Research article

Climate Change Vulnerability: Household Assessment Levels in Kampong Speu Province, Cambodia

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Abstract Cambodia's Ministry of Environment (MoE) conducted vulnerability and adaptation assessments using two different methodologies: the Global Circulation Model (MoE, 2001) and Household Surveys (MoE, 2005). They found that Cambodia is vulnerable to climate change and has a low adaptive capacity compared to other countries in Southeast Asia. Flood and drought were identified as the climatic hazards that imposed the greatest threats to rural farmers. This study, which assessed vulnerability at the household level in the drought-prone Kampong Speu (KPS) province, calculates climate change vulnerability based on the framework developed by the Inter-governmental Panel on Climate Change (IPCC). The results indicate that drought is the most severe climate hazard experienced in KPS. Farmers reported that they regularly experienced irregular rainfall distribution during cropping season that results in crop damage and/or loss. Adaptations to drought adopted by farmers include water storage, introducing drought-tolerant crop varieties, and improving knowledge about farming techniques. Other mechanisms that are also feasible are providing or enhancing secondary income capacity.

Keywords climate change, vulnerability, adaptation, assessment, rural development

INTRODUCTION

Climate change is the term most frequently used in global studies to refer to significant and lasting changes in the Earth's weather pattern that are evident in effects such as worldwide changes in in precipitation, and temperature (IPCC, 2007). However, 'climate change' is not commonly used in Cambodia, where this phenomenon is instead called 'climate variability'. The impacts of climate change can be seen spatially, temporally, socio-economically and through many other factors. An assessment of vulnerability to climate change is required before any prescriptions are given to mitigate and/or to adapt to climate change.

As defined in the IPCC report Climate Change 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 (IPCC, 2001 , p. 89). The definitions of exposure, sensitivity, and adaptive capacity can be found in climate change literature (Adger, 2006; Fankhauser et al., 1999; Eriksen and O'Brien, 2007). Explanations of how to quantify vulnerability can be found in Fussel (2007) and Hinkel (2011).

When studying vulnerability on a fine scale, for example at a household level, the study of climate change is associated with the outcomes of changes in climate in a particular geographical area such as a commune. A study may focus on a single element, such as changes in productivity, economic loss, or local knowledge of adaptation.

This paper aims to estimate and quantify vulnerability to climate change in Cambodia using household data and to identify the household characteristics that are most impacted by climate change effects such as flood and drought.

Background

One study on vulnerability related to climate change at the household level in Cambodia was completed by the Ministry of Environment (MoE) in 2005. Climatic hazards including flood, drought, and windstorms were studied. That study (MoE, 2005) demonstrates that Cambodians have observed changes in weather patterns and experienced losses in farming production due to climatic hazards because of their low adaptive capacity. A number of possible coping and adaptation mechanisms were identified by the study, which noted there were a number of constraints to effectively adapting to climate change such as lacks in the financial, knowledge and skill aspects required to mitigate impact. Following the MoE's study, there have been a number of studies related to climate change assessment that use different frameworks, such as Try Toun (2009) and Yusuf and Francisco's (2010) EEPSEA's study. From these studies, it can be concluded that Cambodia is exposed to climate variability and that even with low degree of exposure; rural communities are highly vulnerable to changes in climate due to low adaptive capacity.

Fig. 1 shows the production lost due to flood and drought between 1984 and 2011. During the 1990s, droughts were more common than floods and occurred with very high severity, except for in 1996 when both disasters hit Cambodia at the same time during growing seasons. During the 2000s, the both floods and drought occurred every year, with the highest concentration of disasters occurring in the middle of the decade.

There was flooding in Cambodia every year between 1998 and 2011, with the most severe floods occurring in the 2000-01 growing season, based on the average level of flooding in Cambodia as recorded over the last 70 years (the 2011 flood is not included for the comparison due to lack of literature). The 2000-01 floods caused extensive damage to many social infrastructure systems, properties and agricultural plantations and during the wet season affected both people and animals in 22 provinces.

The Kampong Speu (KPS) province is the second priority project implementation in the National Adaptation Program of Action to Climate Change (NAPA) of Cambodia. The NAPA priority for adaptation is consistent with the finding of EEPSEA vulnerability mapping study, which identified that Kampong Speu is the third most vulnerable province of the 17 provinces in Cambodia. As mentioned earlier, KPS has a high incidence of poverty, and experienced drought more often and intensively than other provinces in Cambodia.

