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Quantitative Analysis of Household Vulnerability to Climate Change in Kampong Speu Province, Cambodia

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April, 2015

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QUANTITATIVE ANALYSIS OF HOUSEHOLD VULNERABILITY TO CLIMATE CHANGE IN KAMPONG SPEU PROVINCE, CAMBODIA

Chhinh Nyda, Cheb Hoeurn and Poch Bunnak

EXECUTIVE SUMMARY

This study focused on measuring household vulnerability to climate change in six communes in Kampong Speu Province (KPS) and on identifying locally appropriate options and relevant policy interventions. Vulnerability was measured in terms of a Vulnerability Index (derived from exposure, sensitivity, and adaptive capacity indices) and Vulnerability as Expected Poverty (VEP).

In terms of exposure, the results showed that from 2008 to 2010, the communes under study had been severely hit by drought, the biggest threat to agriculture. Floods and windstorms had lesser but differing effects over different communes. The exposure indices of windstorms, flashfloods and droughts were 0.065, 0.067 and 0.868, respectively.

The sensitivity index was based on human, livelihood, infrastructure and financial sensitivity determinants. These determinants were disaggregated into topographical areas (lowland and highland), livelihood dependency, and household characteristics. Results showed that livelihood was the most sensitive determinant with a value of 0.57, followed by human sensitivity at 0.33. The main implications drawn were that many people relied heavily on a single source of livelihood (in this case, rice cultivation) and that the average household size was relatively big.

The adaptive capacity index is composed of five determinants: infrastructure, economic, technology, social capital, and human capital. The human capital rating was the highest at 0.43, followed by technology at 0.27, and infrastructure at 0.26. This means that people used their labor to cope with climate shocks and hardly relied on external assistance. Communes in the highlands were found to have lower adaptive capacity than those in the lowlands.

In using VEP index to predict future incidence of poverty, majority of the respondents from the communities were found to be poor and likely to continue to be poor in the future. We found that increasing the threshold of per capita income from USD1.00 to USD1.25 resulted in more households moving into future poverty and that future incidence of poverty would be more severe for those currently poor.

In conclusion, the study found that households in KPS had low exposure, average sensitivity, and low adaptive capacity. About 67% of the sample showed medium to very high vulnerability. The findings of this study are consistent with those of other studies and government reports.

1.0 INTRODUCTION

1.1 Problem Statement

Beyond the natural cycle of climate variability, climate change is known as changes in atmospheric compositions (using statistical tests) over a comparable time period (IPCC 2001; UNFCCC 2007). IPCC (2007) demonstrated that the global average surface temperature (one of the components of atmospheric climatic composition) has been instrumentally proven to increase since 1950. The changing temperature, induced by human activities causing the emission of carbon dioxide (CO_2), has brought about tremendous negative impacts, especially relating to precipitation and sea level rise. These, in turn, impact many sectors such as health, agriculture and water (IPCC 2007).

The changes in temperature in Cambodia were determined by the Ministry of Environment and UNDP based on people's perceptions. Also, every year, Cambodia has witnessed floods, droughts, windstorms, insect outbreaks, underground water salinization and seawater intrusion (MoE 2005). The most pronounced are floods and droughts. For instance, in 2000, Cambodia experienced severe flooding, which cost USD 150 million on infrastructure and property and killed 347 people (70% of whom were children). The following year, floods occurred while other parts of the country were affected by drought; these resulted in USD 36 million worth of property damage and the loss of 61 lives. In 2002, although there was no climatic disaster, the country experienced a rice shortage because 63% of its agricultural land was either flooded or exposed to drought (ADRC 2002; Chan and Sarthi 2002).

The impact from natural calamities driven by climate change has hindered Cambodia's achievement of the Millennium Development Goal to eradicate extreme hunger and poverty[1]. Since the country is heavily dependent on agriculture (about 84% of its population are farmers), floods, droughts and insect outbreaks have had severe effects on rural livelihoods (MoE 2005; NCDM 2008; GERES 2009; Sumaylo 2009; Toun 2009; Kong 2010). It is reported that flooding and droughts accounted for 70% and 20% of total damages in agriculture in Cambodia, respectively (Poffenberger 2009).

In Kampong Speu (KPS) Province, flashfloods occurred in **1922**, **1941**, **1971**, 1973, **1991**, **1994**, **2000**, **2001**, 2002, 2003, 2004, 2006, and 2010[2]. Droughts occurred in 1999, **2000,** 2001, 2002, 2003, **2004** and 2010[3]. Therefore, it can be said that KPS has experienced severe disasters almost every year from 1999 to 2006, with both severe droughts and flashfloods in 2000. Every district of the province has experienced flashfloods and/or droughts. According to the Provincial Committee for Disaster Management (PCDM), Aoral, Thpong, Samraong Tong, Phnum Sruch and Kong Psei districts have experienced the most severe natural disasters (PCDM 2011). At the provincial level, the most severe disaster is drought (Figure 1). It is a slow onset disaster and attracts little interest, but it does more harm than floods in KPS.

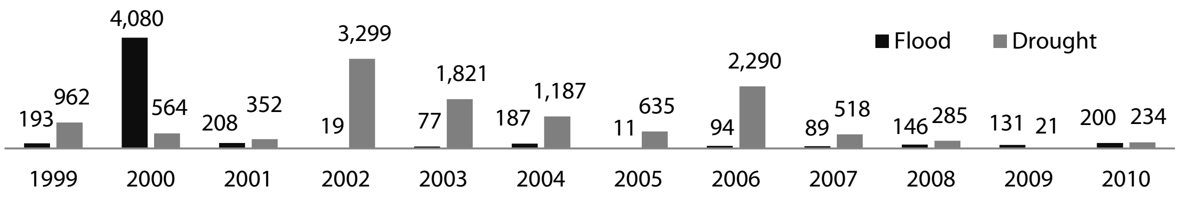


Figure 1. Rice and cash crop field damage by hectare due to floods and droughts in KPS (1999-2010)
Source: PCDM (2011)

Since the KPS population is almost homogenously involved in agriculture, flashfloods and droughts have badly affected the people's livelihood. As a result, families are forced to seek alternative livelihoods by, among other things, migrating to other places within and outside the country to take on jobs as garment workers, laborers clearing forestland, agricultural laborers, or construction workers.

1.2 Research Objectives

This study is part of a larger project entitled "Building Capacity to Adapt to Climate Change in Cambodia", which lasted from 2011 to 2014. It aimed to build the capacity of researchers, local government officials, and NGO staff in conducting vulnerability assessments and adaptation analysis. There were three components of the vulnerability assessment research, namely; (1) vulnerability mapping (commune level), (2) household vulnerability analysis, and (3) social and gender vulnerability analysis. Each component was reported in a separate research report.

This report is the product of the household vulnerability assessment. The specific objectives of the household vulnerability study are as follows:
1) To measure household vulnerability to climate change among communities in KPS;
2) To identify locally appropriate adaptation options; and
3) To discuss policy interventions related to climate change adaptation in the communities.

[1]This goal corresponds to Cambodia's Strategic Development Plan 2006-2010, which is to develop the agricultural sector.
[2] The years in bold indicate those with severe flood
[3] The years in bold indicate those with severe drought.

1.3 Research Questions

The following are the research questions for this study:

a) Among droughts, floods and windstorms, which were most intense and frequent in KPS given the household-geographical characteristics?

b) How do the impacts differ among communities in KPS?

c) Given the diverse household characteristics, livelihood dependency, and agro-ecological ownership, what are locally appropriate adaptation options?

d) What policy interventions could help mitigate the climate change vulnerability of the communities in KPS?

e) How could policy design be improved to enhance the adaptive capacity of the communities in KPS?

2.0 LITERATURE REVIEW

2.1 Vulnerability

Theoretically, there are many controversies in quantifying vulnerability within and across disciplines. Current vulnerability research models, as analyzed by Adger (2006), have so far not manifested the full picture of vulnerability. Nevertheless, as long as a vulnerability study can serve its purpose(s), it will contribute to policymaking (Hinkel 2011).

There are at least two approaches to conceptualizing vulnerability including Hazards and Entitlement (known as the Antecedents Approach) and Holistic Vulnerability Assessment (Adger 2006). Tuner *et al.* (2003), Adger (2006) and Hinkel (2011) confirmed that research in vulnerability should be driven by objectives and contextualization. Cutter (2003) classified vulnerability into: (1) conditions that make people or places vulnerable to hazards; (2) social conditions that enhance or mitigate the hazards; and (3) the integration of future exposure with societal resilience within households, communities or places. Smit and Wandell (2006), in their Nested Hierarchy Model of Vulnerability, affirmed this in concluding that the processes that contribute to exposure, sensitivity, and adaptive capacity are interdependent. O'Brien *et al.* (2007) called this 'contextual vulnerability'.

This paper uses the definition of vulnerability from the Inter-governmental Panel on Climate Change (IPCC 2001): "Vulnerability is a function of the *sensitivity* of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), *adaptive capacity* (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of *exposure* of the system to climatic hazards". This section provides a review of literature on concepts and empirical measurements of vulnerability and its independent variables: exposure, adaptive capacity, and sensitivity.

Vulnerability is the inherent value of a system at a particular point in time, place, and quality when it is exposed to something (in this case, climate stimuli). Calculating exposure is necessary when we want to know how much emission reduction is required in order to reduce exposure. When we look at the adaptive capacity of a household, we are really looking at its socioeconomic exposure. Sensitivity is 'the potential output' (if a hazard is approaching) or the 'output/outcome' (if a hazard is arriving or crashing with the system). The status (quality/change) after the crash (i.e.. the residue of the system) reflects the adaptive capacity of the system up to the crash. In other words, sensitivity is really the residue from the adaptive capacity from the household. Through time, scale and quality of new/reinforced adaptation, the sensitivity of the system can be improved and with it, the level of vulnerability reduced.

2.2 Exposure

Exposure is defined as the nature and degree to which a system experiences environmental or socio-political stress. The characteristics of these stresses include their magnitude, frequency, duration and areal extent of the hazard (Burton *et al.* 1993 cited in Adger 2006).

Exposure to environmental hazards, especially floods and droughts, have been well studied in many countries where agriculture is dominant. The methods employed to understand the nature of these climate-induced disasters varies from author to author. Liverman's (1990) study on the vulnerability of farmers in Mexico to drought suggested that using diverse quantitative data sources enabled researchers to identify the places and people most prone to drought. The National Committee for Disaster Management (NCDM 2003) identified droughts and floods in terms of affected areas, rice dependency, and food security based on rice production. Qualitative approaches aim to detect the intensity felt by communities in the absence of technological data.

2.3 Sensitivity

Sensitivity is defined as "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli". The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damage caused by an increase in the frequency of coastal flooding due to sea level rise) (Adger 2006).

Once social and biophysical entities are faced with floods and droughts, there will be changes. Social changes can be effected through migration, education, health, conflict, gender disparity, and the like, as discussed in Kundzewicz and Kaczmarek (2000), IPCC (2001), and Hinkel (2011). Biophysical changes can be known by, for example, crop yield losses, reduction in alternative resources for livelihood, and land use changes. The methodologies to measure the sensitivity at the household level can be both quantitative and qualitative (Hinkel 2011).

2.4 Adaptive Capacity

The social and biophysical changes discussed above will become severe when the adaptive capacity of affected entities is too low to be able to resist the climate stimuli. Adaptive capacity can be categorized as structural or non-structural and reactive or proactive, according to six determinants. Adaptive capacity can be measured quantitatively and qualitatively, as discussed in IPCC (2001), Gallopin (2006), Smit and Wandel (2006), and Engle (2011).

Households that are assumed to be highly adaptive should exhibit capacity in six components, with policy support and joint action from all stakeholders (Smit and Pillifosova 2001) (Figure 2). The six components for farming households are as follows:

1) Strong **economic** performance, especially in saving rice production surplus, and other income or other livelihood options.
2) The farmers have **technological capacity** (e.g., in making organic fertilizer) as well as own some **essential agricultural equipment** like pumping machines.
3) The farmers are exposed to **information and skills training** provided by associated stakeholders and are kept updated on climate-related information disseminated by the government.
4) The farmers have **access to disaster-reduction infrastructure**, including irrigation systems, dikes, and small-scale water management systems, through farmer associations.
5) Farmers are **affiliated with institutions through networking** to gain access to agricultural training, and banking and crop insurance schemes to help them recover from any external shocks.
6) The community practices **equity.** This refers not only to the opportunity but also the willingness of members to participate in any decision-making process at the community level.

