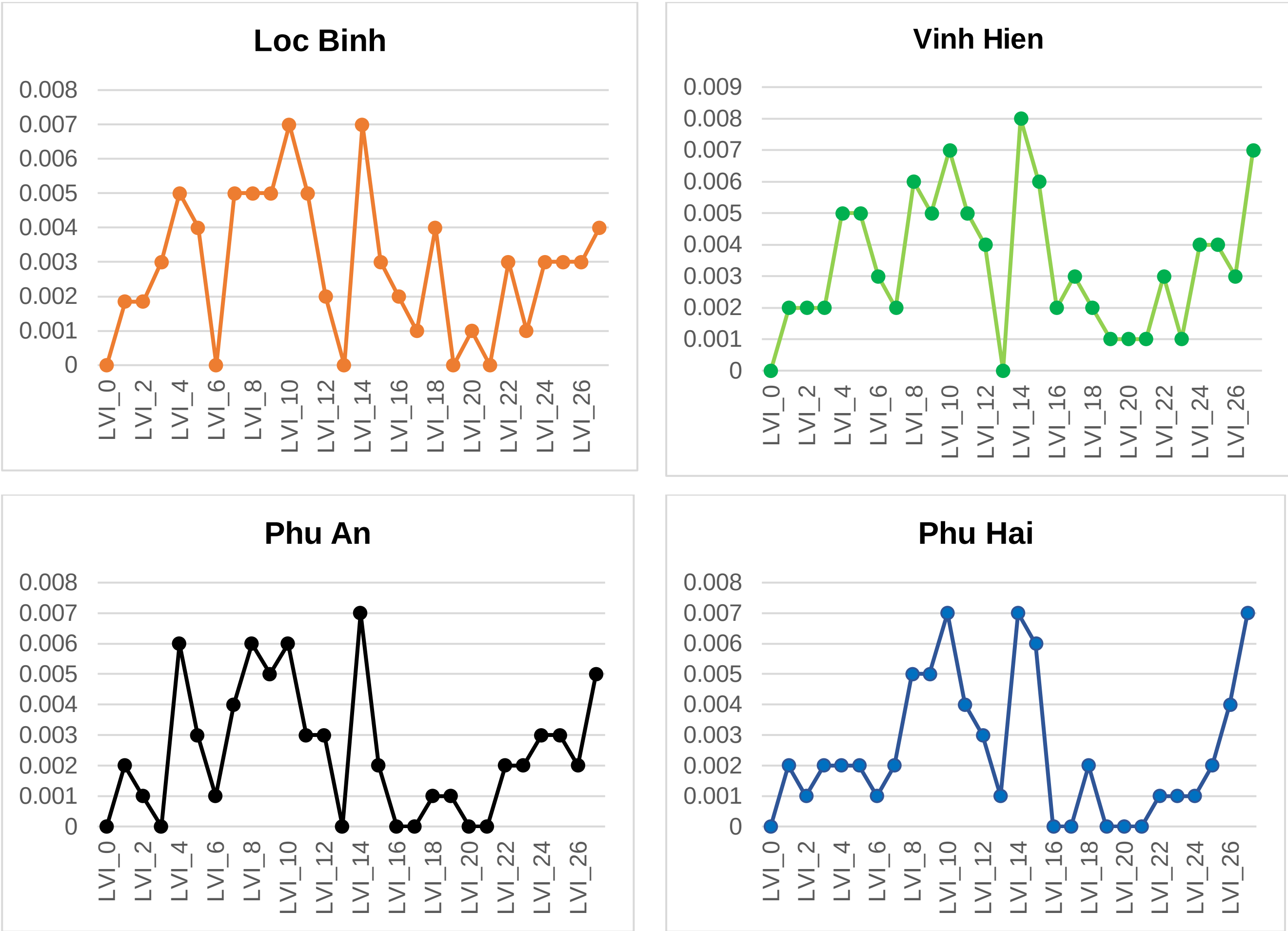
No	Sub-indicators	Loc Binh		Vinh Hien		Phu An		Phu Hai		Huong Phong	
		Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27
1	Dependency percentage	0.312	0.408	0.265	0.434	0.332	0.340	0.379	0.395	0.389	0.377
2	Percent of households where the head are female	0.360	0.408	0.240	0.434	0.133	0.339	0.277	0.394	0.212	0.375
3	Percent of households where household head did not attend school	0.420	0.409	0.320	0.434	0.067	0.338	0.369	0.395	0.071	0.375
4	Percent of households who have main income source from agriculture and aquaculture	0.840	0.411	0.720	0.437	0.933	0.344	0.369	0.395	1.059	0.381
5	Percent of households without second main occupation	0.600	0.410	0.720	0.437	0.533	0.341	0.462	0.395	0.212	0.375
6	Percent of households who have unemployed member	0.060	0.406	0.400	0.435	0.133	0.339	0.277	0.394	0.141	0.375
7	Percent of households without saving a part of income	0.780	0.411	0.320	0.434	0.600	0.342	0.462	0.395	0.776	0.379
8	Percentage of households who borrowed money or goods	0.900	0.411	0.880	0.438	1.000	0.344	0.831	0.398	1.129	0.381
9	Percent of households who did not receive money from family member or others	0.840	0.411	0.800	0.437	0.867	0.343	0.831	0.398	0.847	0.379
10	Percent of households who did not receive advice on farming activities	1.200	0.413	1.120	0.439	1.000	0.344	1.200	0.400	0.918	0.380
11	Average distance to go health facilities	0.900	0.411	0.720	0.437	0.480	0.341	0.700	0.397	0.491	0.377
12	Percent of households with members having chronic illness (get sick very often)	0.300	0.408	0.560	0.436	0.533	0.341	0.554	0.396	0.706	0.379

