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Farm households' vulnerability to climate change in Cambodia, Myanmar, and Vietnam: An advanced livelihood vulnerability indexing approach

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ABSTRACT

Southeast Asia is considered one of the world's climate hotspots as the countries in the Mekong region, in particular, will be the hardest hit by the impacts of climate change if the global temperature continues to rise. This study aims to evaluate the differences in climate change-induced vulnerability of farm households in Cambodia, Vietnam, and Myanmar. The total sample size was 999 farm respondents, of which 304 were from Myanmar, 350 from Vietnam, and 345 from Cambodia. The farm households' vulnerability was measured using an advanced indicator or indexing method with balanced or equal weighting. A total of 36 indicators were selected based on an extensive literature review and expert judgment. Each major component was comprised of sub-components and indicators, which were standardized using a balanced weighted average approach. The findings reveal that Myanmar was high in all components of climate change vulnerability, whereas Vietnam was the second most vulnerable country, followed by Cambodia. Based on the findings, we suggest implementing policy measures that aim to reduce the sensitivity dimension of farm households, such as by improving early warning systems, increasing public funding investment in infrastructure development, and creating embankments to prevent saltwater incursion, while empowering the adaptive capacity of farm households. Furthermore, we also recommend establishing the necessary healthcare facilities, strengthening the public-private partnership, increasing outreach and healthcare services, and improving access to the formal credit system.

Contribution/Originality: This study's originality lies in the fact that it provides the first comparison of the livelihood vulnerability index among Cambodia, Vietnam, and Myanmar; also, it combines novel and advanced index approaches that allow for the identification of the magnitude of the impact of each indicator and sub-component.

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1. INTRODUCTION

Following the fourth IPCC Assessment Report, it is estimated that the flooded surface area in 33 deltas around the world will increase by 50% by 2100 (Intergovernmental Panel on Climate Change (IPCC), 2007). Nguyen (2008) highlighted that saltwater intrusion could reach long distances from the coastline and affect water use in estuaries. It is forecasted that this will result in decreased wetland areas, coastal erosion, and increased salinization of cultivated land and groundwater (Day et al., 2011; Mcleod, Poulter, Hinkel, Reyes, & Salm, 2010; Syvitski et al., 2009). Southeast Asia is considered one of the world's climate hotspots, as this region will be the hardest hit by the impacts of climate change if the global temperature continues to rise (Kreft, Eckstein, Junghans, Kerestan, & Hagen, 2013). It is highly vulnerable to adverse climate change impacts as it has extensive, heavily populated coastlines, large agricultural sectors, and large sections of the population living under $2 or even $1 per day (Asian Development Bank (ADB), 2009; Gerlitz, Hunzai, & Hoermann, 2012). Agriculture plays an important role in many countries in the region, accounting for 11% of gross domestic product (GDP) in 2006, and providing 43.4% of employment in 2004; although rapid economic growth and structural transformation are taking place, the increasing effects of climate change on the region's agricultural sector will be more severe in the future (Asian Development Bank (ADB), 2009). In particular, the Mekong region, which comprises Cambodia, Myanmar, Vietnam, Laos, and Thailand and is renowned for its rice production, is severely impacted by the adverse effects of climate change, including flooding and saltwater intrusion.

Several studies have forecasted a potential decline in crop yields and production areas in the Mekong and Southeast Asia regions (Asian Development Bank (ADB), 2014; USAID, 2019; World Bank, 2010). In the Mekong Delta, for example, a loss of 193 thousand hectares of rice paddies may result from inundation caused by the expected 30 cm sea level rise by 2050 (World Bank, 2010). Given that about 58% of the population of Asia lives in rural areas where their main livelihood relies on agriculture, the negative impacts of climate on agriculture and rural poverty are serious concerns (Intergovernmental Panel on Climate Change (IPCC), 2014). In this region, flood risks are also extremely high; the greatest recorded losses of life and economic losses resulted from riverine flooding and saltwater intrusion during 2011–2015 (Debarati, Hoyois, & Below, 2016). The risk of flood is large in the Mekong river basins, as heavy precipitation is often recorded, and the frequency is projected to increase (Asian Development Bank (ADB), 2014; Kundzewicz et al., 2014). In the Mekong region, households are facing more adverse impacts that threaten their livelihoods than in other countries (Martin & Lorenzen, 2016). In fact, farming activities and vulnerability have often been noted as a vicious cycle that pushes households into higher-risk positions. Various evidence has shown that households in developing countries tend to be more vulnerable due to their dependence on subsistence agriculture and livestock production combined with poor adaptive capacity and limited access to resources and production capital to mitigate the impacts of climate change (Baffoe & Matsuda, 2018; Nguyen, Shunbo, & Shah, 2019).

In Vietnam, Myanmar, and Cambodia, the majority of citizens live in rural areas, and their main source of income is farming activities (approximately 70%, 80%, and 65.1% of the population living in rural areas of Myanmar, Cambodia, and Vietnam, respectively (Tran & Shaw, 2007; USAID, 2019; World Food Program, 2008). These countries are considered the most vulnerable to the impacts of climate variability and natural hazards in the Mekong region. Of these, Myanmar is ranked second on the list of the top ten climate-hazardous countries in the world, while Vietnam and Cambodia are considered the most vulnerable countries on the mainland of Southeast Asia (Department of Foreign Affairs and Trade, 2019; Tran & Shaw, 2007; World Food Program, 2008). A recent report showed that in May 2008, Cyclone Nargis caused severe damage across the Ayeyarwady Delta region, reportedly killing around 140,000 people. In August 2018, monsoon flooding across Myanmar displaced more than 150,000 people (Department of Foreign Affairs and Trade, 2019). In the case of Vietnam, the impacts of climate change and natural hazards are increasing and various types of damage have been reported. Vietnam is one of nine countries where at least 50 million people will be exposed to the impacts of rising sea levels and more powerful storms, among other dangers (IPCC, 2018). Vietnam is among the countries of the world most vulnerable to climate change in the next couple of decades. Similar climate issues are observed in the case of Cambodia. For example, a report by the United States Agency for International Development (USAID; 2019) stated that in 2015, adverse climate impacts resulted in losses of approximately $1.5 billion, equivalent to 10 percent of its annual GDP. The country is particularly challenged due to low adaptive capacity, widespread poverty, and its geographic location in the Mekong River and Tonle Sap basins. Climate change will threaten this country in various ways in the coming decades, including in the areas of food security, water availability, human health, fisheries, and ecosystems (USAID, 2019). If proper management practices and adaptation measures are not implemented, severe flood risks will exist, and farm households will be the most vulnerable to erratic rainfall, increased precipitation, and saltwater intrusion into farmlands (Intergovernmental Panel on Climate Change (IPCC), 2014). Therefore, an empirical study on the impacts of climate change on farm households in the Mekong River basin is quite relevant. However, few previous studies have been conducted on the likely impacts of climate change on agriculture and the vulnerability of farm households. Moreover, previous studies have not compiled information on the entire Mekong region and have failed to present strategies to tackle farm households' increasing vulnerability to climate change in the Mekong region. Consequently, there is a critical need to conduct empirical research studies in Cambodia, Myanmar, and Vietnam (CMV) to evaluate the climate change vulnerability of farm households in the Mekong region and to prepare for short-term and long-term adjustments to the expected changes at different levels. This study aims to compare the level (index) of vulnerability to the adverse effects of climate change in CMV countries, and based on the results, the study will propose orientations, solutions, and recommendations for households, local governments, and central governments. This study is guided by the following questions: (i) What are the indicators that could be applied to calculate the livelihood vulnerability index (LVI)? (ii) Which country is most vulnerable based on the evaluation of LVI? (iii) Based on the LVI findings and each major component, what are essential solutions/recommendations that should be implemented to reduce the LVI in CMV countries? The remainder of this

paper is structured as follows: Section 2 discusses the theoretical conceptualization; Section 3 describes the study areas; Section 4 presents and discusses the results, and Section 5 offers conclusions and recommendations.