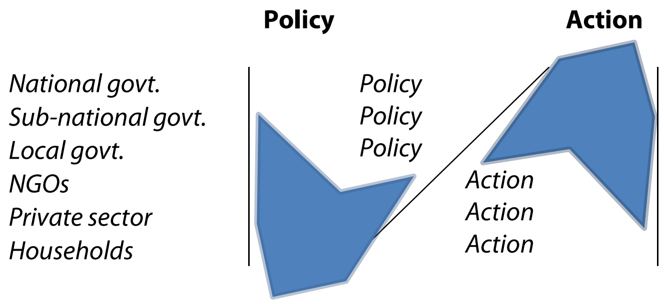


Figure 2. Hierarchy of adaptation policies and action by stakeholders

While famers have to improve their own adaptive capacity, other stakeholders also have a role to play in supporting famers such as in providing training and emergency seeds, encouraging farmers to use organic fertilizer, planning risk reduction actions, investing in irrigation, disseminating information, among others. Ghimire *et al.* (2010) found that Nepalese farmers' vulnerability to drought was associated with (lack of) access to land, irrigation, market, social networks and agricultural training; crop-livestock integration; and employment diversification. McLeman and Smit (2006) emphasized that migration was an adaptation strategy to climate change impacts.

We can conclude that, at any point in time, the greater the exposure of a system (people, agriculture, business, etc.) to climate impacts, the higher its vulnerability. However, vulnerability is reduced when the system is less sensitive. Sensitivity is reflected through damage (costs) from any disaster(s) in the past and it can decrease or increase over time, depending on adaptation measures taken following the disaster(s).

There are case studies in many parts of the world on how to quantify 'vulnerability' in the context of climate change. These studies (e.g., Adger and Kelly 1999, Ouma and Tateishi 2014) warn that the indicator selection process must be taken into account and numerical indices should be treated carefully when dealing with policymakers; for the numbers are not for actual comparison purposes but rather to highlight areas for further investigation on the ground and for consideration in policy design.

3.0 METHODOLOGY

This study used IPCC's definition of vulnerability as a function of exposure, sensitivity and adaptive capacity (IPCC 2001) to select determinants for the study. Floods and droughts were selected to examine exposure in terms of occurrence and intensity while the determinants for sensitivity were derived from the impacts on social, biophysical and economic aspects that the households depended on for survival. For adaptive capacity, we used the determinants proposed by Smit and Pillifosova (2001): (1) economic resources; (2) technology; (3) information, skills, and management; (4) infrastructure; (5) institutions and networking; and (6) equity. Indicators were deployed to measure the state of affairs of systems. While the failure of one element will not necessarily disrupt the entire system, failure of critical elements/determinants will indeed do so.

3.1 Conceptual Framework

Figure 3 illustrates the climate change vulnerability framework used by Yusuf and Francisco (2009), adapted from the vulnerability framework of the IPCC (2001). The framework is a composite of the three attributes: hazards, sensitivity and adaptive capacity. Each attribute has determinants that, in turn, have indicators. The attributes are then quantified and converted into indices. The level of vulnerability is thus measured. The results allow comparisons to be made of vulnerability between sub-regions or countries.

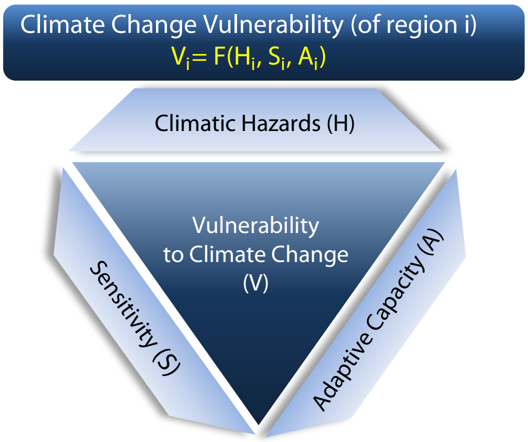


Figure 3. Vulnerability conceptual framework
Source: Yusuf and Francisco (2009)

3.1.1 Measuring exposure

Exposure is the probability of occurrence of a hazard (in this case, windstorms, flashfloods and droughts, as indicated in Appendix 1) that may or may not trigger a disaster or a series of disasters depending on what the system is exposed to. The probability of a disaster or outcomes may be viewed differently for it depends on the interaction between the hazard events, sensitivity and adaptive capacity (Brooks *et al.* 2005). For example, one survey question was: "From 1999 to 2010, have you experienced any natural disaster or not?" The response would be a 'yes' or a 'no'. The indexing of exposure was then calculated based on Formula 1, presented in Section 3.3.

3.1.2 Measuring sensitivity

Essentially, sensitivity (or impacts) is highly associated with adaptive capacity. It means that every unit of adaptive capacity will reduce one unit (if not all) of the system's sensitivity. The sensitivity factor in our study was divided into human, livelihood, infrastructure and financial sensitivity.

In terms of human sensitivity, it was hypothesized that an increase in exposure will cause more hardship to families that have a higher dependency ratio and more labor force working in agriculture, which is climate-sensitive. Similarly, livelihood sensitivity refers to the dependency of income generated from agricultural sectors, perennial planted areas of rice fields, and aquaculture areas as a proportion of the total agriculture area of the household capital (see Appendix 1 for list of sensitivity indicators). Infrastructure sensitivity was limited to distance from water sources. The indexing of sensitivity was also based on Formula 1.

3.1.3 Measuring adaptive capacity

The impacts (residue) of hazards are measured as sensitivity. However, finding out what factors contribute to current outcomes of vulnerability is missing in the previous two measurements. We measured adaptive capacity from five aspects: infrastructure, economic, technology, social capital and human capital (see Appendix 1 for list of adaptive capacity indicators per aspect). For infrastructure, it was assumed that the bigger the irrigated agricultural land of a household, the higher its adaptive capacity would be; likewise for the average area of permanent dwelling per family member. Similar assumptions were made for the other determinants of adaptive capacity.

Here we can see the relationship among households; local, sub-national, and national governments; society; NGOs; and the private sector in coping with climatic hazards. Also, it allows us to understand human dependency on ecosystems before, during and after the hazards.

3.2 Data Collection

The total land area of KPS is approximately 653,396 ha, divided into 8 districts and 87 communes. The biggest district is 237,000 ha and the smallest is 4,738 ha. The total land area is composed of 390,276 ha for forests, 167,771 ha for cultivation, 37,753 ha for construction, and the remaining 57,597 ha for reservoirs, rivers, etc. (NCDD 2009).

The household survey samples were selected from six (6) communes in two highland districts and four lowland districts to study three natural disasters (i.e, flashfloods, droughts, and windstorms). The study communes were selected based on key informant interviews with officers from the Provincial/District Committee for Disaster Management, Provincial/District Department of Agriculture, and Provincial/District Department/Office of Meteorology and Water Resource Management. The study sites were demarcated using the Geographical Information System and Digital Elevation Model along with administrative boundaries.

Actually, there were 600 questionnaires prepared for the purpose of collecting data on hazards and the adaptive capacity of the households. This number was increased by 5% to avoid non-responses, incomplete responses, or recoding errors during data collection. Therefore, 630 household questionnaires were given out and collected from August to December 2011 from among 154,171 families in KPS. Of these, 600 questionnaires were completely encoded and analyzed.

To ensure data reliability and validity, data collection took place in several phases (Figure 4):

- ***Phase 1:*** This phase was devoted to ensuring that the data was collected from a truly representative sample of KPS as a whole, including highland and lowland areas.
- ***Phase 2:*** Six districts were identified as target sites among the eight KPS districts, two in the highlands and four in the lowlands. Key informant interviews with commune chiefs were done to target the districts and communes in terms of the occurrence of particular hazards, namely, flashfloods, droughts, and windstorms. The selected districts and communes are shown in Table 1.
- ***Phase 3:*** Once the communes were identified through key informant interviews, villages were selected based on focus group discussions (FDGs) participated in by village chiefs and commune headmen. Accordingly, 105 households in each of the six communes were systematically selected for interview. In total, 630 households were interviewed from the six communes.

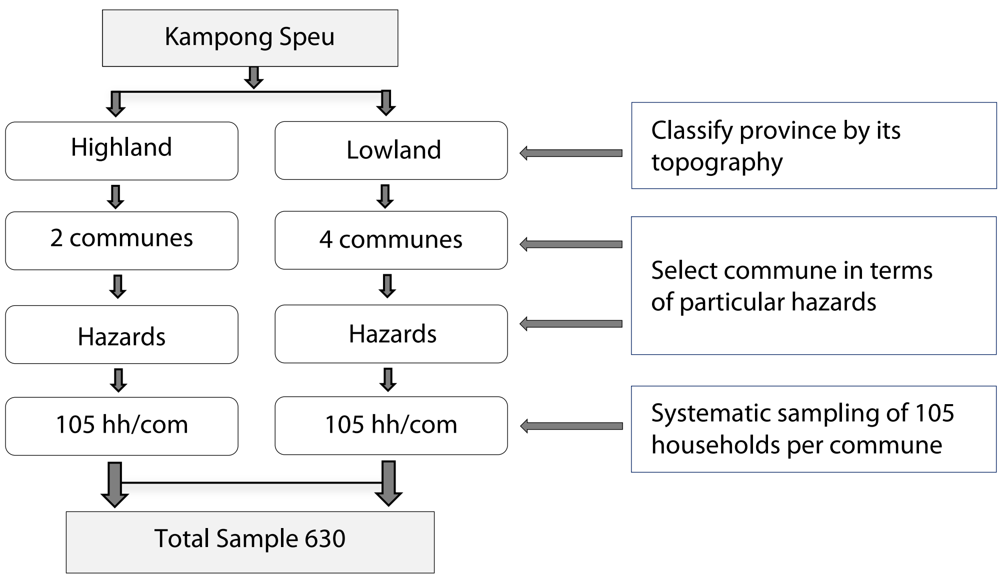


Figure 4. Sample selection process

Table 1. Sample communes in KPS

Hazard	Lowland (Commune/District)	Highland (Commune/District)
Windstorms	Peng Lvea/Odongk	Moha Sang/Phnum Sruoch
Flashfloods	Chbar Mon/Chbar Mon	Ta Sal/Aoral
Droughts	Peang Lvea/Odongk Kak/Basedth and - Roleang Chak / Samraong Tong	Moha Sang/Phnom Srouch Ta Sal/Aoral

3.3 Data Entry and Analysis

3.3.1 Vulnerability as a composite index

We surveyed 630 households with 630 questionnaires, and the latter were carefully checked by team leaders and field supervisors. Finally, 600 questionnaires were analyzed as described below.

Normalizing procedures were applied for all calculations of the indicators as it helped to put them on the same scale for comparable purposes between different locations. In this study, the scores for each indicator were calculated using Formula 1:

$$I_i=\frac{X_i-X_{min}}{X_{max}-X_{min}} \qquad (1)$$

where I_i is the index of the indicator (I), X_i is the original value of the indicator i, and X_{max} and X_{min} are the highest and lowest values from the survey, respectively. It means that the range of values for all indicators is from 0 to 1, in which 0 is not at all and 1 is the highest value.

After this step, all determinants were calculated so as to put them on the same scale for comparison purposes between different locations. In this study, the scores for each determinant were calculated using Formula 2:

$$D_j=\sum_{i=1}^{n} I_i W_i \qquad (2)$$

where D_j is the score of the determinant (j) in a particular location, n is the number of indicators within a particular determinant, I_i and W_i are the index and weight values of each indicator, respectively. The value of the determinants' scores range from 0 to 1, in which 0 is not at all and 1 is the highest value.

Then, the vulnerability attribution scores for exposure, sensitivity, and adaptive capacity were calculated for the same purpose as the above indicators and determinants using Formula 3:

$$VA_k=\sum_{j=1}^{n} D_j W_j \qquad (3)$$

where VA_k is the vulnerability attribution score (k) in a particular locality, n is the number of determinants within a particular vulnerability attribution, and D_j and W_j are the index and weight value of each determinant, respectively. The vulnerability attribution score range is from 0 to 1, in which 0 is not at all and 1 is the highest value.

Finally, vulnerability, which is a function of exposure, sensitivity and adaptive capacity, was calculated using Formula 4:

$$VI=\left(e+s+(1-ac)\right)/3 \qquad (4)$$

where VI is the index of vulnerability in particular location and e, s, and ac are the vulnerability attributions of exposure, sensitivity, and adaptive capacity, respectively. The vulnerability index range is from 0 to 1, in which 0 is not at all and 1 is the highest value.

3.3.2 Weighting

As stated above, determinant and indicator identification is very important to quantify vulnerability attribution while the weighting of these determinants and indicators also play a vital role in determining the contribution of each indicator within a particular determinant (Formula 2) and that of a determinant within a vulnerability attribution (Formula 3).

There are ways to determine weighting such as Principle Component Analysis (PCA), Analytical Hierarchy Process (AHP), consensus, and so on. The consensus method was applied in this study. Two provincial FGDs were conducted with participants from all stakeholder groups plus NGOs. Furthermore, two FGDs and four FGDs also were conducted at the district level and the commune level, respectively. Altogether, eight FGDs were conducted. The weights were averaged out from among all the FGDs and levels (see Appendix 1 for weights).