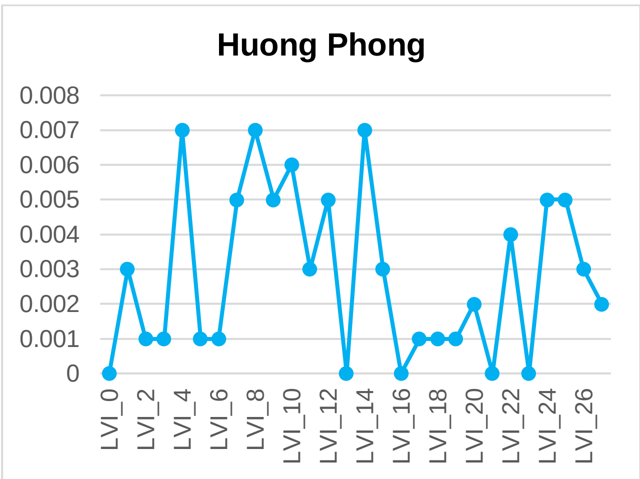
Table 4.14 (continued)

No	Sub-indicators	Loc Binh		Vinh Hien		Phu An		Phu Hai		Huong Phong	
		Increase 20% of sub-indicators	**Re-calculated LVI_1 to LVI_27**	**Increase 20% of sub-indicators**	**Re-calculated LVI_1 to LVI_27**	**Increase 20% of sub-indicators**	**Re-calculated LVI_1 to LVI_27**	**Increase 20% of sub-indicators**	**Re-calculated LVI_1 to LVI_27**	**Increase 20% of sub-indicator s**	**Re-calculated LVI_1 to LVI_27**
13	Percent of households who have inadequate food for whole year	0.000	0.406	0.000	0.432	0.000	0.338	0.185	0.394	0.000	0.374
14	Percent of households that did not save seeds	1.140	0.413	1.200	0.440	1.067	0.345	1.200	0.400	1.129	0.381
15	Percent of households that did not reserve a part of agriculture production	0.540	0.409	0.960	0.438	0.400	0.340	1.015	0.399	0.424	0.377
16	Percent of households who used natural sources of water for drinking	0.300	0.408	0.320	0.434	0.000	0.338	0.092	0.393	0.000	0.374
17	Percent of households who did not have tap water inside house	0.240	0.407	0.480	0.435	0.000	0.338	0.092	0.393	0.071	0.375
18	Percent of households who used natural sources of water for agriculture land (rainfed, well)	0.660	0.410	0.320	0.434	0.200	0.339	0.369	0.395	0.141	0.375
19	Percent of households affected by flooding of agriculture land in last three years (2013 - 2016)	0.060	0.406	0.086	0.433	0.141	0.339	0.000	0.393	0.080	0.375
20	Percent of households affected by drought in last three years (2013 - 2016)	0.180	0.407	0.171	0.433	0.000	0.338	0.000	0.393	0.320	0.376
21	Percent of households affected by storm in last three years (2013 - 2016)	0.060	0.406	0.171	0.433	0.000	0.338	0.000	0.393	0.000	0.374
22	Percent of households affected by pest and livestock diseases in last three years (2013 - 2016)	0.420	0.409	0.429	0.435	0.282	0.340	0.240	0.394	0.560	0.378
23	Percent of households who did not perceive the change of the climate in general	0.120	0.407	0.080	0.433	0.267	0.340	0.277	0.394	0.000	0.374
24	Percent of household members affected by these above events	0.420	0.409	0.600	0.436	0.424	0.341	0.240	0.394	0.800	0.379

Table 4.14 (continued)

No	Sub-indicators	Loc Binh		Vinh Hien		Phu An		Phu Hai		Huong Phong	
		Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicators	Re-calculated LVI_1 to LVI_27	Increase 20% of sub-indicator s	Re-calculated LVI_1 to LVI_27
25	Percent of households that have loss of income and assets because of those events	0.480	0.409	0.600	0.436	0.424	0.341	0.360	0.395	0.800	0.379
26	Percent of households who did not have a plan for applying mitigation/prevention strategies	0.420	0.409	0.480	0.435	0.333	0.340	0.738	0.397	0.494	0.377
27	Percent of households who did not adjust their agricultural activities	0.600	0.410	1.040	0.439	0.800	0.343	1.200	0.400	0.353	0.376





LVI_0: original LVI with no change of sub-indicators

LVI_1 to LVI_27: Values of LVI with changed each of 27 sub-indicators

Figure 4.3. Sensitivity analyses of changes to the overall LVI values by sub-indicators in each commune compared to the original LVI with no changes of sub-indicators (LVI_0).

It can be seen that the scores of LVI based on sub-indicators vary in different proportions, ranging from 0.001 to 0.009 in comparison to the original LVI values with no change of sub-indicator values.

Figure 4.3 illustrates that the values of vulnerability (LVI) of all five communes were exceedingly affected by the sub-indicator of ‘percent of households without saving seeds for the succeeding crops’, with the largest changes of LVI_14 compared to LVI_0 for all communes (ranges from 0.007 to 0.008).

The results of sensitivity analyses for Loc Binh commune in Figure 4.3 indicate that the vulnerability of Loc Binh commune was the most influenced by two sub-indicators. They are ‘the percent of households without saving seeds for the succeeding crops’ (LVI_14), and ‘the percent of households who did not receive advice on farming activities’ (LVI_10), with the same value of changed LVI (0.007).