Not only does this study provide meaningful comparisons of the LVI among CMV countries and precise policy recommendations at the regional level, but it also offers an advanced approach to LVI by exploring the specific contribution (negative or positive) of each indicator of the major components and overall LVI. This innovative approach offers new guidelines for scholars working in the fields of climate change impacts, climate change adaptation, and water insecurity.

2. THEORETICAL CONCEPTUALIZATION

2.1. Context

Rising sea levels, a longer dry season with less rainfall, more intense rainfall in the rainy season, and shifts in the timing, duration, and intensity of seasons are currently the major challenges in the Mekong region (Parry, 2007). Climate change has impacted agricultural crop production and challenged food security in the Mekong region. Flooding and saltwater intrusion pose threats to the livelihoods and socioeconomic status of farm households in delta and lowland areas. For instance, in Cambodia's delta region, the severe impacts of climate change include a series of severe floods and droughts (Ministry of Agriculture Forestry and Fisheries, 2014). This climate variability and change has adverse effects on climate-sensitive livelihood-dependency farmers. In Vietnam, households' vulnerable features combined with the negative effects of climate change trap them in increasing challenges (Tran & Shaw, 2007). Rising sea levels cause saltwater intrusion and flooding of agricultural land, ultimately threatening the livelihoods of farm households in the delta region of Myanmar (Oo, Huylenbroeck, & Speelman, 2018; Sein et al., 2015).

2.2. The Concept and Measurement of Vulnerability

The concept of vulnerability was first proposed and developed in the sustainable livelihood framework (SLF) in the 1980s (Chambers, 1989; Scoones, 1998). Since then, this idea has been applied by various practitioners in different fields of rural development study (Carswell, 1997; DFID, 2008; Ellis, 1998). With the increasingly adverse impacts of climate change, vulnerability evaluations have drawn much attention in the literature (Tian, Brown, Bao, & Qi, 2015). This involved a broad approach including many principles from economics, sociology, anthropology, psychology, and engineering (Adger, 2006; Sujakhu et al., 2018). It was divided into two schools of thought, one side focused on theory and definitions (Baffoe, 2019; Bebbington, 1999; Carr, 2014; Carswell, 1997; Engle, 2011; Hinkel, 2011a; Smit & Wandel, 2006; Wiréhn, Danielsson, & Neset, 2015), while the other side developed and applied the indicator system to empirical research (Adu, Kuwornu, Anim-Somuah, & Sasaki, 2018; Ahsan & Warner, 2014; Baffoe & Matsuda, 2018; Bhattacharjee & Behera, 2018; Few & Tran, 2010; Hafezi, Sahin, Stewart, & Mackey, 2018; Hahn, Riederer, & Foster, 2009; Huang, Huang, He, & Yang, 2017; Nguyen, Nguyen, Le, Burny, & Lebailly, 2018; Nhuận, 2015; Oo et al., 2018; Rahman, Mia, Ford, Robinson, & Hickey, 2018; Shah, Dulal, Johnson, & Baptiste, 2013; Vincent, 2004).

Several authors have argued that vulnerability remains a vague concept and is still inconsistently defined (Adger, 2006; Hinkel, 2008), leading to different indexes. In the same vein, others have even stated that vulnerability cannot be measured at all (Moss, Brenkert, & Malone, 2001; Patt, Schroter, & De la Vega-Leinert, 2008). Nevertheless, Hinkel (2011b) presented four types of arguments for the development of vulnerability indicators: (i) deductive, (ii) inductive, (iii) normative, and (iv) non-substantial arguments. The strength of this approach was the simplicity of forming an index. In fact, it has been previously applied by several researchers on climate change vulnerability (Hinkel, 2011b). However, it remains difficult to select appropriate indicators. The Intergovernmental Panel on Climate Change (IPCC) (2014) proposed that an LVI evaluation should include three dimensions of vulnerability: sensitivity, adaptive capacity, and exposure. Thus, vulnerability was conceptualized as being constituted of a group of components including exposure and sensitivity to external stressors, and the capacity to adapt (Adger, 2006). Exposure is the degree, duration, and/or extent to which the system is in contact with, or subject to, the disturbance; sensitivity is the degree to which the system is modified or affected by a disorder; finally, the capacity to adapt (also known as adaptive capacity) is the system's ability to cope with or recover from the disturbance (Fischer, 2018).

2.3. The Livelihood Vulnerability Index

When building and applying an indicator-based approach, there are several important considerations. Firstly, they are commonly used to assess the climate vulnerability of a system or society and are used for assessment at all levels to aggregate data into vulnerability indices (Hinkel, 2011b). Secondly, the indicators or selected variables in these approaches are very site-specific and vary between regions. Hence, climate change vulnerability has been analyzed in different contexts and can be assessed exclusively from a climate perspective or at a regional or national level (Diouf & Gaye, 2015). In the assessment of climate vulnerability, Adger (1996) and Kelly and Adger (2000) recommended that a vulnerability index should be considered a function of social vulnerability and environmental risk. Also, most vulnerability assessment indicators are used to indicate how vulnerable a system or community is; generally, a single measurement of characteristics is needed to develop an advanced approach that allows the LVI to cover multiple aspects, such as comparing different countries (Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Hinkel, 2008, 2011a). Last but not least, Diouf and Gaye (2015) pointed out that three main limitations of index-formulation must be taken into account. These relate to the inappropriate nature of the relationship posed by the indices, the incumbent relationship of these indices upon aggregation, and questions about local specificities in the formulation of national indices. Recently, vulnerability assessment has become a core exercise in understanding development challenges and climate change influences in many contexts (Baffoe & Matsuda, 2018). Consequently, specialists have stated that vulnerability assessment should cover the connections between humans and their physical and social surroundings, as

well as their economic and political environments (Intergovernmental Panel on Climate Change (IPCC), 2014; United Nations Office for Disaster Risk Reduction (UNDRR), 2004). Hence, many scholars posited that the LVI assessment was a vital step in developing adaptation strategies, policies, and programs to reduce risks associated with climate change (Nguyen et al., 2019; Sujakhu et al., 2018). Reasonably, an LVI assessment plays a critical role in answering three important questions about households' adaptation strategies, including, "What to adapt to?", "How to adapt?" and "When to adapt?" (Hafezi et al., 2018). To establish an LVI record, scholars have proposed and applied a wide range of approaches; however, they share some general steps. In the first step, it is necessary to identify the indicators to collect information (Oo et al., 2018; Tessema, Joerin, & Patt, 2018). Next, an indicator-based approach is applied to score the overall index as well as the partial score of each major component. This approach is adopted following strictly a balanced weighted average approach (Carl, Gary, & Stuart, 2009; Hahn et al., 2009).