3.3.3 'Vulnerability as Expected Poverty'

The study adopted an economic approach to measuring household vulnerability as described by Chaudhuri (2003) in a study of household vulnerability in the Philippines. Household vulnerability as expected poverty was defined as the probability that households will move to poverty, given certain environmental shocks, current poverty status, and household characteristics. While poverty reflects the current state of deprivation, vulnerability reflects what a household's future prospects will be. Thus, a household's consumption or income can be regressed based on household characteristics and shocks in order to obtain the estimated coefficients to be used for further prediction of the same household's future poverty. In this regard, households with high predicted poverty are considered as vulnerable.

However, unlike Chaudhuri (2003) who analyzed household monthly per capita consumption expenditure, which is common in the existing literature, this study analyzed household monthly per capita income to measure household vulnerability index due to lack of data on expenditure.

Technically, a household vulnerability index is the difference between the expected log per capita income[4] and the minimum log per capita income threshold, with households having a per capita income lower than the minimum per capita income being considered as vulnerable (poor). The expected log per capita income was estimated using the three-step feasible generalized least squares (FGLS) method (see Chaudhuri 2003 for details).

The predictors of log per capita income used in the analysis were: droughts in the previous 12 years (1999-2010), windstorms in the previous 12 years (1999-2010) (dummy[5]), floods in the previous 12 years (1999-2010) (dummy), household size, education, possession of motorized vehicles (dummy), access to credit (dummy), presence of disabled persons in the households (dummy), and livelihood dependency on agriculture (dummy).

4.0 RESULTS

4.1 Profile of the Respondents

Six communes were selected from six districts for the study, with 105 respondents being selected for interview in each commune; four communes being from the lowlands, and two communes from the highlands. Out of these respondents, 68.3% were female and 31.7% were male. The proportion of interviewed female respondents varied from 61.0% in Peang Lvea Commune to 77.0% in Ta Sal Commune.

Unlike the national scenario, most of the respondents in the study communes (92%) do not rely exclusively on agriculture for their livelihood (Table 2). With the exception of Ta Sal Commune, more than

[4] Log per capital income is the per capita income in logarithm form.
[5] A dummy variable is a variable that has a value of 0 or 1. 0 means "no" while 1 means "yes". These variables can be used in running a regression.

90% of the respondents reported that at least one of their household members had a secondary occupation in addition to agriculture (Table 2). In Ta Sal, 13% of the respondents reported that their households made a living exclusively from agriculture.

Table 2. Sex and occupation of respondents

	Topography	Total Number of Respondents	Sex of respondents		Occupation of respondents	
			Female	Male	Agriculture only	Agriculture and others
Chbar Mon	Urban/Lowland	100	65	35	9	91
Kak	Rural/Lowland	100	69	31	7	93
Moha Sang	Rural/Highland	100	73	27	6	94
Peang Lvea	Rural/Lowland	100	61	39	7	93
Roleang Chak	Rural/Lowland	100	65	35	7	93
Ta Sal	Rural/Highland	100	77	23	13	87
Total N		**600**	**410**	**190**	**49**	**551**
Total percentage		**100%**	**68.3%**	**31.7%**	**8.2%**	**91.8%**

Source: Survey 2011

On average, all the respondents had completed 7.7 years of schooling, with those in Chbar Mon and Roleang Chak having the highest level of education on average (9 years and 9.6 years of schooling, respectively). The respondents from Ta Sal Commune had the lowest level of education, with the average years of schooling being only 5.2 (Figure 5).

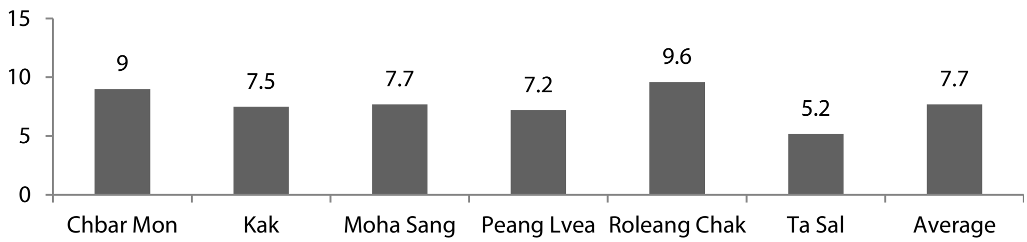


Figure 5. Average years of schooling per commune

4.2 Household Characteristics

Average household size is five (Figure 6). Roleang Chak had the smallest household size but the highest level of education. Kak and Chbar Mon seemed to have larger household sizes than the other selected communes (about six persons per household, on average).

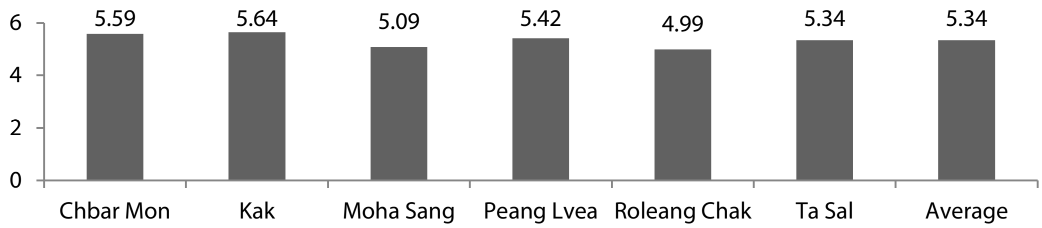


Figure 6. Average household size per commune

About 60% of the respondents reported that their household had at least one motorcycle (Table 3). The variation in the proportion of households possessing motorcycles indicate that those in Chbar Mon

(73%), Peang Lvea (74%), and Roleang Chak (68%) were better off than those in Ta Sal (44%), Kak (50%), and Moha Sang (53%).

Table 3 below also shows that 11.7% of the respondents lived in households with at least one disabled person. Peang Lvea had the highest proportion of households with disabled persons (21%), followed by Roleang Chak (13%), Kak (12%), Ta Sal (11%), Moha Sang (7%), and Chbar Mon (6%).

Table 3. Households with motorcycles and disabled persons per commune

	Topography	Total Number of Respondents	Households with at least one motorcycle		Households with disabled persons	
			No	Yes	No	Yes
Chbar Mon	Urban/Lowland	100	27	73	94	6
Kak	Rural/Lowland	100	50	50	88	12
Moha Sang	Rural/Highland	100	47	53	93	7
Peang Lvea	Rural/Lowland	100	26	74	79	21
Roleang Chak	Rural/Lowland	100	32	68	87	13
Ta Sal	Rural/Highland	100	56	44	89	11
Total N		**600**	**238**	**362**	**530**	**70**
Total Percentage		**100%**	**39.7%**	**60.3%**	**88.3%**	**11.7%**

Source: Survey 2011

4.3 Exposure Index

Three important indicators of environmental impacts on people's livelihood in the study areas were floods, windstorms, and droughts. It is important to note that these indicators were measured using dummy variables, indicating whether the respondents had experienced these events in the last 12 years (1999-2010).

Overall, 95% of the respondents had experienced drought[6], with all respondents from Peang Lvea, Moha Sang, and Ta Sal indicating that they have experienced it (Table 4). The percentages of respondents who had experienced floods or windstorms from1999-2010 were significantly lower than those experiencing droughts as indicated in Table 4 below.

Table 4. Households experiencing floods, windstorms, or droughts per commune (1999-2010)

	Urban/ Rural	Total Number of Respondents	% of households (1999-2010)		
			Floods	Windstorms	Droughts
Chbar Mon	Urban	100	12	5	83
Kak	Rural	100	2	6	99
Moha Sang	Rural	100	9	13	100
Peang Lvea	Rural	100	2	5	100
Roleang Chak	Rural	100	31	12	90
Ta Sal	Rural	100	4	1	100
Total Number		**600**	**60**	**42**	**572**
Total Percentage		**100%**	**10%**	**7%**	**95%**

Source: Survey 2011

Although the respondents from the FGDs reported a slight decline in the occurrence of droughts, they emphasized that the droughts in 1999, 2000 and 2004 were the most severe ever reported in the lifetime of the population in the communes and in the province, especially those of 1999 and 2004. Villagers from Pongrek Village, Peang Lvea Commune, Odongk District expressed that 2010 had the worst drought in 10 years, which badly affected rice yields.

[6] Drought impacts all three stages of rice production, i.e., planting (Jun-Jul), growing (Aug-Sept), and harvesting (Oct-Nov).

Figure 7 shows the index of the occurrence of windstorms, flashfloods, and droughts as reported by the study households from 1999–2010 at 0.02, 0.03 and 0.31, respectively. Only around 6% of the households in both highland and lowland areas reported windstorms during the last 12 years (1999-2010). The FGDs revealed that windstorms were not considered a big hazard; however, windstorms did wipe out 367 impermanent dwellings from 2001-2010 (PCDM 2011). It can be inferred that windstorms occurred the least among the three hazards and lowland residents experienced these more than those in the highlands.

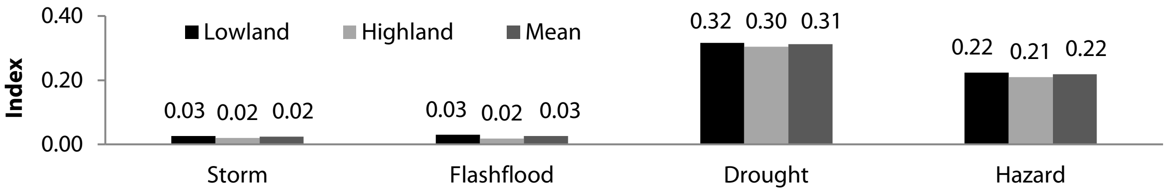


Figure 7. Indices of natural hazards in KPS (1999-2010)

Flashfloods were the second most reported hazard that the people of KPS faced during the period of 1999-2010. The occurrence of flashfloods can be traced mainly to the fact that the province has the catchment areas of two rivers (i.e., Raleang Chreay and Stoeung Prek Thnoth), which originate from the southeast to east of the Elephant Mountain region with an elevation of about 1,780 m above mean sea level. Two channels were built to divert the water for agricultural activities within the province, which absorbs a huge volume of water.

With the highest index value of occurrence of drought at 0.31, drought has clearly done the most damage to the study communes, especially during the rice grain-filling and harvesting periods. According to the FGDs in Rong Masin Village, Ta Sal Commune, Aoral District, droughts occurred annually in the last ten years (2001-2010) and most seriously in 2003 between July and November.

It should be noted that we pre-selected the communes based on the hazards experienced. All of the respondents from the selected communes reported that they had experienced all three hazards, especially droughts and flashfloods. During the year, when there is heavy rain, there are flashfloods. However, after these floods, the farmers begin to grow rice, but then they face drought. Water shortage is a persistent problem.

Table 5 shows the primary household occupations against the hazards experienced using the mean values (from the hazard indices). In general, the aggregate hazard indices of non-agricultural work, rice cultivation and rice cultivation with livestock raising were similar at 0.20, 0.23 and 0.25. Compared to flashfloods and windstorms, drought was the most impactful among the three primary occupations at 0.33, 0.35, and 0.28 for rice farming, rice farming and raising livestock, and non-agricultural work, respectively. The small difference between all three can be explained by the fact that water is very important for everyone. In conclusion, drought is the central point of concern and discussion among all the stakeholders.

Table 5. Hazard indices by household occupation

Primary Occupation		Droughts	Flashfloods	Windstorms	Exposure index
Rice farming	Mean	0.33	0.02	0.03	0.23
	Std. Deviation	0.30	0.07	0.11	0.20
	Minimum	0.00	0.00	0.00	0.00
	Maximum	1.00	0.43	0.75	0.77
Rice farming and raising livestock	Mean	0.35	0.03	0.01	0.25
	Std. Deviation	0.31	0.10	0.05	0.21
	Minimum	0.00	0.00	0.00	0.00
	Maximum	1.00	0.43	0.25	0.83
Non-agricultural work	Mean	0.28	0.03	0.03	0.20
	Std. Deviation	0.26	0.10	0.11	0.18
	Minimum	0.00	0.00	0.00	0.00
	Maximum	1.00	1.00	1.00	1.00

4.4 Impact Analysis and Sensitivity Index

The index of sensitivity was based on human, livelihood, infrastructure and financial sensitivity determinants. These determinants were disaggregated by topographical area (lowland and highland), livelihood dependency, and household characteristics.

The results showed that the index of livelihood was the most sensitive followed by human factors. The rest were comparably low or negligible. The main implication was that many people relied heavily on a single livelihood (i.e., rice cultivation) and that household size was relatively big (i.e., high number of dependents). Geographically, the aggregate sensitivity indices of the highland communes were higher than those of the lowland communes while the values of each determinant by topography were in line with the rest.