For the Vinh Hien commune, Figure 4.3 shows the percent of households without saving seeds had the most influence on the value of LVI, with the changed LVI by increased by 20% of this sub-indicator (LVI_14) compared to the original LVI (LVI_0) was 0.008. Furthermore, the vulnerability of this commune was also highly affected by sub-indicators of ‘percent of households without receiving advice on farming activities’ (LVI_10), and ‘percent of households who did not adjusted their agricultural activities’ (LVI_27), with the changed LVI being 0.007.

The sensitivity analyses in Figure 4.3 indicate beside the significant effect of saving seeds factors (LVI_14), the vulnerability of Phu An commune was also highly impacted by three other sub-indicators; ‘percent of households who have the main income source from agriculture and aquaculture’ (LVI_4), ‘Percent of households who borrowed money or goods’ (LVI_8), and ‘percent of households who did not receive advice on farming activities’ (LVI_10).

Regarding the Phu Hai commune, Figure 4.3 shows that ‘percent of households who did not receive advice on farming activities’ (LVI_10), ‘percent of households without saving seeds’ (LVI_14), and ‘percent of households who did not adjust their agricultural activities’ (LVI_27) significantly influenced the vulnerability of this commune under the climate change context, with the same values of changed LVI (0.007).

Finally, for Huong Phong commune, the sensitivity analyses in Figure 4.3 indicate the level of vulnerability of households in this commune were shaped by 'percent of households who have main income from agriculture and aquaculture' (LVI_4), 'percent of households who borrowed money or goods' (LVI_8), and 'percent of households without saving seeds' (LVI_14).

4.7. Summary of research findings

This chapter has analysed the results of the calculations of the vulnerability of communes based on the LVI and LVI_IPCC models. Firstly, the vulnerability of communes to each of the seven major indicators (socio-demographics, livelihood strategies, social networks, health status, food security, water access, and natural disasters and climate variability) and sub-indicators were diverse. Particularly, Loc Binh commune had the highest vulnerability in regard to socio-demographics, livelihood strategies, social networks and water access. Vinh Hien commune was the most vulnerable to health status and natural disaster and climate variability indicators, and Phu Hai commune had the highest vulnerability to food indicators.

Based on the LVI_IPCC model, the vulnerability of communes according to the contributing factors (adaptive capacity, sensitivity and exposure) were also different among communes. Remarkably, Vinh Hien commune reported not only the most exposure to natural disasters and climate variability, but also highest sensitivity to climate change impacts than others. Phu Hai commune had highest adaptive capacity.

In addition, the statistical differences in means of the major indicators in the LVI and contributing factors in the LVI_IPCC was also examined to find details of differences in vulnerability between communes. In general, there were statistically significant differences in means of food security and water access between communes, whereas there were no statistical differences in the remaining major indicators. These differences were only found between some pairs of communes, not between all of communes.

Finally, the sensitivity analysis results show that the influence of sub-indicators to the vulnerability of each commune were different, implying different interventions are required to reduce the vulnerability and improve the adaptive capacity to climate change for each commune.

5. DISCUSSION

This section will discuss the main results presented in the previous section based on the aims and objectives of the research as well as in the context of the literature review (Chapter 2).

5.1. Vulnerability differences in major indicators of LVI model among the communes

This section discusses the interrelation in choosing sub-indicators for major indicators of LVI models and vulnerability of communes as well as explains the reasons for the variances in the vulnerability of the five communes based on each major indicator in the LVI model.

Socio-demographic

The research findings confirm that gender and education level of household heads contribute significantly to the vulnerability of households. There is a relationship between gender and the education level of people in Vietnam. The commune in which the percentage of female household heads was high, the level of education was low (percentage of household heads who did not attend school was high) and vice versa. In this research, the average age of household heads of Loc Binh commune is around 59 years old. This reflects the fact that Vietnam is influenced by Confucianism during Chinese domination, in which the males were given prominence for their critical roles in their family, society and education (Mai 2015). There is a discrepancy between the education fulfilments of male and female in the central coastal region of Vietnam compared to the national average (Hao 2012, p. 135). Particularly, females in poor households tend to have less opportunity to attend school than those in more affluent. The vulnerability level of Loc Binh commune based on the socio-demographics indicator was the highest due to the high percentage of female heads along with the lowest education level of household heads. Brody, Demetriades and Esplen (2008) and Klasen and Povel (2013) indicate that climate change has dissimilar impacts on women and men, of which women are more likely vulnerable than men. Tran (2015) states that Vietnamese women face higher risks to shocks than men because the average age of female heads is often higher than male heads, with the mean of 54-years old compared to 47-years old.

Additionally, a high level of education tends to enhance the awareness of the community to climate change impacts and offers best practices to climate change response (Hess & Collins 2018; Lee et al. 2015). According to Hao (2012), the education level was low in coastal households in the central region of Vietnam in general. In this research, the limitation of education level might affect the ability for household heads of Loc Binh commune to access information in terms of climate change impacts as well as the adaptation options, therefore increasing the susceptibility to natural disasters and climate change impacts.

Livelihood strategies

The results in Table 4.1 and 4.2 show that agriculture, aquaculture and fishing are the main livelihood of coastal communities in Thua Thien Hue province and the study communes in particular. These livelihoods highly rely on natural resources and weather condition changes (Füssel & Klein 2006; Tran & Ha 2014). This implies that the main income that is highly dependent on agriculture and aquaculture tend to be more likely vulnerable to climate change impacts (Organization for Economic Cooperation and Development (OECD) 2015; Wreford, Moran & Adger 2010).

The vulnerability level of coastal communes was also influenced by the diversification of income sources in the household (Swanson et al. 2007). This could be due to the fact that these families have a second occupation (in the non-agriculture sector or governmental sector) which provides more sources of income, and thereby diminishing the vulnerability of households to climate change. The findings of this research showed Huong Phong commune had the highest percentage of households with a second source of income (the lowest proportion of households without second income). In fact, Huong Phong commune has a mangrove forest located along Tam Giang lagoon, called Ru Cha, with an area of 5 ha. Due to the development of tourism, this mangrove forest provides a significant source of income for this commune (Huong Phong Commune People's Committee (CPC) 2016).