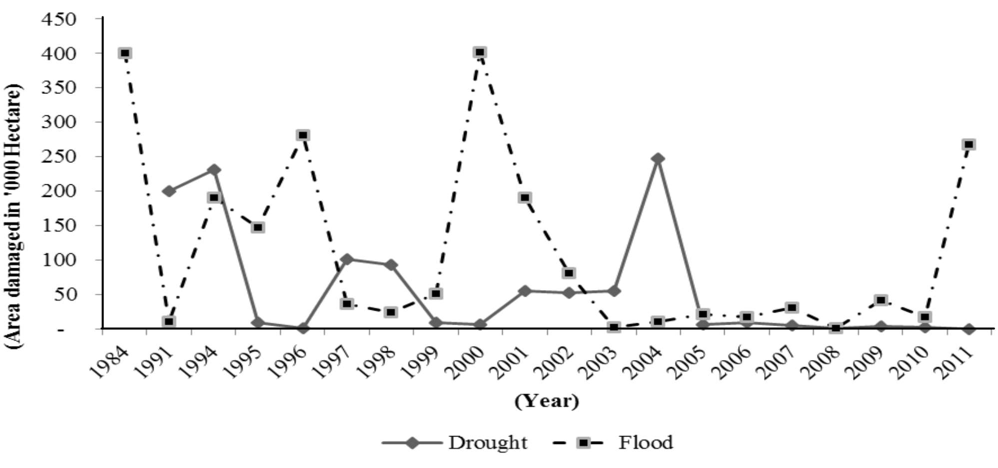

Fig. 1 Distribution of paddy rice destroyed by flood and drought in Cambodia, 1984-2011

Kampong Speu is about 40 km to the west of Phnom Penh. The province is comprised of 8 districts. The total population of the province is 716,944, of which 368,432 are female. Similar to other provinces in Cambodia, the economy of this province is agriculture-dominant and primarily involved in rice production. The total paddy rice area of this province in 2007 was 78,000 ha, which accounted for 3.81% of the total paddy rice in Cambodia. KPS produces 245,000 tons of rice annually, approximately 4% of the county's total rice production.

Data gathering

The household survey samples were selected from 6 communes in 6 districts within two geographical areas: highland areas (2 districts/communes: Phnom Sruch/Morhasang, Oral/Tasal) and lowland areas (4 districts/communes: Chbar Mon/Chbarmon, Oudong/Peng Lavea, Bor Sedth/Kork, Somrong Tong/Rolang Chork). A total of 600 questionnaires were collected of which 200 from highland and 400 from lowland. The occurrence of natural hazards, including flash flooding, drought and windstorm, were recorded based on yes/no questions. Other variables that contributed to the index calculation were collected based on Table 1, 2 and 4.

METHODOLOGIES

Composite indicators involve two steps. First, it involves in normalizing of each indicator based on Eq. (1) and then, aggregating the indicators into one index as in Eq. (2).

The normalizing procedure is based on Eq. (1).

$$Ii = (xi - x\min)/(x\max - x\min) \tag{1}$$

Where I_i is the normalized value of indicator i, x is the original value for indicator for individual household, and x_{max} and x_{min} are the highest and lowest values of the indicator.

In order to aggregate the indicators (as in Eq. 2), weighting among the indicators is employed. The weights are obtained from focus group discussion, expert judgment and key informant interview from the study site. This is to reduce subjectivity*. It is very important to quantify vulnerability according to the different weights for each indicator and dimensions. The consensus method was used to gather the weight of different determinants and indicators. Eight Focus Group Discussions (FGDs) were conducted with participants from a range of backgrounds at the provincial, district and commune levels in order to come up with different weights. Weights were then averaged among all FGDs and levels.

$$Dj = \sum_{i=1}^{n} IiWi \tag{2}$$

Where D_j is the aggregate value from the product of normalized value of indicator, j is the name of index, n is the number of indicators within a particular index and I_i and W_i are the normalized value of indicator and weight of each indicator respectively.

Exposure Index (EI)

Table 1 Example of Exposure Index calculation

HH No.	Number of hazard events			Normalized Value (index)			Hazard Index
	Drought	Flood	Windstorm	Drought	Flood	Windstorm	
1	10	3	0	1.00	0.75	0.00	0.77
2	5	0	1	0.50	0.00	0.33	0.31
3	2	2	0	0.20	0.50	0.00	0.27
4	3	1	2	0.30	0.25	0.67	0.34
5	0	4	0	0.00	1.00	0.00	0.33
6	1	0	3	0.10	0.00	1.00	0.22

Exposure index in this study is composed of three hazards indicators: flash flooding, drought and windstorms. Based on social perception of hazard, we recorded number of events that household

* In our study site, the weights are 0.53, 0.32, and 0.15 for drought, flash flood, and windstorm respectively.

experienced. For example, within 1990-2010 one household may experience 10 drought events, 3 flash floods and 1 windstorm. Different localities of household experienced differently (Table 1). Each hazard event, such drought, is normalized to get the value between 0 and 1.

Sensitivity index (SI)

Sensitivity of a household composed of four dimensions (with different weight) namely: human capital (0.23), livelihood (0.26), infrastructure (0.21), and financial capital (0.30). Meaning that sensitivity index is the aggregated value of the four dimensions after applying weight. Each dimension is measured by different indicator as in Table 2.

After normalizing the indicator based on (Eq.1), we aggregate the normalized value of indicators with weighting of each indicator by their own dimension (Table 3). We assume that the higher the weight, the more sensitive to natural hazard. For example, in human dimension, a household may experience more hardship if there are more children compared to other households.