To conclude, the dilemma of selecting which framework to apply and how many indicator systems to use for vulnerability assessment depends on many factors, including geographic conditions, temporal scale, and socioeconomic status of the research sites. No single approach is flawless because each has strengths and limitations (Oo et al., 2018). Moreover, few previous studies have conducted collaborative research to examine LVI by country. This cross-country study tried to fill this gap with the aim of proposing solutions at the regional level. To do so, literature-grounded and locally specific indicators were selected. In addition, the selected indicators were checked by local experts in a focus group discussion and validated with 10 pilot respondents. Therefore, the indicators include 36 units, grouped into 7 major components, which convey farm households' vulnerability to climate change in Cambodia, Myanmar, and Vietnam (CMV).

3. STUDY AREAS

Empirical research was conducted in three delta areas of the CMV countries. To select the sampling areas, we first collected demographic data and secondary data to find areas prone to frequent flooding and saltwater intrusion. In Vietnam, Thua Thien Hue Province is located along the inner border of the East Sea and has a total area of 503 thousand ha, of which 75.1% is mountainous, and 24.9% is delta area. The average annual rainfall ranges from 2600 mm to 4000 mm. Thua Thien Hue Province is known as a flood-prone area in the delta of Vietnam. The survey was conducted in four communities: Vinh Thai and Vinh Phu in Phu Vang district and Quang Loi and Quang Thai in Quang Dien district (see Figure 1). A total of 350 samples from Thua Thien Hue were collected for the study.

Figure 1. Thua Thien Hue province and research areas.

Note: Provincial Committee of Thua Thien Hue (2018).

In Cambodia, Prey Veng province borders Kampong Cham to the northwest, Tbong Khmum to the northeast, Svay Rieng to the east, and Vietnam to the south. It is traversed by the Mekong and the Tonle Bassac, two of the nation's principal rivers. The province covers 4,883 km², which equals 2.7% of the total land area of Cambodia (181,035 km²). Two districts in the floodplains of the Mekong River, Peam Chor, and Sithor Kandal, were selected for this study (see Figure 2). These are categorized as 'flood-prone' areas. Four communities were selected, Romlech, Chhrey Khmom, Koh Chek, and Preak Sambour, which are located in the floodplain of the Lower Mekong River (Am, Cuccillato, Nkem, & Chevillard, 2013). The target communities and villages were selected based on discussions with key informants from the Department of Agriculture and the communities' chiefs. In total, 369 samples were collected, but due to missing information, only 345 were used in this study.

In Myanmar, empirical research was conducted in the Labutta and Pyapon districts in the lower Ayeyarwaddy region (see Figure 3). The Ayeyarwady delta basin is the largest river basin in Myanmar, covering 404,200 km². It is known as the rice pot of Myanmar. Rice production in the region accounts for 30% of Myanmar's total production (Department of Agricultural Planning, 2014; Ministry of Agriculture, Livestock and Irrigation (MOALI), 2016). The

Pyapon district comprises four townships (Bogale, Pyapon, Kyaiklat, and Dedaye), which include 298 village tracts and 1,450 villages.

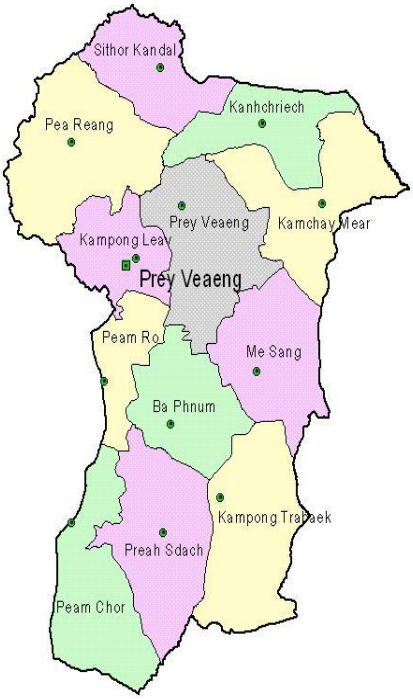


Figure 1. Map of research regions in Prey Veng province.

The Pyapon district is situated between 16° 15' N and 95° 30' E, while the Labutta district is located between 16° 10' N and 95° 00' E. These regions are located 131 km from Yangon, the capital. The total area of Pyapon is about 5,500 km², and its cultivable land area is roughly 3,400 km². The total population of Pyapon is around 1.03 million, 13.11% of whom are urban dwellers, while 86.89% live in rural areas. The total population of Labutta district is around 0.626 million, 10.5 % of whom are urban dwellers. A total of 345 farms' respondents were interviewed. Due to the missing information and incomplete data, only 304 samples were used as data.

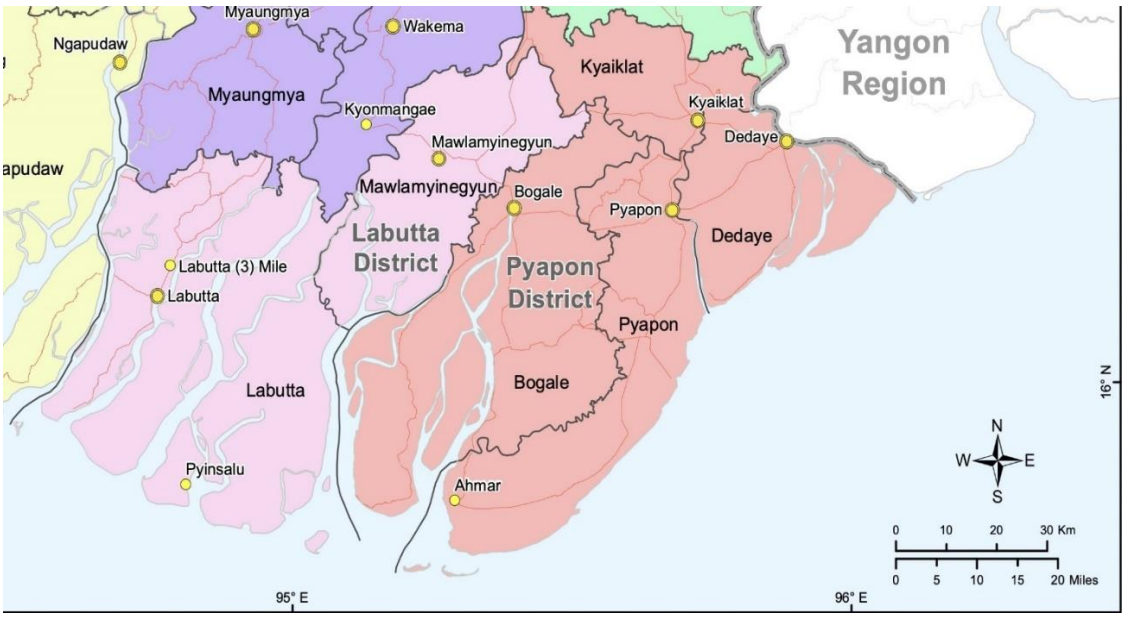


Figure 3. Map showing the location of Pyapon and Labutta districts.

4. RESULTS AND DISCUSSION

A comparative analysis of the climate change vulnerability of farm households to saltwater intrusion and flooding was carried out based on 7 major vulnerability index components. The sub-component indicators were acquired based on structured questionnaires and in-depth analysis of the study areas of Myanmar, Vietnam, and Cambodia (Table 1, Table 2, and Figure 4). The following sections present and discuss the findings.