The high number of unemployed members in a family and lack of saving income also contributed to a high level of susceptibility of the household to climate change impacts (Cutter et al. 2008). In this research, the vulnerability of households and communes was measured by the average of four sub-indicators (see Table 4.1 and 4.2). Due to Loc Binh commune had high vulnerability in terms of the four sub-indicators, thus, this commune was the most vulnerable to the livelihood strategies indicator. Conversely, the values for all sub-indicators of livelihood strategies vulnerability of Phu Hai commune were low, thereby, this commune had the lowest averaged score of vulnerability, meaning least vulnerability to climate change impact in terms of livelihood strategies.

Social networks

The differences of social networks vulnerability between the communes can be explained based on the literature in terms of the factual situation of these communes. The findings of this research show the percentage of households who borrowed cash and food throughout the five communes were relatively high. This is because there was the moderate rate of poor households in all of five communes, range from 4.99% (Phu Hai commune) to 19.43% (Loc Binh commune) as presented in Table 3.1. In addition, a large amount of borrowed cashed or food implies the financial shortage of a household, and thereby, reducing the adaptive capacity of households to shocks or damages caused by climate change (Abdul-Razak & Kruse 2017; Panthi et al. 2015).

Similarly, the amount of money received from relatives can help households strengthen financial sources to respond to damage or consequences, thereby, reduce the vulnerability to climate change impacts (Abdul-Razak & Kruse 2017). However, the findings of this research indicate that a majority of households in the five communes experienced a high amount of borrowed money or food and did not receive financial support from their relatives. Therefore, the five communes had high scores of the vulnerability (see Table 4.2).

The support from government may help farmers improve their adaptive capacity to climate change impacts, and thereby less vulnerability (Abdul-Razak & Kruse 2017; Soubry 2017). The findings of this study show a minority of households in the five communes received support or advice on farming activities from local authorities (see Table 4.2). Thus, these communes were highly vulnerable to climate change impacts regarding social networks indicator.

Health status

The distance to access health facilities influences the health status of households (Adu et al. 2017; Hahn, Riederer & Foster 2009). According to those authors, a long distance from the house to health facilities affects the accessibility of households to health services, thereby, intensifying the susceptibility of families to disasters and extreme climate events. In Vietnam in general and Thua Thien Hue province in particular, the health stations at commune level have poor facilities and services, with more than 40% of commune stations below national standards (Vietnam National Assembly Web Portal 2018). As such, communities are less likely to access healthcare services at commune health facilities compared to a higher level, such as district or province. That was the reason why the average distance from households to health facilities in all of the five communes in this research ranged from 2.6 to 4 (equal to 10 to 25 km) (Table 4.1).

Most likely, families with members who have chronic illness or disability are more exposed to risks and external stresses (Adu et al. 2017; Klasen & Waibel 2013; Levy & Patz 2015). According to Hanson-Easey and Hansen (2016, p. 6), poor communities 'living in small coastal settlements may have the limitation in access to health care system'. Thus, the chronic illness health status, observed as poor health status, implies a disadvantage to the community in terms of the ability to adapt to climate change-related stresses. The five communes had the average percentage of households with members who get sick very often or disabilities (Table 4.1 and 4.2). As a result, the aggregated scores of the vulnerability of each of the five communes regarding health status were not high and not significantly different between communes.

Food security

Food security is exceedingly vulnerable to climate change (Misra 2014; Parry et al. 2007). The findings of this research in subsection 4.1.5 show that almost none of the five communes struggled with food access within a whole year (Table 4.1 and 4.2). Thus, accessibility to food can help households improve their resilience to climate-related risks and stresses (Tyler, Keller & Swanson 2013; World Bank 2010).

However, the findings of this research show the high percentage of households without saving seeds for the succeeding crops, as well as the significant number of households without reserving parts of agriculture production. These imply a high level of vulnerability. Indeed, saving seeds can improve the resilience of farmers or households to the shock and stresses caused by climate change (Vernooy et al. 2017). Furthermore, the reserve of agriculture production may reduce the risk of food shortage due to extreme climate events (Ali et al. 2017). As a consequence, households who do not save seeds have less capacity to adapt to climatic stresses. In this research, the results as shown in Table 4.2 indicate that Phu Hai commune had the most vulnerability to food security indicator compared to others. This is because this commune had the highest percentage of households who struggled with finding food in a whole year, as well as the highest number of households without saving seeds and agriculture production.

Water access

The research findings indicate the overall scores of vulnerabilities of communes regarding water access indicators were fairly low compared to other major indicators. Water access is more likely threatened under climate change impacts and climate variability (Misra 2014). The reliance on natural sources of water implies high sensitivity to climate change impacts, especially water scarcity due to drought or in the dry season (Etwire et al. 2013). In this research, there was a minority of households in the five communes who used natural sources of water for drinking and a moderate number of them used natural water for agriculture land, especially Loc Binh commune. This can be interpreted that Loc Binh commune was likely more vulnerable to climate change impacts in terms of water accessibility.

In addition, the vulnerability of households in terms of water availability may also be affected by water conflicts (Gunasekara & Kazama S 2011; Gunasekara et al. 2014). This is because sharing water resources may lead to conflict in accessing scarce water resulting from climate change impacts. In this research, the water conflict is assessed via the percentage of households without tap water inside their houses. The findings in Chapter 4 (as presented in Table 4.1 and 4.2) show that all households of the five communes had tap water inside houses, which provides freshwater from water suppliers for households. Vinh Hien commune still had a significant number of households without tap water, leading to the high number of those using shared water or natural sources of water. As a result, the score of vulnerability to water access indicator of Vinh Hien commune was high, just lower than Loc Binh commune.