4.4.1 Impact analysis

Table 6 shows the percentage of respondents who reported damages from various hazards that they had experienced during the past 12 years (1999-2010). Tangible damage to houses by windstorms and flashfloods were reported by 43% and 11% of the respondents, respectively. Windstorms reportedly impacted animal and rice production, and crop yields for 2%, 14% and about 10% of the households, respectively. Flashfloods and droughts did a lot of damage to rice production impacting about 77% and 87% of the households, respectively. Droughts also impacted animal and crop yields for 38% and 12% of the respondents, respectively.

Table 6. Frequency of impact by natural disasters in KPS (1999-2010)

Indicator	Windstorms (%)	Flashfloods (%)	Droughts (%)
House	42.90	11.1	0
Animal	2.38	16.8	38.2
Rice production	14.25	76.6	86.7
Crop yields	9.52	7.5	12.2

Source: Survey 2011

Table 7 shows the costs associated with the most severe windstorms, flashfloods and droughts that the respondents experienced from 1999 to 2010. The costs were varied among communes. Some communes experienced only one type of hazard while some experienced all. For example, Ta Sal experienced only drought at the maximum cost of USD 2,200 and an average of USD 370 per year. This amount of loss is enough to put family members at risk of food insecurity. Among the study communes, Peang Lvea experienced the maximum loss due to drought at around UDS 2,278 and an average of USD 343 per year while the loss from drought at Roleang Chak was the least at a maximum of USD 1,000 and an average of USD 236 per year. Drought accounted for 97% of damage costs followed by flashfloods at 2%. The distribution of drought damage among the six communes was from 12% in Chbar Mon to 22% in Moha Sang.

Physical damage to houses from windstorms was reported by the respondents in all the study communes except Ta Sal. The highest amount of damage was in Chbar Mon at the maximum cost of USD 244, followed by Roleang Chak at USD 122, and Kak at USD 146 (Table 7). On average, the loss caused by windstorms was about USD 60 among the five of study communes affected. Two out of the five experienced minor damage in monetary terms, but the household members said that they were too poor to recover even from those losses.

Flashfloods were the second most frequently experienced hazard by the communities. Three communes experienced loss from floods, namely, Kak, Roleang Chak and Chbar Mon at the maximum of around USD 126.8, USD 487.8 and USD 975.6, respectively (Table 7). A household from Moha Sang reported that the last flashflood caused property losses of USD 243. The highest cost was in Chbar Mon, the business center of the province. This came mainly from the damage to homes.

Table 7. Damage costs of the most severe disasters in the study communes, in USD per year (1999-2010)

Commune	Ta Sal	Kak	Moha Sang	Roleang Chak	Chbar Mon	Peang Lvea	Total
Windstorms							
Minimum	-	7.31	4.87	12.19	24.39	48.78	-
Average	-	62.80	36.75	73.67	134.14	67.07	-
Maximum	-	146.34	73.17	121.95	243.90	97.56	-
Sub-total	**0**	**251.21**	**257.31**	**589.36**	**268.29**	**268.29**	**1,635.48**
Flashfloods							
Minimum	-	24.39	-	3.65	25.60	-	-
Average	-	75.60	243	155.52	293.41	-	-
Maximum	-	126.82	-	487.80	975.60	-	-
Sub-total	**0**	**151.21**	**243.90**	**2,332.92**	**1,467.07**	**0**	**4,195.12**
Droughts							
Minimum	17.56	36.58	45.12	19.51	10.97	19.51	-
Average	370.29	322.95	437.63	236.26	290.40	342.95	-
Maximum	2,221.95	2,195.12	1,829.26	1,072.68	1,951.21	2,278.04	-
Sub-total	**35,918.44**	**31,327.09**	**41,575.02**	**20,790.97**	**21,780.24**	**33,609.51**	**185,001.31**
Total	**35,918.45**	**31,729.54**	**42,076.24**	**23,713.27**	**23,515.61**	**33,877.81**	**190,830.91**

Source: Survey 2011

4.4.2 Sensitivity index

Climate change sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli (Yusuf and Francisco 2009); the higher the index, the higher the sensitivity. We calculated the sensitivity index by capturing four determinants: human, livelihood, infrastructure and financial sensitivity (see the indicators of each determinant in Appendix 2).

Figure 8 compares the mean values of the four sensitivity determinants. We found that livelihood sensitivity had the highest mean value at 0.684, followed by human sensitivity at 0.396; the others were negligible. This shows that the households' livelihood was highly sensitive to changes in climatic events and that the number of dependents was high.

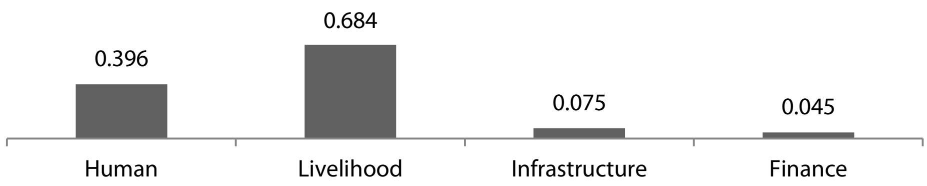


Figure 8. Comparison of sensitivity determinant indices of households in KPS

Table 8 compares the sensitivity indices of those from the lowlands and the highlands. In terms of the human dimension, it was found that the lowland communes, with a mean human sensitivity of 0.41, were more sensitive than highland communes, with its mean human sensitivity at 0.37, because they have a higher number of dependents (either young or old).

The livelihood sensitivity index of the lowlands was lower, at a 0.64 mean value, compared to the highlands at 0.78. This is associated with the primary occupation being the main source of income. The mean annual income from agriculture in the highlands was KHR 4,027,836[7] per year compared to that of the lowlands at KHR 3,559,077 per year; these represent 78% and 64% of the total annual household income in the highlands and the lowlands, respectively. Since the lowland households have better access to main roads and infrastructure as well as markets, this could mean that they can rely less on agriculture as the main

[7] 1 USD = 4,000 KHR

source of income than those in the highlands. So, if agriculture is hit by a chronic hazard, e.g., drought, the highlands will be more hard hit than the lowlands in terms of livelihood.

Table 8. Sensitivity indices of household in KPS (1999-2010)

Topography	Determinants	Minimum	Maximum	Mean	Std. Deviation
Lowland	Human	0.00	1.00	0.41	0.19
	Livelihood	0.00	1.00	0.64	0.34
	Infrastructure	0.00	1.00	0.08	0.13
	Finance	0.00	0.69	0.05	0.11
	Sensitivity	*0.00*	*1.00*	*0.46*	*0.19*
Highland	Human	0.00	0.94	0.37	0.16
	Livelihood	0.09	1.00	0.78	0.30
	Infrastructure	0.00	1.00	0.07	0.12
	Finance	0.00	1.00	0.04	0.11
	Sensitivity	*0.08*	*0.95*	*0.49*	*0.17*

In terms of infrastructure sensitivity, the highland communes mean index was slightly lower than that of the lowland communes, at 0.07 and 0.08, respectively. This could be due to the slightly farther distance (379.27 m) from water bodies in the lowlands compared to those in the highland communes (366.75 m), on average.

Lastly, we found that the lowlands (at 0.05) were a little more financially sensitive than the highlands (at 0.04). This could be due to the fact that the percentage of loan-taking among lowland households was around 4% compared to around 3% in the highlands.

By tabulating the mean sensitivity indices against primary occupations, we found that those who depended solely on rice farming and rice farming with raising livestock had similar overall sensitivity values of 0.57 and 0.53, respectively, while the value for non-agricultural activities was 0.33 (Table 9). This coincides with the mean values for livelihood for households depending on rice farming and rice farming with raising livestock, which were very high at 0.90 and 0.88, respectively, compared to the mean for non-agricultural work at 0.40. This indicates that households depending on climate-sensitive occupations can reduce their sensitivity by engaging in other occupations that are not directly impacted by climate changes. The human sensitivity index, while significant in its contribution to overall sensitivity, was similar across the three primary occupation groups.

Table 9. Sensitivity analysis by household occupation

Primary occupation		Human	Livelihood	Infrastructure	Finance	Overall sensitivity
Rice farming	Mean	0.27	0.90	0.07	0.07	0.57
	Std. deviation	0.13	0.18	0.14	0.13	0.14
	Minimum	0.06	0.10	0.00	0.00	0.20
	Maximum	0.67	1.00	1.00	1.00	1.00
Rice farming and raising livestock	Mean	0.24	0.88	0.09	0.03	0.53
	Std. deviation	0.11	0.16	0.14	0.08	0.13
	Minimum	0.06	0.26	0.00	0.00	0.13
	Maximum	0.50	1.00	1.00	0.55	0.94
Non-Agriculture	Mean	0.27	0.40	0.07	0.04	0.33
	Std. deviation	0.11	0.28	0.12	0.09	0.16
	Minimum	0.00	0.00	0.00	0.00	0.00
	Maximum	0.60	1.00	1.00	0.52	0.79

Based on the analysis, we concluded that the most sensitive determinant among the four used to determine sensitivity was livelihood followed by the human dimension. This was clear when we compared the mean index values of the highland and lowland communes. The former depended more on agriculture compared to the latter. Additionally, when livelihood dependency was distributed among the four determinants, those who relied on agriculture were found doubly sensitive compared to those in non-agricultural occupations.

4.5 Adaptation Practices and Adaptive Capacity Index

The adaptive capacity index we calculated was based on five determinants; infrastructure, economic, technology, social capital, and human capital, with their own indicators. From our survey, we found that the percentages of household members who were illiterate and those who attended primary school, secondary school, high school and university were 5.5%, 34.5%, 32.5%, 22.5% and 4.5%, respectively. At the same time, about 60% of the households owned at least one motorcycle. About 35% depended solely on agriculture and 35% had access to irrigation for wet season rice.

4.5.1 Adaptive capacity analysis of household in KPS

Figure 9 illustrates that the human capital index for adaptive capacity is doubly high as the indices of infrastructure, economics, and technology while the social capital determinant is significantly small. This can be interpreted as human-power being the only way the communes handle shocks. It should be noted that "human capital" refers to labor/working force while "social capital" refers to social bonding and linkages mentioned in social study literature (see Woolcock 1998 for the definition of social capital).

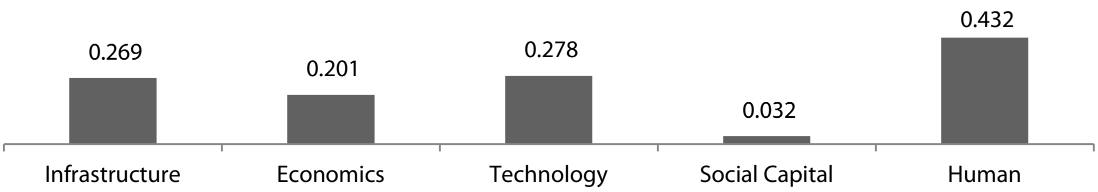


Figure 9. Comparison of adaptive capacity determinant indices of households in KPS

The five determinants were disaggregated into lowland and highland areas as shown in Table 10. The lowland communes were found to be more adaptive than those in the highlands as the product of the five determinants of adaptive capacity in the lowlands (0.38) was higher than for the highlands (0.28). The infrastructure indices were 0.31 and 0.20 for lowlands and highlands, respectively. This indicates that most lowland households had more access to water from irrigation systems than those in the highlands; 30.47% of the lowland households had access to irrigation for their wet season rice while only 19.65% of highland households had the same access.

Table 10. Adaptive capacity of households in KPS (1999-2010)

Topography	Determinants	Minimum	Maximum	Mean	Std. deviation
Lowlands	Infrastructure	0.00	1.00	0.31	0.42
	Economic	0.00	1.00	0.23	0.20
	Technology	0.00	1.00	0.30	0.19
	Social capital	0.00	0.66	0.03	0.07
	Human capital	0.00	1.00	0.46	0.19
	Adaptive capacity	*0.03*	*1.00*	*0.38*	*0.19*
Highlands	Infrastructure	0.00	1.00	0.20	0.34
	Economic	0.00	0.57	0.15	0.17
	Technology	0.00	0.79	0.23	0.18
	Social capital	0.00	1.00	0.04	0.12
	Human capital	0.00	0.78	0.38	0.16
	Adaptive capacity	*0.00*	*0.78*	*0.28*	*0.16*

In terms of economic adaptive capacity, the mean value for lowland households was 0.20, higher than that of the highland households (0.17). The mean values of income per capita, amount of remittances received (from family members working away from home), and percentage of income from non-agricultural activities (e.g., services and crafts) in the lowland communes were KHR 1,212,069, KHR 918,801, and 36.21% per year, respectively, while for the highland communes, the corresponding values were KHR 1,195,329, KHR 476,140, and 21.59%, respectively.