4.1. Socio-Demographics

In the socio-demographic dimension, five indicators were considered: farm households without electricity, average age, household-head without secondary education, female-headed household, and population density. The results showed that Cambodia was the most vulnerable country, after which came Vietnam (scores: 0.368 and 0.331, respectively), while Myanmar was less vulnerable (0.325). The data showed that the distribution of the Vietnamese population was younger than that of Myanmar and Cambodia (0.354, 0.412, and 0.485, respectively), implying that Vietnam has more advantages when diversifying livelihood activities for earning a larger income through labor productivity. Vietnam and Cambodia have achieved more success in widening access to the electrical network through a variety of sources, while Myanmar still has a limited supply. The results showed that in Vietnam (0.044) and Cambodia (0.092) there was less vulnerability than in Myanmar (0.756). Cambodia was the most vulnerable for the indicator *household-head without secondary school* (0.74), followed by Vietnam (0.214) and Myanmar (0.095). In the case of Vietnam, since the 2000s, in the context of a large average family size, households tended to encourage family members to leave their communities to get a job in a nearby town or abroad. Myanmar has recently achieved success with its national education program, while Cambodia still lacks a focus on this important sector, especially in rural areas. The highest proportion of female-headed households was found in Cambodia (0.13), followed by Vietnam (0.052) and Myanmar (0.043), respectively. Women generally have more decision-making power in Cambodia, while in the other countries, the man still plays a crucial role; the marked inequality of gender contribution reduces the vulnerability. Regarding the population density, for the whole region in Vietnam, the majority of populated areas were close to the sea where the impacts of rising sea levels and flooding often affected the community, while Cambodia and Myanmar were found to be less vulnerable in terms of population density (0.312 and 0.392, respectively).

4.2. Livelihood Strategy

This domain included the indicators: household with agriculture as the main income source, household without a secondary job, household receiving non-farm income, household with at least one migrant, and household without insurance. This study found that the agricultural sector is the main source of livelihood in the CMV countries. In Myanmar, many households reported that agriculture was their main income source (0.98), followed by Cambodia and Vietnam (0.81 and 0.723, respectively). In the case of Vietnam, although the central government has recently begun to encourage the application of new machines, technologies, and models in the agricultural sector to increase farm productivity, it still needs to increase the industrial and service sectors' share of the GDP. This would downscale the influence of agriculture on economic development. Regarding the other indicators, an interesting feature of agricultural activities is their seasonality, which provides households with another strategy to reduce their vulnerability and diversify their income inflow. The survey findings showed that the proportion of households with a second job was high in all three countries; the highest vulnerability was in Myanmar (0.681), followed by Vietnam (0.583) and Cambodia (0.545). There is no doubt that migration is a crucial strategy for households in developing countries. It is important not only as it increases income, but it also supplies livelihood diversification to support local economic development (Adger, Kelly, Winkels, Huy, & Locke, 2002; Aggarwal, 2016; Coffey, Papp, & Spears, 2015; Nguyen, Raabe, & Grote, 2015). The study found that Vietnam scored the highest value on the migration indicator (0.574); Myanmar ranked second with a moderate score (0.501), and the lowest value was found in Cambodia (0.211). Having insurance contributes significantly to an improvement in the quality of life, especially as it allows poor households to cope with issues of illness. In Vietnam, the national health program encourages every household to take part in the insurance program. This was a successful policy leading to an absolute minimum of vulnerability (0.000). In contrast, this indicator was very high in Myanmar (0.756), while none of the studied households in Cambodia had insurance (1.000).

4.3. Social Network

This major component included four indicators: average distance to the nearest market, household received remittance help, household received social help, and household received community help. The distance from the household to the nearest market affects its ability to access food and drink as well as production means; therefore, it is important for satisfying basic household needs.

Table 1. Sub-components and major components of the livelihood vulnerability index for farm households in CMV countries (2017–2019).

Major components	Sub-components	Myanmar	Vietnam	Cambodia	Myanmar	Vietnam	Cambodia
		Value of observation			Value of LVI		
	Average age	41.2	35.4	48.5	0.412	0.354	0.485
	% Household without electricity	75.6	4.4	9.2	0.756	0.044	0.092
	% Household head without secondary education	9.5	21.4	74.0	0.095	0.214	0.740
	% Female household head	5.2	4.3	13.0	0.052	0.043	0.130
	Population density	188.6	605.3	237.0	0.312	1.000	0.392
Socio-demographics (5)	Overall socio-demographics score				0.325	0.331	0.368
	% Household with agriculture as main income source	98.0	72.3	81.0	0.980	0.723	0.810
	% Household without secondary job	68.1	58.3	54.5	0.681	0.583	0.545
	% Household income from non-farm act.	34.9	19.1	38.5	0.349	0.191	0.385
	% Household without at least one migrant	21.1	57.4	50.1	0.211	0.574	0.501
	% Household without insurance	75.6	1.9	100.0	0.756	0.019	0.000
Livelihood strategies (5)	Overall livelihood strategies score	-	-	-	0.595	0.418	0.448
	Average distance to nearest market	6.2	3.2	1.9	1.000	0.522	0.299
	% Household without remittance help	93.4	6.2	50.1	0.934	0.549	0.501
	% Household without social help	96.1	52.0	61.8	0.961	0.520	0.618
	% Household without community help	4.3	7.7	4.6	0.043	0.077	0.046
Social network (4)	Overall social network score	-	-	-	0.735	0.417	0.366
	Average distance to health facilities (Miles)	3.9	2.9	2.0	1.000	0.734	0.505
	Average time to health facilities	0.4	0.1	12.2	0.441	0.082	0.122
	% Household with sanitary latrine/toilet	9.8	0.0	20.9	0.098	0.000	0.209
	% Household missed work or school due to illness	39.4	7.7	11.1	0.395	0.077	0.111
	% Household with members with chronic illness	21.1	8.3	24.4	0.211	0.082	0.244
Health (5)	Overall health score	-	-	-	0.429	0.195	0.218
	% Household food strategy: take loan	62.8	88.0	38.8	0.628	0.880	0.388
	% Household food strategy: sell property	75.3	3.4	29.0	0.753	0.034	0.290
	% Household that does not save food	19.1	2.0	4.3	0.192	0.020	0.043
	% Household that does not save seed	14.1	0.0	2.7	0.141	0.000	0.027
	% Household consumes non-cash food items	57.2	57.4	59.1	0.572	0.574	0.591
	Average food insecure months	1.3	0.1	1.2	1.000	0.060	0.481
	Average household food expenditure	217.2	109034.0	80.6	1.000	0.502	0.371
Food (7)	Overall food score	-	-	-	0.612	0.296	0.313
	% Household reporting water conflict	36.2	3.7	16.8	0.362	0.037	0.168

Water (4)	% Household difficulties in drainage	56.6	5.7	46.3	0.566	0.057	0.463
	% Household no secure water in rainy season	28.9	17.4	32.2	0.289	0.174	0.322
	% Household no secure water in dry season	12.2	17.7	58.3	0.121	0.177	0.583
	Overall water score	-	-	-	0.335	0.111	0.384
Natural hazards (4)	% Household reports no early warning	30.3	96.3	69.9	0.303	0.372	0.699
	% Household with injuries as a result of NH	3.6	2.9	1.4	0.036	0.029	0.014
	% Household loss of housing (Asset) as a result of natural hazards	91.4	48.6	22.0	0.914	0.486	0.220
	Average mean rainfall (mm)	3050.1	3468.9	1413.0	0.824	1.000	0.407
	Overall natural hazards score	-	-	-	0.519	0.472	0.335
	LVI	-	-	-	0.511	0.317	0.344

Table 2. Sign of contribution of each component to major components and overall LVI.