Natural disasters and climate variability

Climate change is likely intensifying the severity of natural disasters to the coastal communities (IPCC 2014a; Krishnapillai 2018). The findings of this research examine that flood, droughts, storms and pet and livestock diseases have often affected the five communes in the period 2013 to 2016. Droughts and livestock diseases have more substantial effects than other threats. Many scholars cite that droughts, storm and floods are common threats for rural areas in Vietnam, especially the central highland and coast (Chaudhry & Ruysschaert 2007; Praneetvatakul, Phung & Waibel 2013). Praneetvatakul, Phung and Waibel (2013, p. 190) and Gloede, Menkhoff and Waibel (2015) highlight that rural areas in Vietnam have been strongly impacted by crop pests and livestock diseases, for instance, 'avian flu and foot and mouth diseases'. The findings of this research point out there was a majority of households in the five communes affected by those threats, including loss of income from agricultural production and assets loss. These imply high exposure to natural disasters and climate-related risks.

According to Toan et al. (2014) and Waibel, Pahlisch and Völker (2018), a high level of perceptions of climate change may increase the success of preventing and mitigate climate change impacts, and thereby reduce the vulnerability of households. In this research, the percentages of households with perception of climate change were large differences between communes. This led to the vulnerability to disasters and climate risk between communes were dissimilar. In addition, the lack of mitigation strategies as well as adjustments for crops could increase the susceptibility of the communes to disasters and climate variability (Adger et al. 2007; Howden et al. 2007; Paton & Johnston 2001; Smit & Wandel 2006).

5.2. Vulnerability differences in three contributing factors in LVI_IPCC model between the communes

This section will discuss the differences between the communes based on three factors of vulnerability according to the IPCC definition, including adaptive capacity, sensitivity and exposure.

Adaptive capacity (AC)

The adaptive capacity in the LVI_IPCC model is measured by equation 4 (see Section 3) undertaking the inverse of three major indicators, including Socio-demographics profile, Livelihood strategies and Social networks. The results of one-way ANOVA in Section 4.3 confirm that no significant differences were found in mean socio-demographics, livelihood strategies as well as social networks between the communes. Therefore, it could be concluded that the statistical differences in adaptive capacity between the communes were not significant.

Exposure (E)

In the LVI_IPCC model, the natural disasters and climate variability major indicator of the LVI model is observed as contributing to the exposure of households to climate change impacts. The research findings show no statistically significant differences in natural disasters and climate variability indicators between the communes. Therefore, it can conclude that the statistical differences in exposure between the communes were also not significant. Particularly, Vinh Hien commune had higher exposure to natural disasters and climate variability in comparison to other communes. This is because Vinh Hien had the highest level of vulnerability to natural disasters and climate variability as presented in the results Section (see subsection 4.1.7).

Sensitivity (S)

The sensitivity in the LVI_IPCC model is calculated based on three major indicators, namely health status, food security and water access. The findings show Vinh Hien commune was the most sensitive regarding health status, food security and water access variables. It can be explained that due to Vinh Hien had the greater vulnerability in terms of health status, food and water sub-indicators.

In addition, the result of one-way ANOVA analyses in the previous sections indicates that the statistical differences in food security and water access indicators between the communes were significant. As a result, there were statistically significant differences in mean sensitivity between the communes.

5.3. A comparison for the different vulnerability of communes between LVI and LVI_IPCC models

This section aims to examine the reasons for disparities of vulnerability level of each commune based on the two models, LVI and LVI_IPCC.

The results of the vulnerability of communes based on LVI and LVI_IPCC models presented in Section 4 indicate there were disparities in the vulnerability level of each commune (see Table 4.2 and Table 4.5). In the LVI model, Vinh Hien commune was observed as the most vulnerable to climate change impacts while Phu An commune had the lowest vulnerability (Table 4.2). In contrast, the results of the LVI_IPCC model point out Huong Phong commune had the highest vulnerability whereas Phu Hai commune had the lowest vulnerability level (Table 4.5). Based on these findings, it can be observed that the variances of vulnerability to climate change impacts of the five communes between the two models, LVI and LVI_IPCC, can be attributed to the differences of vulnerability for the major indicators as well as the approach of each model.

In the LVI model, the vulnerability of each commune was computed by the weighted average of the seven major indicators with the different number of sub-indicators. The results of one-way ANOVA statistical analysis indicate that there were no statistically significant differences between communes in mean LVI for the socio-demographic, livelihood strategies, social networks, health status, and natural disasters and climate variability indicators (*p_value* >0.05). However, the statistical differences in mean LVI for food security and water access indicators were found to be significant, with *p_value* ≤ 0.05. As a result, it could be concluded that the mean differences between communes in food security and water access profoundly influence the vulnerability level of each commune in the LVI model. To illustrate, according to the findings (see Table 4.2), Vinh Hien commune had a very high vulnerability score for both food security and water access indicators, thereby, this commune had the highest vulnerability to climate change impacts. Conversely, the susceptibility to these two indicators of Phu An commune was the lowest and resulted in the lowest vulnerability to climate change impact. The LVI result was measured by major indicators and sub-indicators, therefore, it can be assumed that the change of sub-indicators, and the number of sub-indicators, may influence the communes' vulnerability (LVI).