The determinant of technology was measured by the number of televisions (TVs), radios, landline telephones, cell phones, motorcycles and boats. These indicators represented information sharing, communication, and transportation means before and during natural disaster occurrences. If households had more TVs, radios, landline phones, cell phones, and motorcycles, they could be considered as having up-to-date information and communication.

The survey found that the mean index value for technology capacity was 0.30 and 0.23 for lowland and highland households, respectively. All the sample lowland households had radios or televisions (mean number 1.04) while not all highland households had these (mean value 0.80). In terms of telephones, lowland households had 1.09 phones on average while highland households had 0.88. The mean was 0.83 motorcycles per household in the lowlands, meaning that almost all lowland households had motorbikes while the mean for highland households was 0.54. Thus, highland households had poorer access to technology.

Social capital was measured based on the amount of money that a household could borrow from relatives or friends in case of disaster. The more the people could borrow, the richer they were considered in terms of social capital and vice versa. The survey and FGDs found that the people could rely first on their relatives, followed by friends and other villagers in the community, and local authorities. It was found that those from the highlands had better social capital than those from lowland communes. The index for the former was 0.04 compared to 0.03 for the latter (Table 10).

The households' number of workers and level of education were the indicators for human adaptive capacity. Households with more working members were considered more adaptive to drought because they had more income-generating members contributing money for household expenses. The working force per household in the lowlands was higher (3.15) than the highland communes (2.85).

In addition, if the household heads finished schooling at a higher level, it was assumed that they could more effectively address shocks than less educated ones. It was found that lowland household heads had an average of 8.35 years of education compared to 6.45 years for highland household heads. Altogether, the lowland-household human adaptive capacity index value was 0.46; this was lower for the highlands at 0.38.

In short, in terms of mean index values of adaptive capacity, the human capital determinant was highest at 0.43, followed by technology at 0.28, and infrastructure at 0.27 (Figure 9). This can be translated to mean that the ways in which people cope with shock is more through their labor force and less through external assistance. By disaggregating data into highland and lowland indices, it can be seen that the former's adaptive capacity (0.28) is comparatively lower than the latter's (0.38) (Table 10).

The adaptive capacity determinants of households in KPS were disaggregated across primary occupations (i.e., rice farming, rice farming with raising livestock, and non-agricultural activities) (Table 11). Non-agricultural-based households were more adaptive in terms of infrastructure with a mean index value of 0.30 compared to rice households and rice with livestock households at 0.26 and 0.22, respectively. This means that non-agricultural households have better access to infrastructure, such as water supply piping, than farming households.

In terms of economic adaptive capacity, the mean index value for non-agricultural households was 0.36, followed by rice with livestock households at 0.10, and 0.07 for rice farming households. This means that non-agricultural households also have better economic opportunities than those that relied mainly on agriculture for income.

The mean values of the technology adaptive capacity index were not significantly different among the three primary occupation groups at around 0.3; the same is true for the mean values of the human adaptive capacity index for the three groups at around 0.43. Lastly, the mean value for the social capital determinant for rice and livestock households was 0.05, higher than those for non-agricultural and rice households, both at 0.03.

Table 11. Adaptive capacity analysis by household occupation

Primary occupation		Infrastructure	Economic	Technology	Human capital	Social capital	Adaptive capacity
Rice farming	Mean	0.26	0.07	0.25	0.40	0.03	0.30
	Std. deviation	0.39	0.10	0.18	0.19	0.07	0.16
	Minimum	0.00	0.00	0.00	0.00	0.00	0.00
	Maximum	1.00	0.47	0.87	0.88	0.59	0.76
Rice farming with raising livestock	Mean	0.22	0.10	0.29	0.43	0.05	0.32
	Std. deviation	0.38	0.11	0.19	0.18	0.14	0.17
	Minimum	0.00	0.00	0.00	0.09	0.00	0.04
	Maximum	1.00	0.57	0.87	0.97	1.00	0.91
Non-agricultural work	Mean	0.30	0.36	0.30	0.46	0.03	0.42
	Std. deviation	0.42	0.17	0.20	0.19	0.07	0.19
	Minimum	0.00	0.00	0.00	0.00	0.00	0.05
	Maximum	1.00	1.00	1.00	1.00	0.66	1.00

4.5.2 Household adaptation practices

Given the exposure and sensitivity analysis, we found that the people did not do anything to adapt to windstorms but did so for flashfloods and droughts. Table 12 shows the typical adaptation practices of the local communities in KPS. For the urban dwellers in KPS, they made temporary dikes (9%) of sand bags around their homes during floods. Some of those who could afford it raised their houses and/or relocated their houses to higher ground.

Table 12. Frequency of adaptation options by natural disaster in KPS (1999-2010)

Adaptation Practice	Windstorms	Flashfloods	Droughts
Move to the hills	No	31 (29%)	No
Prepare dried food	No	28 (26%)	No
Build permanent houses	No	24 (22%)	No
Change crop calendar	No	22 (21%)	112 (19%)
Plant drought-resilient crop varieties	No	16 (15%)	284 (47%)
Diversify crops		15 (14%)	No
Build dikes or irrigation canals	No	10 (9%)	270 (45%)
Raise land around house	No	10 (9%)	No
Applying more chemical fertilizers	No	No	224 (37%)

Source: Survey 2011

Farmers who lost their rice crops to flashfloods replanted using new varieties, especially those that can be harvested in a shorter period of time. Given the short duration of flashfloods[8], about 30% of the people prepared dried food and moved to the hills. The hill shelters were in bad condition. After the floods, the people would practice small-scale home gardening to grow food to feed their families.

Table 12 shows that the main adaptation practices to drought as reported by respondents within the six communes were: changing crop calendar (19%), irrigating their rice fields (45%), planting drought-resilient crop varieties (47%), and increasing their use of chemical fertilizers (37%).

[8] It is worth noting that people reported a decreasing frequency of flashfloods.

4.6 Vulnerability Analysis: Index Composition

As mentioned earlier, household vulnerability is a function of exposure, sensitivity and adaptive capacity. The contribution of each index to the mean value of the vulnerability index (0.485) in KPS is the mean value of the sensitivity index (0.459), followed by the adaptive capacity index (0.351), and the exposure index (0.219) (Table 13).

Based on this result, we can say that KPS households experience low exposure to climatic hazards but their vulnerability is high due to low adaptive capacity and medium sensitivity (especially in terms of agriculture-based livelihood, which is climate-sensitive).

Table 13. Mean of vulnerability indices of households in KPS

	Min	Max	Mean	Std. Deviation
Exposure	0	1	0.219	0.195
Sensitivity	0	1	0.459	0.182
Adaptive Capacity	0	1	0.351	0.185
Vulnerability	0	1	0.485	0.184

Source: Survey 2011

Figure 10 presents the hazard/exposure, sensitivity, adaptive capacity, and vulnerability indices by disaggregating them across topographical areas (highlands and lowlands) based on household data. It appears that the hazards in the lowlands and highlands are not very different. Drought is considered as the most serious hazard among the three considered in this study (i.e., droughts, windstorms and flashfloods).

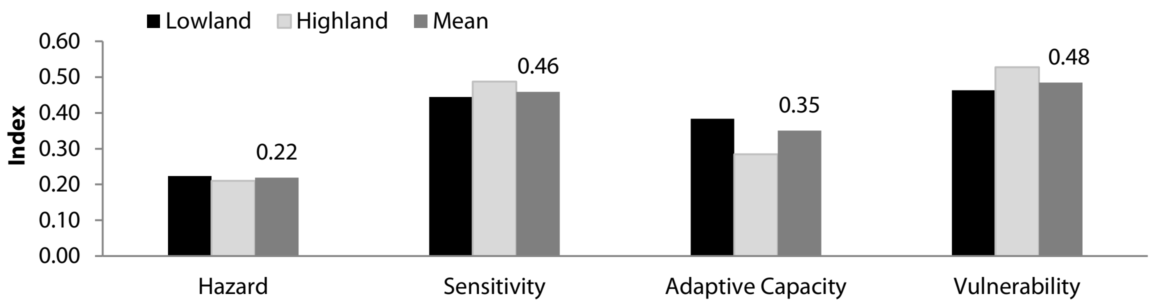


Figure 10. Comparison of KPS highland and lowland households' vulnerability (1999-2010)

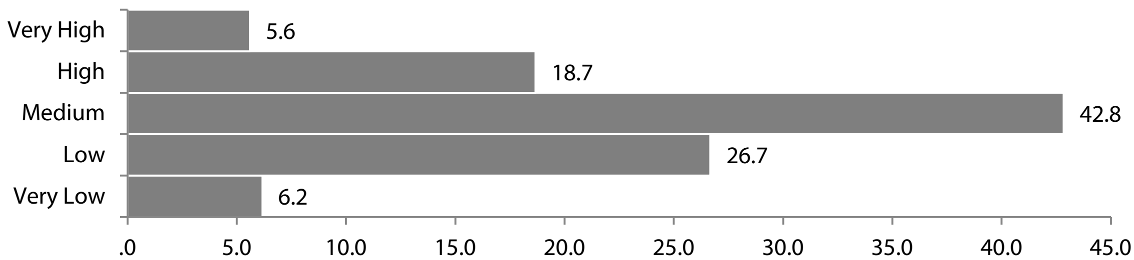
Sensitivity to climate change is affected by topography. Highland communes are generally more sensitive than lowland ones because the former are totally dependent on climate-related livelihoods and live far from healthcare centers, as is the case in the study communes. In addition, the sample highland communes had lower adaptive capacity than those in the lowlands. Therefore, it can be summarized that the highland communes are more vulnerable to climatic hazards than the lowland communes because of lower adaptive capacity and higher sensitivity.

The vulnerability analysis breakdown by primary occupation is presented in Table 14. Rice-growing households (with a mean vulnerability index value of 0.57) were found more vulnerable than those farming rice with livestock (0.55) and non-agricultural households (0.38). This means that farmers, whether relying solely on rice cultivation or in combination with livestock raising, were more vulnerable to climate impacts compared to those engaged in non-farming jobs. This is clear from the differences in the sensitivity indices of the three occupational groups even though exposure and adaptive capacity indices among them were comparatively similar.

Table 14. Vulnerability analysis by household occupation in KPS

Primary Occupation		Exposure	Sensitivity	Adaptive capacity	Vulnerability
Rice farming	Mean	0.23	0.57	0.30	0.57
	Std. deviation	0.20	0.14	0.16	0.15
	Minimum	0.00	0.20	0.00	0.13
	Maximum	0.77	1.00	0.76	1.00
Rice farming and raising livestock	Mean	0.25	0.53	0.32	0.55
	Std. deviation	0.21	0.13	0.17	0.16
	Minimum	0.00	0.13	0.04	0.18
	Maximum	0.83	0.94	0.91	0.92
Non-agricultural work	Mean	0.20	0.33	0.42	0.38
	Std. deviation	0.18	0.16	0.19	0.17
	Minimum	0.00	0.00	0.05	0.00
	Maximum	1.00	0.79	1.00	0.82

Figure 11 categorizes the sample households from very low to very high vulnerability. The graph shows that almost 43% of the households were in the medium vulnerability category while about 19% and 6% were highly and very highly vulnerable, respectively. Collectively, these three categories can be considered as a very likely vulnerable group, making up about 68% of the sample households in KPS.



Note: 0.00-0.20: very low, 0.21-0.40: low, 0.41-0.60: medium, 0.61-0.80: high, and 0.81-1.00: very high vulnerability

Figure 11. Vulnerability categorization of KPS sample households

Table 15 shows the distribution of the households across the three components of vulnerability. Surprisingly, 64% of the households had very low exposure while about 64% had medium to very high sensitivity. Moreover, many households (65%) had very low to low adaptive capacity. The implication is that sensitivity and adaptive capacity played significant roles in making households vulnerable. The households were clearly sensitive to drought as they were heavily dependent on rain-fed paddy for food and livelihood.

Table 15. Overview of vulnerability of households in KPS

Vul. index	Exposure		Sensitivity		Adaptive capacity		Vulnerability	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Very low	381	63.50	54	9.00	139	23.17	37	6.17
Low	110	18.33	164	27.33	249	41.50	160	26.67
Medium	61	10.17	253	42.17	139	23.17	257	42.82
High	46	7.67	114	19.00	67	11.16	112	18.67
Very high	2	0.33	15	2.50	6	1.00	34	5.67
Total	**600**	**100**	**600**	**100**	**600**	**100**	**600**	**100**

Source: Survey 2011

From the qualitative point of view, natural disasters, especially drought, have placed the communities in an insecure position. Although livestock is stolen every year, this increased in drought years, probably stolen by those who had lost their rice production to drought. This was revealed during the FGD in

Prekdey Village, Roleang Chak Commune, Samraong Tong District. The FGD in Chrok Trach Village, Moha Sang Commune, Phnum Sruoch District confirmed that some families experienced hardship because of droughts. For instance, they did not have enough money so their children had to drop out of school to reduce expenses or to help the family earn extra income. Other families which suffered severe damage to their rice production from the drought had decided to sell off their property and migrate to other places. The FGD in KrangTroak Village, Kak Commune, Basedth District reported cases of domestic violence because of the stress caused by droughts that damaged household rice production.