Major component	Sub-component	Myanmar				Vietnam				Cambodia			
		Major component		LVI		Major component		LVI		Major component		LVI	
		+/- Value	Sign of contribution	+/- Value	Sign of contribution	+/-Value	Sign of contribution	+/-Value	Sign of contribution	+/-Value	Sign of contribution	+/-Value	Sign of contribution
Socio-demographic (5)	Average age	0.087	*PB	-0.099	**NB	0.023	PB	0.037	PB	0.117	PB	0.141	PB
	% Household without electricity	0.431	PB	0.245	PB	-0.287	NB	-0.274	NB	-0.276	NB	-0.252	NB
	% Household head without secondary education	-0.230	NB	-0.416	NB	-0.117	NB	-0.103	NB	0.372	PB	0.396	PB
	% Female household head	-0.273	NB	-0.459	NB	-0.288	NB	-0.274	NB	-0.238	NB	-0.214	NB
	Population density	-0.013	NB	-0.199	NB	0.669	PB	0.683	PB	0.024	PB	0.048	PB
Livelihood strategies (5)	% Household agriculture as main income source	0.385	PB	0.469	PB	0.305	PB	0.406	PB	0.362	PB	0.466	PB
	% Household without secondary job	0.086	PB	0.170	PB	0.165	PB	0.266	PB	0.097	PB	0.201	PB
	% Household income from non-farm act.	-0.246	NB	-0.162	NB	-0.227	NB	-0.126	NB	-0.063	NB	0.041	PB
	% Household without at least one migrant	-0.384	NB	-0.300	NB	0.156	PB	0.257	PB	0.053	PB	0.157	PB
	% Household without insurance	0.161	PB	0.245	PB	-0.399	NB	-0.298	NB	-0.448	NB	-0.344	NB
Social network (4)	Average distance to nearest market	0.266	PB	0.489	PB	0.105	PB	0.205	PB	-0.067	NB	-0.045	NB
	% Household received remittance help	0.200	PB	0.423	PB	0.132	PB	0.232	PB	0.135	PB	0.157	PB
	% Household received social help	0.227	PB	0.450	PB	0.103	PB	0.203	PB	0.252	PB	0.274	PB
	% Household received community help	-0.692	NB	-0.468	NB	-0.340	NB	-0.240	NB	-0.320	NB	-0.298	NB
Health (5)	Average distance to health facilities (miles)	0.571	PB	0.489	PB	0.539	PB	0.417	PB	0.287	PB	0.161	PB

	Average time to health facilities	0.012	PB	-0.070	NB	-0.113	NB	-0.235	NB	-0.096	NB	-0.222	NB
	% Household with sanitary latrine/toilet	-0.331	NB	-0.413	NB	-0.195	NB	-0.317	NB	-0.009	NB	-0.135	NB
	% Household missed work or school due to illness	-0.034	NB	-0.116	NB	-0.118	NB	-0.240	NB	-0.107	NB	-0.233	NB
	% Household with members _chronic illness	-0.218	NB	-0.300	NB	-0.113	NB	-0.235	NB	0.026	PB	-0.100	NB
Food (7)	% Household food strategy: take loan	0.016	PB	0.117	PB	0.584	PB	0.563	PB	0.075	PB	0.044	PB
	% Household food strategy: sell property	0.141	PB	0.242	PB	-0.262	NB	-0.283	NB	-0.023	NB	-0.054	NB
	% Household does not save food	-0.420	NB	-0.319	NB	-0.276	NB	-0.297	NB	-0.270	NB	-0.301	NB
	% Household does not save seed	-0.471	NB	-0.370	NB	-0.296	NB	-0.317	NB	-0.286	NB	-0.317	NB
	% Household consumes non-cash food items	-0.040	NB	0.061	PB	0.278	PB	0.257	PB	0.278	PB	0.247	PB
	Average food insecure months	0.388	PB	0.489	PB	-0.236	NB	-0.257	NB	0.168	PB	0.137	PB
	Average household food expenditure	0.388	PB	0.489	PB	0.206	PB	0.185	PB	0.058	PB	0.027	PB
Water (4)	% Household reporting water conflict	0.028	PB	-0.149	NB	-0.074	NB	-0.280	NB	-0.216	NB	-0.176	NB
	% Household difficulties in drainage	0.232	PB	0.055	PB	-0.054	NB	-0.260	NB	0.079	PB	0.119	PB
	% Household no secure water in rainy season	-0.046	NB	-0.222	NB	0.063	PB	-0.143	NB	-0.062	NB	-0.022	NB
	% Household no secure water in dry season	-0.214	NB	-0.390	NB	0.066	PB	-0.140	NB	0.199	PB	0.239	PB
Natural hazards (4)	% Household reports no early warning	-0.208	NB	-0.208	NB	0.055	PB	0.055	PB	0.355	PB	0.355	PB
	% Household with injuries as a result of NH	-0.475	NB	-0.475	NB	-0.288	NB	-0.288	NB	-0.330	NB	-0.330	NB
	% Household loss of housing (Asset) as a result of NH	0.403	PB	0.403	PB	0.169	PB	0.169	PB	-0.124	NB	-0.124	NB
	Average mean rainfall (mm)	0.313	PB	0.313	PB	0.683	PB	0.683	PB	0.063	PB	0.063	PB
	% PB	-	52.9	-	47.1	-	50.0	-	44.1	-	52.9	-	52.9

Note: *PB: Positive contribution – an indicator contributes to higher vulnerability; **NB: Negative contribution – an indicator contributes to lower vulnerability.

Myanmar was the most vulnerable according to this indicator (1.000), followed by Vietnam (0.552) and Cambodia (0.229). Households in Myanmar face numerous challenges, not only in accessing input providers but also in accessing markets to sell their farm products. Considering remittance from migrants, Myanmar again scored highest (0.934), implying that very few households in this country receive income from migrant family members. Vietnam had a moderate value (0.549), while Cambodia (0.501) scored the lowest. The social help category generally consisted of support from non-governmental organizations (NGOs) and charity groups. The survey findings indicated that households in Vietnam (0.574) were less vulnerable compared to those in Cambodia (0.618) and Myanmar (0.961). As for community help, this domain showed a low level of vulnerability, meaning that households are well-supported by local communities when facing immediate emergencies. Myanmar and Cambodia recorded the lowest and second-lowest values (0.043 and 0.046), followed by Vietnam (0.077).