In terms of the LVI_IPCC model, the vulnerability is measured by the function of adaptive capacity, exposure and sensitivity. Therefore, the differences of vulnerability level between the communes can be explained by the differences in three these factors. The results of one-way ANOVA analyses for statistical differences in mean adaptive capacity, sensitivity and exposure between communes show that there were only significant differences in sensitivity. In the LVI_IPCC model, the three major indicators contributing to sensitivity of households to climate change impacts are health status, water access and food security. The significant differences were found in terms of mean food security and water access between communes and led to the differences in mean sensitivity. The findings of this research in terms of vulnerability of communes in the LVI_IPCC model suggest that the changes of the three major indicators contributing to the sensitivity may influence the level of sensitivity of households in particular, and each commune in general, thereby, aggravating the overall vulnerability. These changes might also lead to the adjustment of current policies in terms of decreasing sensitivity of households and communes.

5.4. Influences of sub-indicators to the vulnerability of commune to climate change and the policy implications

The results of the sensitivity analyses indicate that the values of the vulnerability (LVI) of all five communes was significantly influenced by the sub-indicator ‘percent of households without saving seeds for the succeeding crops’. All of the livelihoods of households in the five communes have significantly rely on agriculture and aquaculture. In addition, saving seeds is one of the sub-components of the food security major indicator. In fact, climate change profoundly affected agriculture production, and food security problems are likely as a consequence. Thus, it could be argued that saving seed links closely to the vulnerability of livelihoods of these communities. Under the perspective of climate change adaptation, it can be interpreted that saving or reserving seeds have an essential role in reducing the impacts of climate change for farmers, especially in the coastal area, where they are profoundly vulnerable to risks and disasters related to climate change. A wide range of scholars state that saving seeds or intervention related to seed conservation will likely diminish the vulnerability of farming activities to changing climate conditions (Alvarenga & Dayrell 2015; Jarvis et al. 2011; Shrestha & Sthapit 2014; Vernooy et al. 2017).

The advice on farming activities from governments and the percentage of households who borrowed cash or food from their relatives were found as factors which intensely affects the five communes. Both sub-indicators are components of the social networks major indicator. Therefore, it can be assumed that social networks maintain important impacts on the vulnerability of households, especially in rural and poor areas (Nawrotzki et al. 2015). Facilitating interventions related to improving social networking could help communities increase the capacity to adapt to climate change.

Furthermore, the vulnerability of communes in this research are also highly affected by main income from agriculture and aquaculture as well as the adjustment activities in agriculture production to prevent the shocks and risks from climate extreme events. According to Tran

(2015, p.20) households in the central region of Vietnam are typified as being poor, with the main source of income from agriculture or farming activities. Thus, these communities extensively face agriculture shocks each year, with around 49% of households. This finding has an implication in the capacity of households or communes in responding to the impacts of climate change which need to be considered in the coping strategies to climate change for the study area and in rural areas in general.

In short, the results of the sensitivity analyses indicate that selecting the sub-indicators in the LVI models affects the vulnerability of communes' livelihoods to climate change significantly. Identification of the factors (sub-indicators) with the most influence on the vulnerability of communes should be used as instruments in adaptation strategies in order to reduce the vulnerability and improve the adaptive capacity for each commune. Some specific recommendations for each commune in terms of adaptation strategies will be discussed in the Section of recommendations in this research (Section 6).

5.5. Limitations of the LVI method and this research

As presented in the previous section, choosing sub-indicators significantly influenced the vulnerability of households' livelihoods to climate change. This reflects a limitation of the LVI method and that the vulnerability could be affected by the subjectivity in choosing sub-indicators for the LVI designing (Etwire et al. 2013; Hahn, Riederer & Foster 2009). In addition, the situation of the local environment also influences the shape and framing of the indicators for the LVI model (Panthi et al. 2015). In this research, the data used for applying the LVI and analysis of the vulnerability was extracted from the available TVSEP panel wave 6 databases. Thus, designing of sub-indicators also relies on data availability. This might be a restriction which affects the effectiveness of this research regarding measuring the vulnerability of communes.

6. CONCLUSION AND RECOMMENDATIONS

The research used data extracted from the TVSEP panel wave 6 for designing and applying for the Livelihood Vulnerability Index, with two models (LVI and LVI_IPCC), developed by Hahn, Riederer and Foster (2009) to analyse the vulnerability of coastal communities in Thua Thien Hue province, Vietnam. The research study includes five communes, that were also selected from the study area of the TVSEP project; Loc Binh, Vinh Hien communes (Phu Loc district), Phu An, Phu Hai commune (Phu Vang district), and Huong Phong commune (Huong Tra district). In addition, this research examined the differences in vulnerability of communes to climate change impacts and climate variability between two models and evaluated the sub-indicators of LVI influence significantly to the vulnerability of the communes. The summary of the research findings and their implications are as follows:

- The results of the calculations for the vulnerability of the study communes, based on the composite LVI model, indicate the various levels of vulnerability in different sub-indicators among communes. The identification of the different levels of vulnerability at commune level to climate change impacts, and climate variability, is essential to vulnerability studies at the local level, especially in the context of Thua Thien Hue province in particular and in Vietnam in general.

- The results of the overall LVI calculation ranged for different vulnerability of the five communes. The lowest vulnerability (0.338) for Phu An commune to the highest (0.432) for Vinh Hien commune, with the increasing in increments of 0.1. These vulnerability differences were determined by the variances of the major indicator vulnerability of the LVI model of the five communes.

- The findings related to the vulnerability of communes based on the LVI_IPCC model indicates the level of vulnerability among communes differed from the model of the composite LVI calculation. Particularly, based on this model, Huong Phong commune was the most vulnerable and Phu Hai commune has the lowest vulnerability, with the scale of vulnerability ranging from -0.063 (most vulnerability) to -0.115 (least vulnerability). The vulnerability in this model was determined by the three factors, including adaptive capacity, exposure and sensitivity, which were also computed from the major indicators of the LVI model. In this research, the LVI_IPCC value of each commune was the negative value because the scores of exposure of all communes were significantly smaller than the adaptive capacity scores.