4.7 Vulnerability Analysis Based on Expected Poverty

Table 16 presents the results of the feasible generalized least squares (FGLS) analysis. Among the environmental impacts, only drought was found to have had a significant negative impact on log per capita income ($b = -0.379$, $p < 0.001$). This means that households that have experienced drought over the previous three years (2008-2010) would have a log per capita income of 0.379 less than those that did not experience drought, controlling for other household and individual characteristics in the model. An exercise was carried out to replicate the models covering experiences of drought in the last 12 years being replaced by experiences of drought in the last three years. The results indicated that the latter did have a significant impact on log per capita income.

Table 16. Results of least squares regression analysis of monthly log per capita income

	Initial Model			FGLS Model		
	Coefficient	Std. error	P>t	Coefficient	Std. error	P>t
Droughts in past 3 years (2008-2010)	-0.143	0.067	0.035	-0.379	0.071	0.000
Windstorms in past 12 years (1999-2010)	-0.264	0.133	0.047	-0.199	0.132	0.133
Flashfloods in past 12 years (1999-2010)	-0.076	0.113	0.503	-0.137	0.116	0.238
Household size	-0.197	0.017	0.000	-0.182	0.017	0.000
Education	0.047	0.010	0.000	0.044	0.010	0.000
Having motorcycle	0.265	0.071	0.000	0.312	0.072	0.000
Access to credit	-0.091	0.068	0.183	-0.061	0.068	0.375
Presence of disabled household members	-0.033	0.105	0.753	-0.026	0.106	0.808
Agriculture plus secondary occupation	-1.103	0.123	0.000	-0.899	0.118	0.000
Constant	3.700	0.138	0.000	3.714	0.139	0.000
Model summary						
Adjusted R-squared	0.339			0.341		
F (9,590)	33.64			33.97		
N	600			600		

Windstorms and floods in the previous 12 years (1999-2010) were not found to have had a significant impact on log per capita income. This may be due to the measure of these dummy shock indicators covering a long period of time (12 years).

Windstorms and flashfloods in the last five years (2006-2010) were not found to have had a significant impact on log per capita income. Again, this was possibly due to the length of time measured, which would have given the households time to develop strategies to mitigate the negative impacts of these events on their livelihoods. The respondents' experience of windstorms and flashfloods in the last five years (2006-2010) or the last three (2008-2010) years was nearly constant. This suggests that the respondents in the six study communes did not encounter windstorms and flashfloods in the last three to five years or, if they did, they perhaps did not consider them as serious as during the years prior to 2006.

Ideally, environmental hazards in recent years should have a more significant impact on the livelihood of villagers than those that happened a long time ago; people should have developed more coping mechanisms to mitigate the negative impacts of hazards that happened a long time ago. Thus, it should be more difficult to detect the impacts of climate hazards that happened a long time ago.

Only a few respondents reported that they had experienced flashfloods or windstorms over the last three years (2008-2010). Therefore, we measured the respondents' experience of flashfloods and windstorms over the last 12 years (1999-2010) and experience of drought during the previous three years (2008-2010) prior to the survey.

For the vulnerability index analysis, we used 12 years (1999-2010) for floods, windstorms and droughts, and these variables were quantified in numeric form. However, for the Vulnerability as Expected Poverty (VEP) analysis, we used dummy variables (with values of 0 or 1) for three years of drought (2008-2010) and 12 years of floods and windstorms (1999-2010).

Household size, possession of motorcycles, and livelihood dependency on agriculture were found to be significantly and inversely associated with monthly log per capita income. Specifically, the larger the household size, the lower the expected monthly log per capita income (the coefficient was -0.182, $p < 0.001$). Possession of motored vehicle was positively related to expected monthly log per capita income (the coefficient is 0.312, $p < 0.001$) while households whose livelihoods depended on agriculture alone tended to have lower monthly log per capita income than households that had secondary occupations (the coefficient was -0.899, $p < 0.001$). In addition, the respondents' education level was found to have had a positive effect on monthly log per capita income although the effect was small (the coefficient was 0.044, $p < 0.001$). Access to credit and the presence of disabled persons in the household did not significantly affect monthly log per capita income.

4.7.1 Household vulnerability

The expected monthly log per capita income obtained from the above FGLS analysis was used to create vulnerability indices at the USD 1.00 daily threshold and USD 1.25 daily threshold[9]. Households are considered poor and vulnerable in the future if their vulnerability index exceeds 0.50. Tables 17 and 18 present the results of the vulnerability analysis disaggregated by commune.

Using the USD 1.00 threshold, the overall mean vulnerability was 0.65, with small variations in the mean vulnerability across the six communes (Table 17). The commune with the highest mean vulnerability was Ta Sal (0.70), and the commune with the lowest mean vulnerability was Roleang Chak with 0.61.

Using this USD1.00 cut off point, it was found that about 79% of the households interviewed were vulnerable, with the highest vulnerability incidence being in Ta Sal (85%), followed by Peang Lvea (83%), Kak (82%), Moha Sang (76%), and Chbar Mon and Roleang Chak (both at 73%) (Table 17).

Table 17. Vulnerability index and incidence by commune at USD 1.00 daily threshold

Commune	Mean vulnerability index	Standard deviation of vulnerability	Vulnerability incidence (%)	Rank
Chbar Mon	0.63	0.18	73.00	5
Kak	0.68	0.16	82.00	3
Moha Sang	0.64	0.17	76.00	4
Peang Lvea	0.66	0.16	83.00	2
Roleang Chak	0.61	0.17	73.00	5
Ta Sal	0.70	0.17	85.00	1
Average	**0.65**	**0.17**	**78.67**	

In increasing the threshold to USD 1.25, the overall mean vulnerability index increased to 0.72 and the incidence of vulnerability increased to 90.67% (an increase of 12%) (Table 18). This means that with a daily USD 1.25 poverty line, more than 90% of the respondents will become poor in the future. The highest

[9] It is important to note that the poverty line in Cambodia is about USD 1.00 per day. Thus, using the USD 1.00 threshold is more consistent with the poverty line in the country than using the USD 1.50 threshold, as in the Philippines study (Chaudhuri 2003). In this study, we wanted to see the impact of increasing the threshold by 20% to USD 1.25.

percentage of vulnerable households was in Ta Sal (98%), followed by Peang Lvea (93%), Kak (92%), Roleang Chak (89%), Moha Sang (87%), and Chbar Mon (85%).

Table 18. Vulnerability index and incidence by commune at USD 1.25 daily threshold

Commune	Mean vulnerability	Standard deviation of vulnerability	Vulnerability incidence (%)	Rank
Chbar Mon	0.70	0.16	85.00	6
Kak	0.75	0.14	92.00	3
Moha Sang	0.71	0.16	87.00	5
Peang Lvea	0.73	0.15	93.00	2
Roleang Chak	0.68	0.16	89.00	4
Ta Sal	0.76	0.15	98.00	1
Average	**0.72**	**0.15**	**90.67**	

It is apparent that poor communes, like Ta Sal and Kak, with their level of ownership of motorcycles, high percentage of villagers depending solely on agriculture for their livelihood, and high percentage of disabled persons in the families, are vulnerable now and likely to be in the future.

4.7.2 Vulnerability and per capita income

Another exercise was carried out to examine the relationship between the vulnerability index and log per capita income. The results are presented in Figures 12 and 13 below. Each scatter plot is divided into four quadrants, representing the vulnerability cut-off point and poverty cut-off point at the USD 1.00 threshold in Figure 12 and at the USD1.25 threshold in Figure 13.

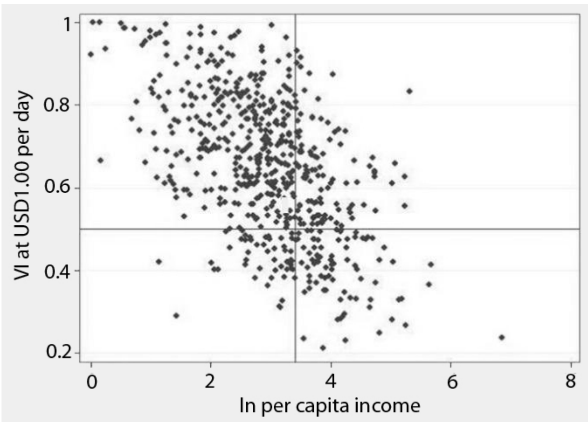


Figure 12. Vulnerability vs log per capita income at USD 1.00 threshold

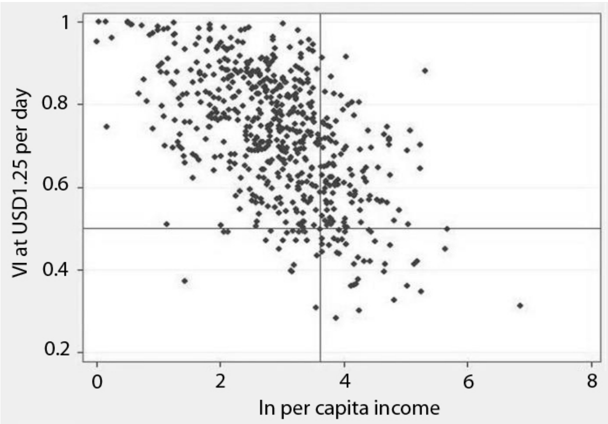


Figure13. Vulnerability vs log per capita income at USD 1.25 threshold

A vulnerability cut-off point is the point that determines if a household is considered vulnerable. As can be seen in the figures, the vulnerability index is between 0 and 1. So the vulnerability cut-off point is 0.5. It means that households whose vulnerability index is over 0.5 are considered as vulnerable. This vulnerability cut-off point applies to both figures. However, the poverty cut-off point is the threshold that determines if a household is poor or not.

The data points in the scatter plots above represent the interviewed households. Households in the upper left quadrant are currently both poor and vulnerable, meaning that they are likely to continue to be poor in the future. Those in the lower left quadrant are households that are currently poor but not vulnerable. Those in the upper right quadrant are households that are currently not poor but vulnerable, meaning that they are likely to be poor in the future. Households that are in the lower right quadrant are neither currently poor nor vulnerable, meaning that they are less likely to be poor in the future.

Comparing Figures 12 and 13, it is evident that an increase in the threshold of per capita income from USD 1.00 to USD 1.25 decreases the number of households that are currently not vulnerable and increases the number of households that are vulnerable. This means increasing the per capita income threshold results in moving more households into future poverty, regardless of their current poverty status (Table 19). However, the increase in the future incidence of poverty due to the increase in the threshold is more severe among those who are currently poor than among their counterparts who are currently not poor and vulnerable in all communes, with the increase of the poor and vulnerable being higher in poor communes like Ta Sal, Roleang Chak, and Kak (Table 19).

Table 19. Vulnerability index and incidence per commune

At USD 1.00 threshold	Chbar Mon	Kak	Moha Sang	Peang Lvea	Roleang Chak	Ta Sal	Total
Currently poor and vulnerable	60.0%	69.0%	63.0%	56.0%	58.0%	60.0%	61.0%
Currently poor but not vulnerable	11.0%	8.0%	6.0%	5.0%	10.0%	7.0%	7.8%
Currently not poor but vulnerable	13.0%	13.0%	13.0%	27.0%	15.0%	25.0%	17.7%
Currently not poor and not vulnerable	16.0%	10.0%	18.0%	12.0%	17.0%	8.0%	13.5%
At USD 1.25 threshold							
Currently poor and vulnerable	70.0%	81.0%	72.0%	65.0%	74.0%	76.0%	73.0%
Currently poor But not vulnerable	8.0%	2.0%	6.0%	1.0%	1.0%	2.0%	3.3%
Currently not poor but vulnerable	15.0%	11.0%	15.0%	28.0%	15.0%	22.0%	17.7%
Currently not poor and not vulnerable	7.0%	6.0%	7.0%	6.0%	10.0%	0.0%	6.0%
Percentage of Change							
Currently poor and vulnerable	16.7%	17.4%	14.3%	16.1%	27.6%	26.7%	19.7%
Currently poor but not vulnerable	-27.3%	-75.0%	0.0%	-80.0%	-90.0%	-71.4%	-57.4%
Currently not poor but vulnerable	15.4%	-15.4%	15.4%	3.7%	0.0%	-12.0%	0.0%
Currently not poor and not vulnerable	-56.3%	-40.0%	-61.1%	-50.0%	-41.2%	-100.0%	-55.6%

4.8 Adaptation Option Analysis

There are many adaptation options that have been applied and proposed (Christian Aid 2009; MoE 2005) and some have been technically investigated (Matthews *et al.* 1997; Tsubo *et al.* 2009). Based on our field survey, we found that local adaptation options being practiced in KPS included changing crop calendars, changing rice varieties, pumping water, digging wells and increasing fertilizer use.