4.4. Health

This major component includes five indicators: average distance to healthcare facilities, average time to healthcare facilities, household with a sanitary latrine/toilet, household missed work or school due to illness, and household with members with a chronic illness. The distance from the household to the nearest healthcare facilities was indicative of the availability of this public service to inhabitants in the case of an emergency. Myanmar had absolute vulnerability in this category (1.000); meanwhile, Vietnam also had a very high score (0.734) compared with Cambodia (0.505). The average time to healthcare facilities reflected the time it took to travel from the home to the nearest healthcare facility. Thanks to the development of its transport system and diversification of vehicles, Vietnam had the advantage in this criterion with the lowest score (0.082), while the household vulnerability was higher in Myanmar due to its limited or poor infrastructure system and lengthy travel times (0.441) and relatively low in the case of Cambodia (0.122). Turning to the point of household access to a sanitary latrine or toilet, with the improvement in living conditions supported by various programs, none of the studied households in Vietnam lacked a sanitary toilet. Similarly, Cambodia and Myanmar have achieved considerable success through programs and, therefore, have a very low vulnerable index (0.098 in Myanmar and 0.209 in Cambodia). Households' general health was evident in the low scores for the indicator measuring households whose members missed work or school due to illness in the three countries (Vietnam: 0.077, Cambodia: 0.111, and Myanmar: 0.395). Similarly, in the case of households having a family member with a chronic illness, the highest household score was in Cambodia (0.244), followed by Myanmar (0.211), and the lowest was in Vietnam (0.082). To sum up, Vietnam has achieved impressive improvements due to the success of its national health program compared to the other countries. Myanmar showed limitations in the health domain, while Cambodia showed various successes. As mentioned above, it is necessary to pay more attention to Myanmar and take a multi-actor, multi-context, and multi-approach perspective to solve the noted issues.

4.5. Food

This major component includes seven indicators: household food strategy: take loan, household food strategy: sell property, household does not save food, household does not save seed, household consumes non-cash food items, average food insecure months, and average household food expenditure. Taking out a loan to buy food was the most popular strategy in Vietnam and Myanmar, with high scores of 0.880 and 0.628, respectively, whereas it was a less common strategy in Cambodia (0.388). For the strategy of selling property, Myanmar again had the highest score (0.753), contrasting with the low scores of Cambodia and Vietnam (0.290 and 0.034). The findings also showed that households were mainly successful in saving food; the three countries each reported low scores. The data show that Myanmar was the most vulnerable (0.192), followed by Cambodia (0.043) and Vietnam (0.020). Regarding the saving of seed, households in Vietnam and Cambodia mainly used seed from providers with the support of the local government, which explains the low scores of these countries (0.000 and 0.027). The findings also showed a low vulnerability score (0.141) in the case of Myanmar. Next, the study findings also indicated that households in the three countries mostly obtained their food items both from existing natural sources and from the market, as each country recorded a moderate value regarding the consumption of non-cash food items (0.591, 0.574, and 0.572 for Cambodia, Myanmar, and Vietnam, respectively). Farm households generally raise poultry for meat and eggs and cultivate vegetable crops as a source of nutrition. The average number of food insecure months was highest in Myanmar (1.000), followed by Cambodia (0.481) and Vietnam as the least vulnerable country in this respect (0.060). Concerning the average household food expenditure, a similar trend was observed; Myanmar again scored highest (1.000), followed by Vietnam (0.502) and Cambodia (0.371). Overall, for food, Myanmar was the most vulnerable country with a high index score of 0.612, while Cambodia and Vietnam scored lower: 0.313 and 0.296, respectively.

4.6. Water

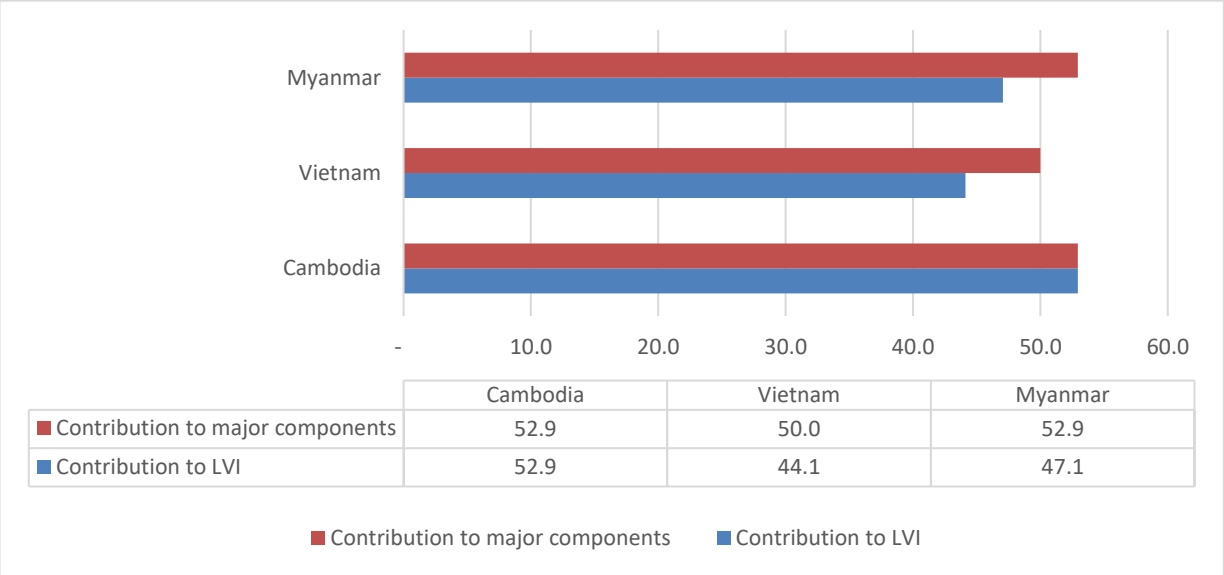
This component included four indicators to analyze water vulnerability: household reporting water conflict, household with drainage difficulties, household with no secure water in the rainy season, and household with no secure water in the dry season. Households rarely reported water conflicts with other users (0.168 in Cambodia and 0.037 in Vietnam), although Myanmar scored higher on this issue (0.362). Conflicts may occur within and between local communities over issues of agriculture and aquaculture. There may be a strong link between the degree of water conflict and drainage systems. Households in Myanmar coped with many challenges in the drainage system, (0.566), followed by Cambodia (0.463), whereas Vietnam's well-constructed drainage system led to a low vulnerability score (0.057). Concerning households' water security by season, in the rainy season, Cambodia was found to have the highest score (0.322), slightly higher than that of Myanmar (0.289), and Vietnam was the least vulnerable (0.174). Turning to the dry season, both Vietnam (0.177) and Myanmar (0.121) had low levels of vulnerability, while Cambodia showed the

highest vulnerability (0.583). Overall, for water, Cambodia was the most vulnerable with a score of 0.384, followed by Myanmar with 0.335 and Vietnam with 0.111.

4.7. Natural Hazards

This domain is comprised of four indicators: household reported no early warning, household experienced injuries as a result of natural hazards, household lost housing (asset) as a result of natural hazards, and average mean rainfall. The study found that a high percentage of households did not receive early warning information. Cambodia had the highest score (0.699), Vietnam ranked second (0.372), and the lowest value was in Myanmar (0.303). Myanmar's success in giving early warnings contributed positively to households' adaptation to natural hazards, compared to the situation in Vietnam and Cambodia. Overall, there was a low level of injuries caused by natural hazards; Myanmar had the highest score (0.036), followed by Vietnam (0.029) and Cambodia (0.014). Regarding damage to housing in the last five years, households in Myanmar were highly vulnerable (0.914), those in Vietnam reported a moderate level (0.486), while Cambodia had the lowest vulnerability score (0.220). Finally, regarding the indicator average mean rainfall, Vietnam had absolute vulnerability (1.000) as it has the highest rainfall in Southeast Asia. Myanmar ranked second (0.824), followed by Cambodia (0.407). Overall, for natural hazards, Myanmar and Vietnam had a relatively high level of vulnerability (0.604 and 0.573, respectively), while Cambodia was less vulnerable (0.335).