- The disparity in the vulnerability level of communes between the two models, LVI and LVI_IPCC, can be explained based on the differences in major indicators vulnerability among communes as well as the structure or equations that each model used. This implies that selecting and weighing specific sub-indicators for major indicators in LVI has influenced the vulnerability level of communes. In this research, the vulnerability levels of all of five communes were significantly influenced by the sub-indicator for saving seed for succeeding crops, implying to the inevitability to engage this factor into strategies to reduce the vulnerability of the study communes to climate change.

The findings of this research contribute suggestively to the policy-making processes for coastal communities. Based on the findings, this research suggests some possible policy-relevant recommendations as follows:

- *Food security interventions*

The research findings indicate that saving seeds or food security has a significant influence on the overall vulnerability level of all the five communes. Thus, policymakers and donors should give priority in terms of fostering households save seeds for the succeeding crops in order to reduce food vulnerability, in particular, and livelihood vulnerability to climate change and variability in general. There is a need to improve the consciousness of communities about climate change effects, together with a clarification of the importance of saving agricultural seeds in relation to reducing the susceptibility to climate change. Furthermore, community seed bank is also a possible solution for effective saving of seeds and to conserve genetic sources for crops which the government could consider to initiate (Vernooy et al. 2014; Vernooy et al. 2017). In addition, food security should be a focus during the process of making policies or strategies to help communities to strengthen their resilience and better adapt to climate change.

- *Water supply intervention*

There is also the need to improve water supply for households in the study area in terms of encouraging and supporting households to set up tap water inside the house to reduce conflicts over water. One form of support that the government or water supplier should do is cutting down the price of supplied water for households in the rural and coastal area. Furthermore, the government also can support households via developing loans with low interest to create the opportunity for poor households to install and use drinking water from the suppliers.

These above interventions can also help the study communes diminish their sensitivity to climate-related risks and variability. In this research, the vulnerabilities of communes measured by the LVI_IPCC model were highly affected by sensitivity, of which water access and food security are two of the three factors contributing to the sensitivity of communes to natural disasters and climate variability.

- *Improvements of agriculture extension*

The research findings show that advice about farming activities from local governments or agriculture extension officers has extensively influenced the vulnerability of communes, especially Loc Binh, Vinh Hien, Phu An and Phu Hai communes. However, there were no households, or just a minority of families in these communes who received agricultural support or advice from the local government. The governments of these communes should strengthen the support for households or farmers undertaking the improvements via agriculture extension. These improvements could be done through regularly organizing meetings or training courses for farmers at the village level or commune level to train, introduce and transfer technology, as well as adopt new agricultural methods. Another activity to improve the support of the local government in terms of communicating advice and technology in farming is designing brochures or leaflets to deliver to households or hang in the community hall. These solutions might help farmers improve agriculture production and hence, increasing farmer's livelihoods.

- *Encouragement of adjustments in agricultural activities*

There is a high influence of adjusted activities in agriculture production to the vulnerability of communes, particularly Vinh Hien and Phu Hai communes. Thus, the governments of these two communes should prioritize to support their community and integrate into the policy process or plan to encourage farmers implementing adjustments for their crops and agricultural activities. To do that, these governments could introduce to farmers adjustment options to reduce the exposure and sensitivity to disasters and climate risks such as crop diversification practices or selecting highly resistant varieties of crops and livestock (Jarvis et al. 2015; Lin 2011). Agriculture insurance is also a form of support that the government should consider and encourage farmers to use to reduce risks and losses caused by disasters and climate change (Wreford, Moran & Adger 2010).

- *The reliance of households' income on agriculture and aquaculture*

This factor was found to be a significant influence on the vulnerability of Phu An and Huong Phong communes. Hence, the governments of these communes should prioritize the relevant interventions to help their communities reduce the dependence of households on agriculture and aquaculture for their main source of income. An effective solution for that is the diversification of livelihood and income for households. For example, income diversification can be developed through off-farm employment or owner business, and even migration for a job (Barrett, Reardon & Webb 2001; Tongruksawattana et al. 2013). Income diversification may also help households to decrease the amount of money and goods borrowed from their relatives, which is also considered a factor that has moderate influence the vulnerability to natural disasters and climate variability of Huong Phong and Phu An communes.

- *Applying and adopting the Livelihood Vulnerability Index (LVI)*

This research is a case study to apply the Livelihood Vulnerability Index (including both the LVI and LVI_IPCC models) at the commune level. These two approaches could be useful methods for governments, policymakers, and development organizations to examine the vulnerability of communities and acknowledge the factors contributing to vulnerability at district or provincial levels. The results of LVI can help governments or policy-makers prioritize the potential interventions and strategies for better adaptation to the impacts of climate change and climate variabilities.

The subjectivity of selecting and weighting sub-indicators for major indicators in the LVI model, and its influences on the vulnerability of households or communes, is a limitation of the LVI methods as discussed in the previous section. This research suggests that effectively identifying the sub-indicators could improve the precision of assessment of the vulnerability of livelihoods to climate change at the local or regional level. To do that, the applicants need to have a deep understanding of local situations including the natural resources, livelihoods assets, social-economic aspects as well as climate conditions.

Finally, the results of LVI_IPCC models in this research recommend that the researchers should use caution in case the scores of LVI is negative or counterintuitive (the adaptive capacity results are greater than the exposure results). Increasing the sensitivity might reduce the overall level of vulnerability. Therefore, in this case, applying the LVI_IPCC model, caution should be taken in suggesting the adaptation options to climate change.