4.8.1 Adaptation practices by households

Figure 14 shows that most of the sample households made efforts to cope with drought. Given that 25% of the households did nothing, the rest did at least one adaptation option each. The most popular practice was changing the rice variety grown, as reported by 284 households, followed by pumping water, and applying fertilizer. For practical reasons, changing varieties is a must for a late onset of rain scenario. This goes hand in hand with applying fertilizer and pumping water.

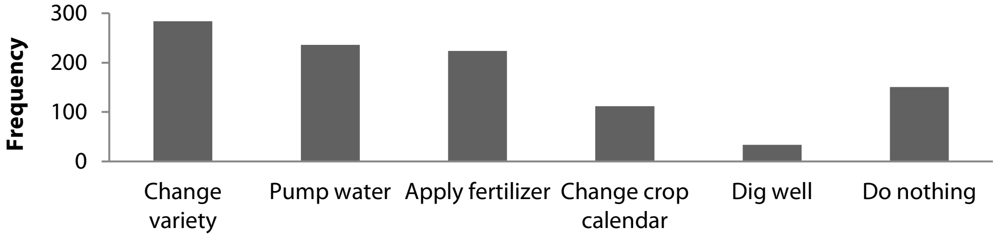


Figure 14. Agricultural adaptation practices at the household level in KPS

Once the rain is late or the young rice plants are destroyed by drought, short-duration rice genotypes are supplied by the Department of Agriculture of the province together with water pumping machines. The farmers usually applied fertilizer to secure their yield. Based on the FGDs, digging wells was costly, which is why few households reported practicing this option.

Table 20 shows the distribution of household vulnerability indices vis-à-vis the number of adaptation options being practiced. More than half of the households surveyed reported that they applied at least one to two adaptation options while about 18% of them did three to four. Also, while 67% (403) of the households were vulnerable (medium to very high), 26% of this (105/403 households) did not practice any adaptation measures. It can be assumed that they were too poor to attempt anything or they did not rely on agriculture as their main source of income, thereby avoiding climate-related impacts on their livelihoods.

Table 20. Distribution of vulnerability indices across agricultural adaptation practices in KPS

Number of adaptation options	Vulnerability index					Total	%
	0.00-0.20 Very low	0.21-0.40 Low	0.41-0.60 Medium	0.61-0.80 High	0.80-1.00 Very high		
0	12	34	73	27	5	151	25.17
1	9	34	74	24	11	152	25.33
2	11	59	75	34	9	188	31.33
3	4	25	25	16	7	77	12.83
4	1	8	10	9	1	29	4.83
5	0	0	0	2	1	3	0.50
Total	**37**	**160**	**257**	**112**	**34**	**600**	

Source: Survey 2011

From the household perspective, the selection of adaption options is highly associated with costs. If the cost is high, the people will wait for government intervention. Based on the key informant interviews, we learnt that during droughts, the government would take all possible action to save the rice growing in the fields and if these are destroyed, the government would provide seeds and water pumping machines. The households, however, would change crop calendars on their own.

4.8.2 Adaptation options proposed by the local government

Local government officials were divided into seven FGDs to suggest locally appropriate adaptation options. They proposed the following: construct and rehabilitate irrigation systems; provide pumping machines; raise public awareness on short duration rice; set up rice banks; raise public awareness on adaptation; form farmer associations; provide more veterinarians; provide training on using chemical fertilizers; construct and restore reservoirs; provide training on using chemical pesticides; construct ponds; dig wells; do crop rotation; and improve water transportation services.

Three adaptation options were the most frequently proposed: constructing and rehabilitating irrigation systems, providing pumping machines, and raising awareness of the benefits of using short-term rice varieties. The next most popular options were: constructing and restoring reservoirs, using pesticides, constructing ponds, and providing training on using chemical fertilizers. The least proposed adaptation options were: setting up rice banks, forming farmer associations, raising public awareness on adaptation, digging wells, doing crop rotation, and improving water transportation (Figure 15).

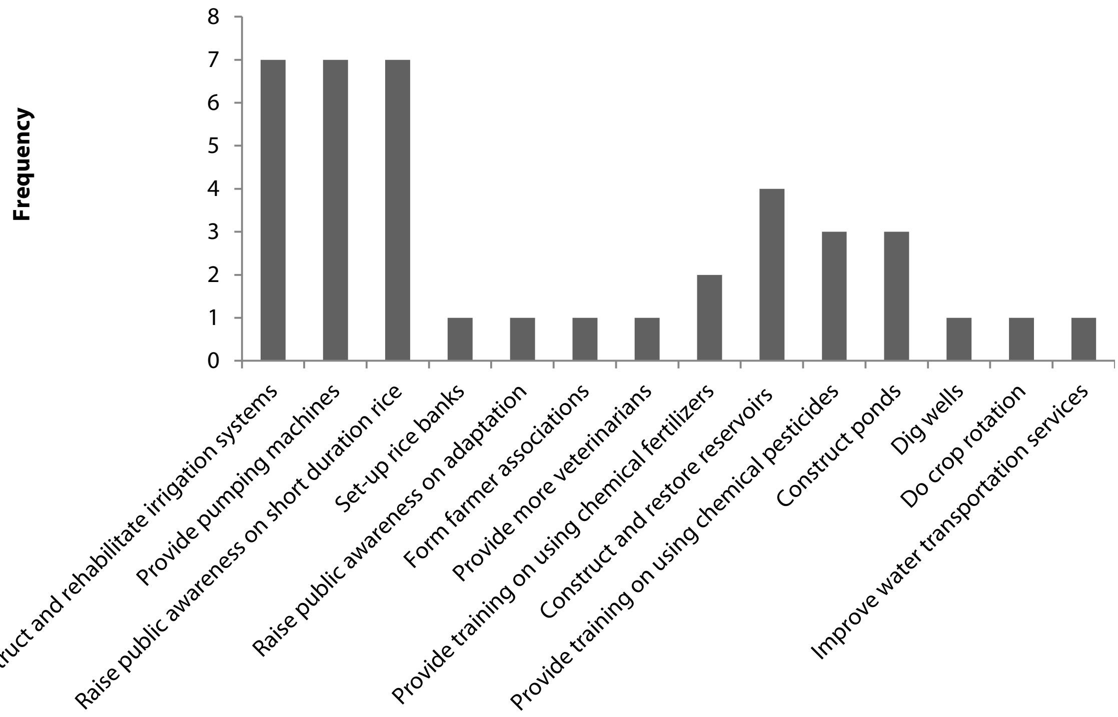


Figure 15. Frequency distribution of locally appropriate adaptation options for KPS

Based on their, the proposed locally appropriate adaptation options were classified into three priority categories. Constructing and rehabilitating irrigation systems, providing pumping machines, and raising awareness of the benefits of using short-term rice varieties were considered top priority to counter drought impacts during all seven FGDs. Farmers will be able to save their rice during mid-wet season drought if irrigation systems are constructed (if there is no irrigation yet) or rehabilitated (for existing irrigation). To make up for inadequate irrigation, pumping machine provision by the KPS Department of Water Resource and Department of Agriculture was considered necessary.

Given the water insufficiency in some communes, raising public awareness on the benefits of using short-duration rice is also essential. It takes a shorter time to grow than long- and medium-duration rice genotypes and requires less water. However, farmers do not recognize the value of this adaptation because of its low yield. So raising awareness in the use of short-duration rice genotypes is necessary to lessen drought impacts.

The second most popular set of proposed adaptation options to climate change were constructing and restoring reservoirs, using pesticides, constructing ponds, and providing training on the use of chemical fertilizers. There are existing reservoirs that have degraded over time; rehabilitating them requires external support. Also, there are places where the community can create reservoirs for agricultural activities but these need external funding; the construction cost is too much to mobilize at the commune level.

While constructing and rehabilitating reservoirs is for large-scale agricultural purposes, ponds are small-scale, household adaptation only. Digging ponds was proposed for the sake of domestic consumption because many households in KPS do not have access to clean water during droughts.

Meanwhile, pesticides are meant to control against or mitigate crop damage due to pest outbreaks. Providing training on how to use chemical fertilizers was the last option in this category, proposed for the purpose of getting high yields for short-duration rice varieties.

The last category is composed of the least proposed options. These were: setting up rice banks, forming farmer associations, raising public awareness on adaptation, planting trees, digging wells, doing crop rotation, and improving water transportation. The rice banks were proposed to store rice seeds for farmers in case droughts destroyed the harvest. Farmer associations were proposed to mobilize community resources. This included providing assistance to households during times of drought or floods. Digging wells and improving water transportation means were proposed for purposes of domestic use. Crop rotation was proposed so people could use the rice fields to grow drought-resistant crops in between rice. Finally, raising public awareness was also proposed because if people had knowledge about climate change adaptation, they were more likely to adapt immediately.

4.8.3 Adaptation practices and proposals by experts

Irrigation has been proposed in the country's National Adaptation Program of Action (NAPA) 2006 and, for KPS, irrigation systems are being constructed in the Basedth District. Historically, the dam system was built in KPS in the 1970s to retain runoff water from nearby mountains and control flashfloods. Its crucial role was to supply water for household consumption and to irrigate paddy fields in Samraong District (Takeo Province) and Basedth District (KPS). Unfortunately, frequent flashfloods and improper maintenance caused one of the main dams (named Slapleng) to be damaged. It fell into disuse in 1983. Consequently, water storage capacity in the area significantly decreased, and it caused a water shortage for irrigation and household use in the dry seasons (MoE 2006).

The irrigation construction project in Basedth District aims to improve water management for multiple uses including irrigation, domestic use in rural communities, recreation and aquatic biodiversity enhancement. It aims to irrigate 500 ha of dry season paddy fields while increasing fish stocks in the reservoir. Forest and non-timber forest products (NTFP) would increase and water quality and water supply to the rural community would be improved. Finally, there would be increased agricultural production (MoE 2006).

According to the key informant interviews with officers from relevant bodies such as the Department of Water Resources, Provincial Committee Disaster Management, and Department of Agriculture of the province, these government officers believe that small-scale infrastructure including reservoirs, and ad hoc assistance such as water pumping machines and seeds were the best options. At the same time, they emphasized that agricultural skills and knowledge were crucial, especially for long-term adaption to climate change.

Changing crop cultivation calendars has been locally and internationally conducted to adapt to drought (Christian Aid 2009; Chambwera and Stage 2010; Halmer and Jigillos 2004). This adaption option is believed to be technically effective (Tsubo *et al.* 2009; Oxfam 2008; ADB 2009). Tsubo *et al.* (2009) explained that changing rice varieties meant changing from one rice genotype to another rice genotype. They found, for example, that to adapt to drought, people should change their rice seed to drought-resistant genotypes and from long-duration rice genotypes to medium- and short-duration rice genotypes in order to avoid growing rice during late season drought. However, there is no clear evidence to prove how much people actually benefitted from this practice.

Changing rice varieties has been proposed by the Department of Agriculture while changing rice cultivation calendars has been applied for years to adapt to drought. According to the study's FGDs, changing the rice cultivation calendar involves changing the time of planting and thus, harvesting, with no change to the rice genotype grown. For example, if people plant long-duration rice then they have to postpone planting if there is insufficient rain early in the growing season (normally the wet season). This means they have to plant their rice a month later.

However, there is controversial discussion on the effectiveness of changing cropping calendars. Matthews *et al.* (1997) found that changes in the planting date could lessen the negative impacts of extreme temperature in Asia. In contrast, Tsubo *et al.* (2009) found that if farmers delayed their planting, they risked facing drought late in the season. They recommended planting on time as usual in combination with other adaptation measures.

In short, structural (such as water reservoirs) and non-structural adaptation options (such as capacity building) are required to mitigate drought impacts in KPS. Improving small-scale water infrastructure and management appears to be popular while knowledge about climate change adaptation is needed by local government units and the people to ensure long-term sustainability of adaptation options. Based on technical feasibility and appropriateness of the various options in the study locality, we chose one structural adaptation option (water reservoirs) and two non-structural measures (climate change adaptation knowledge through training and changing rice varieties) as the most viable to economically evaluate.

4.9 Discussion

It can be seen that climate-induced hazards, especially windstorms, flashfloods, and droughts, have imposed threats to the communities in KPS. The windstorm impacts on communities appeared to be minimal, but those who were impacted were very poor and were hardly able to recover from the damage. The next most frequent climatic hazard in KPS was flashfloods, which hit the business center of the province. However, drought proved to be the most pronounced hazard in KPS; it was the worst affected province in the country, losing 90% of its rice yield in 2004 (NOAA National Climatic Data Center 2004). The villagers had inadequate food to eat so that they ate wild potatoes in place of rice.