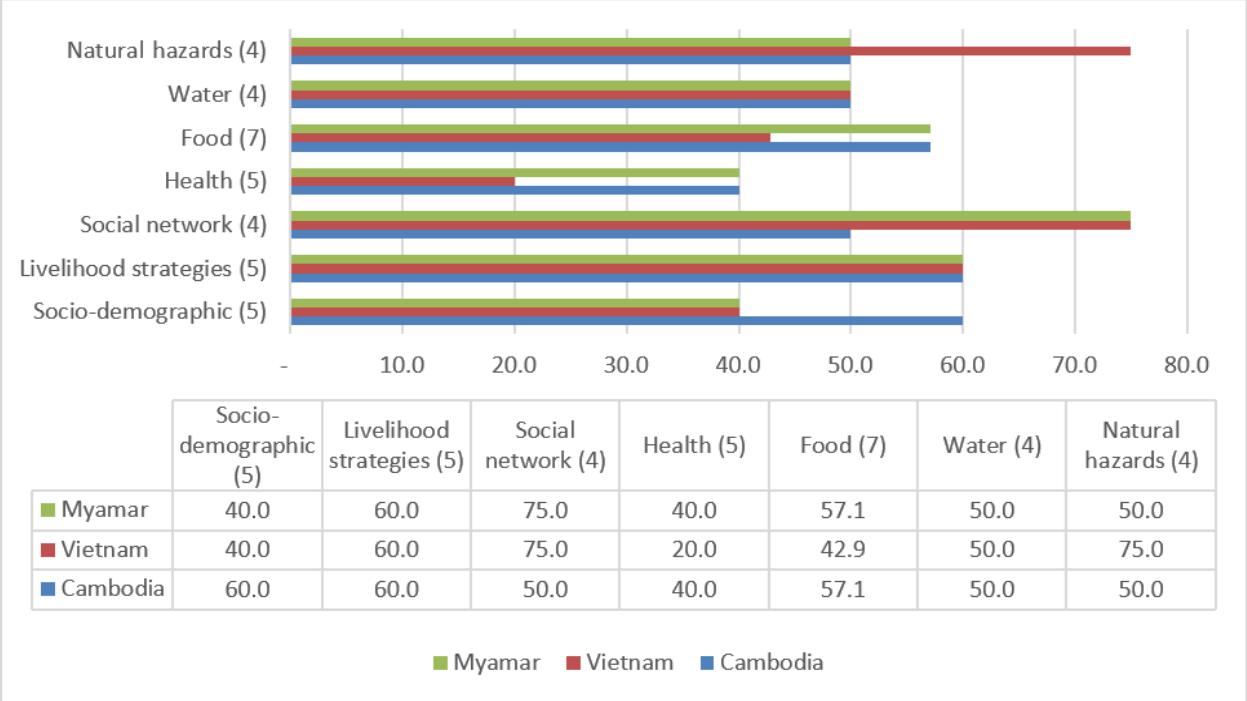
As described above, this study attempts to analyze the impact of the various indicators on the major components and the overall LVI. An indicator may have a positive effect (increasing vulnerability) if its value is greater than the mean of the LVI or major component. In-depth analysis allows the researcher to identify more specific recommendations than those obtained by relying only on the overall score – similar to the marginal analysis of factor analysis. The specific impact analysis results of each factor are presented in Table 2 and Figures 4, 5, and 6. They allow us to determine the particular contribution of each indicator to the LVI and the major components. All three countries share a common feature, which is a large variation between the absolute values of the factors compared to the LVI index and the major components. Given that they show the common features of countries heavily affected by climate change, the large variation explains that the vulnerability will be different for different groups, and different major components have different levels of variation. Vietnam has the most fluctuation in the domains of socio-demographics, food, and natural hazards, while Myanmar has the largest range in livelihood strategies and water. In contrast, Cambodia has a moderate degree of fluctuation in the different major components compared to the other countries.



	Cambodia	Vietnam	Myanmar
Contribution to major components	52.9	50.0	52.9
Contribution to LVI	52.9	44.1	47.1

Figure 4. Positive contribution of indicators to LVI and major components.

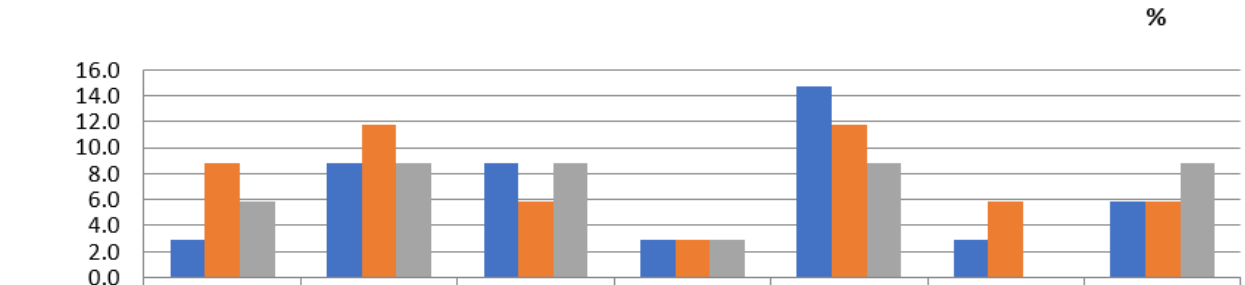
Figure 4 shows that more than 50% of the indicators contribute to the score of the major components of LVI, the greatest contribution of which can be found in Cambodia and Myanmar; in other words, the level of contribution of the indicators that increase the relative vulnerability is relatively higher. For the overall LVI, the contribution of indicators that increase vulnerability accounts for nearly 53% in Cambodia, while this contribution is lower in Vietnam and Myanmar, at 44% and 47%, respectively.



	Socio-demographic (5)	Livelihood strategies (5)	Social network (4)	Health (5)	Food (7)	Water (4)	Natural hazards (4)
Myamar	40.0	60.0	75.0	40.0	57.1	50.0	50.0
Vietnam	40.0	60.0	75.0	20.0	42.9	50.0	75.0
Cambodia	60.0	60.0	50.0	40.0	57.1	50.0	50.0

Figure 5. Detailed contribution of each indicator to the major components of LVI.

Note: % of contribution is calculated as the number of negative contributions/ number of indicators of the major component*100. Example: Socio-demogrphaphic_Myanmar: 2/5*100=40%.



	Socio-demographic (5)	Livelihood strategies (5)	Social network (4)	Health (5)	Food (7)	Water (4)	Natural hazards (4)
Myanmar	2.9	8.8	8.8	2.9	14.7	2.9	5.9
Cambodia	8.8	11.8	5.9	2.9	11.8	5.9	5.9
Vietnam	5.9	8.8	8.8	2.9	8.8	0.0	8.8

Figure 6. Detailed contribution of each indicator to LVI.

Note: % of contribution is calculated by the number of positive contributions/ 34*100; Example SD_Myanmar: 1/34*100=2.9%.

Figures 5 and 6 show the detailed impact of specific indicators on the major components and the overall LVI. The results give us a deeper insight into their contribution to the overall impact level. The post-analysis of the major components shows that the cumulative contributions of the indexes are very different for the component groups, except in the case of livelihood strategy and water, which implies that each country should apply different policies to reduce the impact of climate change, based on the impact level on each specific domain. The detailed analysis of factors affecting LVI allows us to measure the degree to which each major component contributes to the overall LVI. The results show that in Myanmar, the major components that most increase the overall vulnerability are food, livelihood strategy, and social network. Cambodia is similar, although socio-demographics replace social network. In the case of Vietnam, the contribution to increased vulnerability does not differ significantly; it is concentrated on livelihood strategy, social network, food, and natural hazards.