APPENDICES

Appendix 1: Classified using of sensitivity analysis

1	**Decision Making or Development of Recommendations for Decision Makers**
1.1	Testing the robustness of an optimal solution.
1.2	Identifying critical values, thresholds or break-even values where the optimal strategy changes.
1.3	Identifying sensitive or important variables.
1.4	Investigating sub-optimal solutions.
1.5	Developing flexible recommendations which depend on circumstances.
1.6	Comparing the values of simple and complex decision strategies.
1.7	Assessing the "riskiness" of a strategy or scenario.
2	**Communication**
2.1	Making recommendations more credible, understandable, compelling or persuasive.
2.2	Allowing decision makers to select assumptions.
2.3	Conveying lack of commitment to any single strategy.
3	**Increased Understanding or Quantification of the System**
3.1	Estimating relationships between input and output variables.
3.2	Understanding relationships between input and output variables.
3.3	Developing hypotheses for testing
4	**Model development**
4.1	Testing the model for validity or accuracy.
4.2	Searching for errors in the model.
4.3	Simplifying the model.
4.4	Calibrating the model.
4.5	Coping with poor or missing data.
4.6	Prioritising acquisition of information.

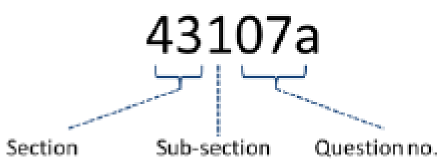
Source: adapted from Pannell (1997)

Appendix 2: The (sub) sections from the household questionnaire and name of data files for TVSEP panel wave 6

	(sub)sections	Data file
2.1-2.3	HH member, Education and Health	mem
2.4	HH dynamics	hhdyn
3.1a,b	Shocks	shock
3.2	Risk	risks
4.1	Land	land
4.2	Agriculture	crops
4.3.1	Stocks	livest
4.3.2	Livestock Products	lstprod
4.4	Fishing, hunting, collecting, logging	hunting
5	Off-farm employment	offempl
6	Non-farm self-employment	selfempl
7.1C	Credit rationing	credrat
7.1D	Default history	defhist
7.1A	Borrowing	borr
7.1E	Savings	sav
7.2A	Public transfers	transf
7.2B	Insurances	insur
8	Household expenditure	exp
6.2	Investment	invest
6.2	Disinvestment	disinvest
9.1	Household Wealth	assets
9.2	Housing conditions	house
	Questions at household level	hh
	Income aggregate	hhinc
	Consumption aggregate	consagg

Note:

Variable names are generated from the section/sub-section (if existing, not all sections have a sub-section) and the question number. For example variable name of question 7a in the sub-section 4.3.1 (stocks) is:



Appendix 3: Map of the study area for the TVSEP panels

Map source: Bernd Hardeweg, 2011 based on ESRI World Map.

Appendix 4: An example for calculating the Socio-demographic component for the LVI of Loc Binh commune

Sub-indicators for Socio-demographics profile indicator	Standardized values of sub-indicators	Max sub-indicator value for study area	Min sub-indicator value for study area	Index value for Loc Binh commune	Socio-demographics value for Loc Binh commune
Dependency percentage	25.98	100	0	0.260	**0.303**
Percentage of households where the head are female	30.00	100	0	0.300	
Percentage of households where household head did not attend school	35.00	100	0	0.350	

Step 1: Calculating the index value of sub-indicators (repeat for all sub-indicators)

$\text{Index}_{\text{Socio-demographic}} = \frac{25.98-0}{100-0} = 0.026$

Step 2: Calculating value of major indicator socio-demographics profile (repeat for all major indicators)

$$\textbf{Socio-demographics}_{\textbf{Loc Binh}} = \frac{\sum_{i=1}^{n} index_{Sci}}{n} = \frac{0.260+0.300+0.350}{3} = 0.303$$

Step 3: Calculating LVI for Loc Binh commune

$$LVI_c = \frac{\sum_{i=1}^{7} W_{Mi} M_{ci}}{\sum_{i=1}^{7} W_{Mi}} = \frac{3*0.303+4*0.475+3*0.817+2*0.500+3*0.467+3*0.303+9*0.256}{3+4+3+2+3+3+9} = 0.406$$

Appendix 5: An example of calculating contributing factors and overall LVI_IPCC value for Loc Binh commune

Contributing factors	Major indicators for Loc Binh commune	Major indicator value for Loc Binh commune	Number of sub-indicators for major indicator	Values of contributing factors	LVI value for Loc Binh commune
Adaptive capacity (A)	Socio-demographic profile	0.697	3	0.474	-0.093
	Livelihood strategies	0.525	4		
	Social networks	0.183	3		
Sensitivity (S)	Health status	0.500	2	0.425	
	Food security	0.467	3		
	Water access	0.333	3		
Exposure E	Natural disaster and climate variability	0.256	9	0.256	

Step 1: Calculating the index value for sub-indicators and major indicators as presented in Appendix 4, taking the inverse of sub-indicators for contributing adaptive capacity (Socio-demographic profile, Livelihood strategies, Social Networks).

Step 2: Calculating the adaptive capacity value for Loc Binh commune, repeat for Sensitivity and Exposure factors

$$\mathbf{A}_{\textbf{Loc Binh commune}} = \frac{\sum_{i=1}^{n} W_{Mi} M_{ci}}{\sum_{i=1}^{n} W_{Mi}} = \frac{3*0.697+4*0.525+3*0.183}{3+4+3} = 0.474$$

Step 3: Calculating LVI_IPCC value (repeat for all of five communes)

LVI_IPCC = (E – A) * S = (0.256 – 0.474) * 0.425 = -0.093

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