As a result of these climatic hazards, people migrated to find employment opportunities in the cities. Among the respondents from the six study communes, temporary migration was at about 30% in Ta Sal and Kak, about 10% in Moha Sang and Chbar Mon, 20% in Roleang Chak, and 60% in Peang Lvea. There were many reports of children dropping out of school, increased burden on women in terms of daily chores, and health-related issues.

FGDs in Krang Troak Village, Kak Commune, Basedth District found that poor families were the most vulnerable to drought, especially the children who consumed unclean water and were more vulnerable to disease. The number of agricultural laborers per household also contributed to high human sensitivity as they are unemployed when hazards damage their paddy fields. During the drought periods, those who can rent pumping machines could pump water from nearby sources to supply their rice fields while those who could not afford these had to take loans from the local banks (e.g., AMK, Prasac, ACLEDA) with interest. Those who took such loans but could not pay the interest or repay the loans had their property confiscated including valuables and land titles. Several families in Prekdey Village lost their land titles to ACLEDA Bank due to their inability to pay the loan interest.

Among the three hazards considered in the study, droughts were the most intense and frequent and caused the most damage in KPS. The people have limited access to irrigation. According to NCDD (2009), only 13.83% of the total area of wet season rice land is irrigated. The damage to planted areas of rice in hectares was as follows: 223 (2010-2011), 322 (2009-2010), 49 (2008-2009), 13 (2007-2008), 3115.20 (2006-2007), 63 (2005-2006), 28,257 (2004-2005) (DoA 2005-2011).

Severe drought that reduces yield occurs late in the growing season, and longer duration genotypes are more likely to encounter drought during grain filling (Tsubo *et al.* 2009). In Cambodia, drought can occur any time during the wet season, and rice production may be reduced greatly (Ouk *et al.* 2006). For instance, lowland rice production in the Mekong Region is generally low because crops are cultivated under rain-fed conditions and often exposed to drought. The occurrence of drought is associated with the long absence of heavy rain and the effects of drought are further enhanced by the low clay content of the soil. The impact of drought on grain yield mostly depends on the severity of the drought (Tsubo *et al.* 2009).

This study had similar findings as other empirical studies. For example, our survey found that farmers usually under-cultivated and produced low yields during a drought spell. Normally, two tonnes of rice per hectare per year can be produced but KPS farmers could only produce 500 kg of paddy per hectare in 2011 due to drought. Lowland and upland residents reported that they faced a lot of hardship with the climate situation and were trying to cope by having fathers or children work in the cities.

According to the ADB (2009), adaptation is urgently needed in developing countries to respond to climate change impacts. It is believed that agricultural adaptation options could increase yields and incomes as well as food security. This is why many strategies have been found to mitigate drought impacts and increase rice production, such as growing high-yielding varieties and providing extension services and supplementary irrigation (RGC 2001, 2006). Based on the current climatic hazards, the most urgent adaptation needed in KPS is to have water for rice production, especially during prolonged droughts in the wet season. Furthermore, providing training on modern agricultural methods and small-scale water management is also needed.

Besides the efforts made by households, other stakeholders also have a role to play in improving farmers' adaptive capacity, for example, by establishing early warning systems for floods and droughts, setting up seed banks, introducing better farming methods, and introducing risk aversion/reduction schemes such as crop insurance (as mentioned in the FGDs), so that the communities can be more resilient and recover from shocks faster. Keeping farmers informed about flashfloods and droughts is imperative while irrigation and drought-resilient farming methods are also top priority.

The National Adaptation Programme of Action to Climate Change (NAPA) includes a proposal for the restoration of a multi-use dam in KPS as a secondary priority. Dams have played a crucial role in rice production and water supply for rural communities in Basedth District, but this dam is relatively small (coverage up to 400 ha).

5.0 CONCLUSIONS

Cambodia, a least developed country in Southeast Asia, is hampered by low income, high mortality rates, an economy highly dependent on agriculture (World Bank 2006), and limited adaptive capacity, making the country highly vulnerable to climate change (Yusuf and Francisco 2009). Shocks like flashfloods, droughts and other climate change impacts may hinder the achievement of Cambodia's Development Goals, especially those related to poverty reduction. As indicated by the MoE (2001, 2005), flashfloods and droughts have accounted for large reductions in rice production in Cambodia. At the provincial level, Yusuf and Francisco (2009) indicated that Kampong Speu (KPS) Province was the third most vulnerable province in Cambodia, which was targeted for a climate change project related to water supply for rice production.

This study aimed at identifying the impact of environmental shocks (i.e., flashfloods, windstorms, and droughts) on KPS communities based on household characteristics and per capita income by estimating vulnerability indices to predict future incidence of poverty.

Drought was found to be the most common environmental hazard experienced by the people in the six study communes. The study found that, among the three environmental shocks, only drought, as experienced by the respondents in the last three years (2008-2010), led to declining household per capita income. Compared to windstorms and flashfloods, drought was also more devastating to crop production.

Two of the household characteristics that negatively affected household per capita income were household size and agricultural dependency. This means that households with many children and no other sources of income other than agriculture were likely to be poor and would continue to be poor (vulnerable) in the future.

In contrast, the education level of the heads of the respondent households and household possession of motorcycles were positively related to per capita income. It is important to note that the causal relationship between motor vehicle possession and per capita income assumed in the model may be reversed in reality in that it is possible that a household has higher per capita income in order to purchase motor vehicles.

In using the Vulnerability as Expected Poverty (VEP) index to predict future incidence of poverty, the majority of the respondents from the communes were found to be poor and likely to continue to be poor in the future. Furthermore, increasing the poverty line from USD1.00 to USD1.25 daily resulted in an increase of the incidence of vulnerability in the communities, the increase being much larger in already poor communities.

Based on the household survey and key informant interviews, KPS was found to be highly prone to flashfloods and droughts. The lack of irrigation systems as well as the technology to save water to save the farmers' rice plants in time contributed to severe damage from drought. The findings from this study using the vulnerability index and calculating VEP showed that the people were unable to cope with shocks, especially droughts. As a result, farmers were not able to fully cultivate their paddy fields during droughts and crop yields fell as low as 500 kg per hectare (e.g., in the drought year of 2001) compared to more than two tonnes per hectare in a normal year.

Living with high livelihood sensitivity and low adaptive capacity to climate change, increasing the adaptive capacity of the households in KPS is imperative. Diversifying household livelihood sources was recommended but was beyond the scope of this study to explore further. While enhancing adaptive capacity is very critical, there is limited intervention from the local and sub-national government. Although NGOs are working with the communities to enhance livelihoods of the latter through community risk management, there is limited progress due to the low capacity of community members and their limited financial resources and access to credit.

Some policy recommendations arising from this study to address the situation in KPS are: building irrigation systems to handle droughts, developing sources of secondary income for poor households so that they do not have to rely exclusively on agriculture, providing access to credit during drought years, and increasing the education level of villagers.

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Appendix 1. List of indicators with corresponding weight and measurement

Determinants	Weight 1	Indicators	Weight 2	Measurement
I. Hazard				
Windstorms	14.51	Number of windstorms (1999-2010)	100.00	No. of windstorms
Droughts	52.96	Number of droughts lasting over 4 weeks (1999-2010)	100.00	No. of droughts
Flash-floods	32.51	Number of flashfloods (1999-2010)	100.00	No. of flashfloods
II. Sensitivity				
Human	23.70	Ratio of dependents (under 15 and over 60 years old) per family	55.50	No. of dependents/ no. of family members
		No. of family members working as agricultural laborer (i.e., cultivation and husbandry, forestry, and aquaculture)	44.50	No. of family laborers
Livelihood	25.57	% of household annual income generated from agriculture	79.60	Income generated from agriculture/total hh income)*100%
		% of perennial planted area (rubber and forestry) to agricultural area	10.20	Perennial planted area/total agricultural area)*100%
		% of aquaculture area to total agricultural area	10.20	Aquaculture area/total agricultural area*100%
Infrastructure	20.68	Distance from residence to water bodies (river, stream, lagoon, sea)	45.50	Meters
		Distance from residence to safe shelters (Committee offices, schools, health centers, multi-storey houses, etc.)	19.00	Meters
		Average area of impermanent dwelling (made of bamboo and palm trees) per family member	35.50	m^2/person
Financial	30.05	% of debt taken to total income of households	100.00	Amount of debt/total hh income*100%
III. Adaptive Capacity				
Infrastructure	19.08	% of irrigated agricultural land of household	61.81	Total area of hh irrigated land/total agricultural land*100%
		Average area of permanent dwelling per family member	18.19	Total area of permanent dwelling/no. of family members in m^2/person
Economic	20.54	Income per family member	31.54	Total income/no. of family members in KHR/person
		Amount of remittances received per year	30.60	KHR/year
		% of income generated from non-agricultural work (services, crafts)	37.86	Income generated from non-agricultural work/total household income)*100%
Technological	20.34	Number of TVs & radios per household	30.44	No. of TVs & radios
		Number of landline phones and cell phones per household	30.90	No. of landline phones and cell phones
		Number of motorcycles per household	29.36	No. of motorcycles
		Number of boats per household	0.93	No. of boats
Social capital	18.42	Amount of money that can be borrowed from relatives and friends in case of disaster	100.00	KHR
Human capital	21.62	Number of working members per household	53.00	No. of working members
		Level of education: schooling years that household head finished	47.00	No. of schooling years

Notes:
(1) hh = household
(2) There are two levels of weighting expressed in percentages: Weight 1 and Weight 2. It is very important to quantify vulnerability according to the different levels of perceived importance of each determinant and its indicators. The consensus method was used to estimate this through a weighting system for the different determinants and indicators. This was done through eight FGDs with participants from a range of backgrounds at the provincial, district and commune level. The weights derived from these discussions were then averaged out. Weight 1 represents the weighting of each determinant. Weight 2 represents the weighting of each indicator of a particular determinant. For example, for the Human Sensitivity determinant, there are two indicators with different weights totaling 100% for this determinant, namely, the number of dependents (55.5%) and number of family members working as farm labor (44.5%).

Appendix 2. Description of vulnerability indicators

Vulnerability attribute	Determinants	Indicators	Description
Hazard	Storms	1. Number of storms in the last 12 years (1999-2010)	Flood years, when households reported rice production damage by storms.
	Droughts	2. Number of droughts in the last 12 years (1999-2010)	Drought years, when households reported rice production damage by droughts.
	Flashfloods	3. Number of flashfloods in the last 12 years (1999-2010)	Windstorm years, when households reported rice production damage by floods.
Sensitivity	Human	1. Ratio of dependents	A household with more young and old dependents is more sensitive than those with fewer dependents.
		2. No. of family members working as agricultural labor on the farm	A household with more family members working in agriculture is more sensitive than one with fewer family members working in agriculture.
	Livelihood	3. % of annual income generated from agriculture	A household with more income from agriculture is more sensitive than one with less income from agriculture.
		4. % of perennial planted area	A household with more perennial planted area is more sensitive than one with less perennial planted area.
		5. % of aquacultural area to total agricultural area	A household with more aquacultural area is more sensitive than one with less aquacultural area.
	Infrastructure	6. Distance from residence to water bodies	A household that lives further from water bodies is more sensitive than one that is nearer.
		7. Distance from residence to safe shelters	A household that lives further from safe shelters is more sensitive than one that is nearer.
		8. Average area of impermanent dwelling per family member	A household with a bigger impermanent dwelling area is more sensitive than one with a smaller impermanent dwelling area.
	Financial	9. % of debt taken to total income of households	A household with more debt is more sensitive than one with less.
Adaptive capacity	Infrastructure	1. % of irrigated agricultural land of household	A household with more irrigated land will be more adaptive than one with less.
		2. Average area of permanent dwelling area per family member	A household with a bigger permanent dwelling area will be more sensitive than one with a smaller permanent dwelling area.
	Economic	3. Income per family member	A household with more income will be more adaptive than one with less.
		4. Amount of remittances per year	A household receiving more income from remittances will be more adaptive than one with less.
		5. % of income generated from non-agricultural work	A household receiving more income from non-agriculture work will be more adaptive than one with less.
	Technology	6. Number of TVs & radios	A household having more TVs and radios will be more adaptive than one with fewer.
		7. Number of landline phones and cell phones	A household having more landline phones and cell phones will be more adaptive than one with fewer.
		8. Number of motorcycles	A household having more motorcycles will be more adaptive than one with fewer.
		9. Number of boats	A household having more boats will be more adaptive than one with fewer.
	Social capital	10. Amount of money that can be borrowed from relatives and friends in case of disaster	A household having access to credit during disasters will be more adaptive than one with less.
	Human	11. Number of working members per household	A household with more working family members will be more adaptive than one with fewer.
		12. Level of education	A household whose head has a higher level of education will be more adaptive than one with a head who has a lower level of education.

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