4.8. Comparison of Major Components in Myanmar, Vietnam, and Cambodia

Finally, we compared the seven major components among the three countries to obtain a regional overview of the climate change vulnerability of farm households. The study found that Myanmar had a high vulnerability score with four major components fluctuating around 0.6, including social network, food, natural hazards, and livelihood strategy (see Table 3). The rest of the major components – the socio-demographic, water, and health dimensions – scored from 0.3 to 0.4. Vietnam had two major components that indicated a moderate level of vulnerability: livelihood strategy (0.418) and natural hazards (0.573). The major components of social network, food, and socio-demographics showed low vulnerability (0.363, 0.32, and 0.266, respectively). The other major components displayed low vulnerability: water

(0.111) and health (0.195). In the case of Cambodia, the majority of major components scored below 0.5. Only livelihood strategy scored relatively high on the vulnerability index (0.448), while most dimensions ranged from around 0.3 to 0.39. Specifically, these were water (0.384), natural hazards (0.335), socio-demographics (0.368), food (0.313), and social network (0.301). Cambodia's lowest vulnerability score was for the major component of health (0.218).

Table 3. Seven major components of LVI by country.

Major components	Myanmar	Vietnam	Cambodia
Socio-demographics (5)	0.325	0.331	0.368
Livelihood strategies (5)	0.595	0.418	0.448
Social network (4)	0.735	0.417	0.366
Health (5)	0.429	0.195	0.218
Food (7)	0.612	0.296	0.313
Water (4)	0.335	0.111	0.384
Natural hazards (4)	0.519	0.472	0.335

By comparison, the study findings indicated that Myanmar was ranked as the most vulnerable in four major components, excluding the water, socio-demographics, and livelihood strategy components, for which it was ranked second in the list of countries. In the case of Vietnam, it had the highest score for livelihood strategy, and ranked second on the list for two major components (natural hazards and social network); it was the least vulnerable in the remaining four dimensions (water, food, health, and socio-demographics). Cambodia had the highest vulnerability score in two dimensions: water and socio-demographics. It came second of the three countries in three major components (natural hazards, livelihood strategy, and social network).

When using a triangle of exposure, adaptive capacity, and sensibility to evaluate vulnerability, Cambodia was the country with the least vulnerability (see Table 4 and Figure 7). Vietnam and Myanmar showed similar trends in the exposure dimension, with dimensional index scores of 0.604 and 0.573, respectively. In terms of adaptive capacity, the study found that Myanmar was the most vulnerable (0.510), followed by Vietnam (0.304) and Cambodia (0.335).

Table 4. Three major components of LVI-IPCC by country.

Major component	Myanmar	Vietnam	Cambodia
Sensibility (s)	0.486 (1)	0.218 (3)	0.301 (2)
Health	0.429(1)	0.195(3)	0.218(2)
Food	0.612(1)	0.296(3)	0.313(2)
Water	0.335(2)	0.111(3)	0.384(1)
Adaptive capacity (a)	0.539(1)	0.387(3)	0.396(2)
Socio-demographics	0.325(3)	0.331(2)	0.368(1)
Livelihood strategies	0.595(1)	0.418(3)	0.448(2)
Social networks	0.735(1)	0.417(2)	0.366(3)
Exposure (e)	0.519(1)	0.472(2)	0.335(3)
Natural hazards and climate vulnerability	0.519(1)	0.472(2)	0.335(3)
LVI-IPCC	(0.099)(1)	(0.060)(2)	(0.004)(3)

Note: 1: Highest level of vulnerability; 2: Second level of vulnerability; 3: Third level of vulnerability.

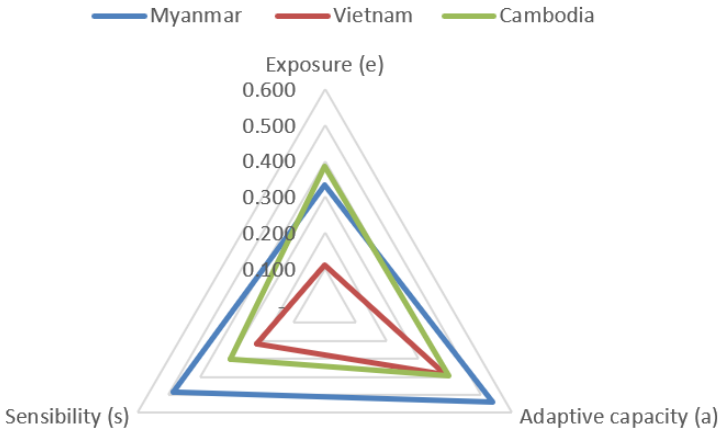


Figure 7. IPCC dimensions of climate change vulnerability of farm households in Myanmar, Vietnam, and Cambodia.

In the sensibility dimension, Myanmar was again found to be the most vulnerable (0.486), while Cambodia and Vietnam had lower vulnerability scores (0.309 and 0.218, respectively) (see Figure 7). When comparing the overall LWI scores of Myanmar, Vietnam, and Cambodia, Myanmar reported the highest value (0.502), Vietnam held the second position (0.353), and Cambodia was the least vulnerable (0.338). Interestingly, Vietnam's score nearly equaled the average of the other countries. In the LVI-IPCC approach, the values scored were as follows: Myanmar (0.045), Vietnam (0.030), and Cambodia (-0.012).

5. CONCLUSIONS AND RECOMMENDATIONS

This empirical research study investigated the climate change vulnerability of farm households in three countries: Cambodia, Myanmar, and Vietnam. The total sample size was 999 farm households, of which 304 respondents were from Myanmar, 350 respondents from Vietnam, and 345 respondents from Cambodia. The vulnerability of the farm households was measured using the indicator or indexing method with a balanced or equal weighting approach. A total of 34 indicators were selected for the model based on an extensive literature review and expert judgment. The findings showed that Myanmar was highly vulnerable to climate change across all components, whereas Vietnam was the second most vulnerable country, followed by Cambodia. In addition, natural hazard incidents were found to be highest in Myanmar, where the adaptive capacity of farmers had increased due to the increased natural hazard exposure. Importantly, the sensitivity of the farm households in these three countries was more or less similar, while in terms of adaptive capacity, there were clear differences among the three countries. Based on the findings, we suggest introducing policy measures to reduce the sensitivity of farm households, such as improving early warning systems and increasing investment of public funds in the development of infrastructure, such as embankments to prevent salter water instruction. We also suggest that improving the adaptive capacity of farm households is essential to reduce the climate change-induced vulnerability of farm households in Myanmar, Vietnam, and Cambodia. To strengthen the adaptive capacity of farm households, the local government should organize outreach activities, capacity training, and climate change information-sharing sessions, as well as empower community-based adaptation planning processes. Hence, there is also a need to enhance the collaboration between the relevant stakeholders and institutions in CMV countries. The empirical results from the study could be used by policymakers and development planners to enhance rapid rural development through social and community networks, as well as public and private organizations. In this way, the government can articulate the deep concerns about the effects of climate change on the agricultural sector and perhaps increase capacity building and training, improving farm households' climate change resilience and adaptation to the negative impacts of climate change and natural hazards in CMV countries.

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Authors' Contributions: All authors contributed equally to the conception and design of the study.

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