Table 2 Sensitivity indicators and weight

Dimension	Indicator	Indicator Weight
Haman	Dependent ratio (S1)	0.55
	Number of family laborers working in agriculture (S2)	0.45
Livelihood	Percentage of annual income generated from agriculture (S3)	1.00
Infrastructure	Distance from household to a body of water (S6)	1.00
Financial	Percentage of debt in (S9)	1.00

Table 3 Example of Sensitivity Index calculation

HH No.	Indicator		Normalized Value (index)		Weight Value
	S1	S2	S1	S2	
1	25	2	0.31	0.25	0.28
2	20	2	0.17	0.25	0.20
3	14	5	0.00	1.00	0.45
4	33	2	0.53	0.25	0.40
5	16	1	0.06	0.00	0.03
6	50	2	1.00	0.25	0.66

Adaptive capacity index (ACI)

This index composed of five dimensions (with different weight) namely: infrastructure (0.19), economics (0.21), technology (0.20), social capital (0.18) and human capital (0.22). The adaptive capacity index is also based on the same principle as in sensitivity index. Each dimension has different indicator with different weight as in Table 4.

Vulnerability index

Vulnerability assessment is based on Eq. 3. For a comprehensive discussion of the Indexes Approach, see 'Handbook on Constructing Composite Indicators: Methodology and User Guide' jointly developed by OECD and JRC European Commission (OECD, 2008). The example related to this approach can be found in Yusuf and Francisco (2010) and International Crop Research Institute for the Semi-Arid Tropics (2009).

The Vulnerability Index (*VI*) is based on three-dimensional indexes (see the definition above) including exposure index, sensitivity index, and adaptive capacity index. The *VI*'s formula is shown in Eq. (3).

$$VI = \left(EI + SI + (1 - ACI)/3\right) \tag{3}$$

Before aggregating vulnerability index (VI), there is a manipulation of adaptive capacity index (ACI) by *'1 – ACI'* so that the direction of ACI is the same as exposure and sensitivity index, meaning that for EI and SI the higher the value, the higher vulnerability while the higher the ACI, the low vulnerability. So, the manipulation of ACI will keep ACI value the same direction as EI and SI.

Table 4 Adaptive capacity and their weight

Dimension	Indicator	Indicator Weight
Infrastructure	Percentage of irrigated agricultural land of household	1.00
Economic	Income per head	0.31
	Amount of remittance per year	0.31
	Percentage of income generated from non-agriculture	0.38
Technology	Number of TVs and radios	0.30
	Number of line phones and cell phones	0.30
	Number of motorcycles	0.40
Social capital	Amount of money that can be borrowed from relatives and/or friends in case of disaster	0.10
Human	Number of laborers	0.53
	Level of education	0.47

RESULTS AND DISCUSSION

Hazard exposure

Almost every household in the sample (574 out of 600 cases) reported that they were impacted by drought at least once between 1999 and 2010. During this 12-year period, 20% of households experienced drought once every two years. Flash floods and windstorms were very rare and, out of 600 cases, 540 were not impacted by flash floods and 558 by windstorms at all during the study period. Compared to flash flooding and windstorms, drought is the major thread to rural households.

Table 5 shows the number of occurrence of natural hazards (windstorms, flash floods and drought) reported by households from 1999 to 2011. It can be inferred from the data that windstorms occurred with a low frequency and had a greater effect on lowland communities more than highland communities. Based on the FGD data, highland residents reported that windstorms are not a major concern and only 6% of both highland and lowland respondents reported experiencing windstorms over the last 12 years.

Table 5 Hazard events experienced by respondents in KPS, 1999-2010

Class	Highland			Lowland		
	Drought	Flash flood	Windstorm	Drought	Flash flood	Windstorm
0-1	58	192	198	107	378	393
2-3	79	8	2	160	20	7
4-5	23	0	0	54	1	0
6-7	10	0	0	7	1	0
8-9	0	0	0	6	0	0
10-12	30	0	0	66	0	0

Sensitivity

Figure 2 shows the comparison of the means of the four determinants of the sensitivity index and meaning that the higher the value, the more sensitive to natural hazards. Horizontal axis is the sensitivity dimensions that will be composited into sensitivity index and vertical axis is the mean value of weighted of each dimension from highland and lowland. The livelihood determinant had the highest mean value at 0.684, followed by human at 0.396. The other determinants were negligible. This implies that the livelihood of households is highly sensitive to the changes caused by climatic events and that the ratio of dependency is also high.

The mean value of human sensitivity in the lowland area (N=400) was 0.26 compared to the highland area (N=200) at 0.29 with the standard deviations of each commune at 0.10 and 0.01 respectively. The independent samples test found that the group means of sensitivity index of highland community are significantly different as the value in the p-value at 0.001 (less than 0.05). Therefore it can be concluded that the highland area is more sensitive to climate change impacts than the lowland area. This is due to either highland households are highly depending on agriculture.

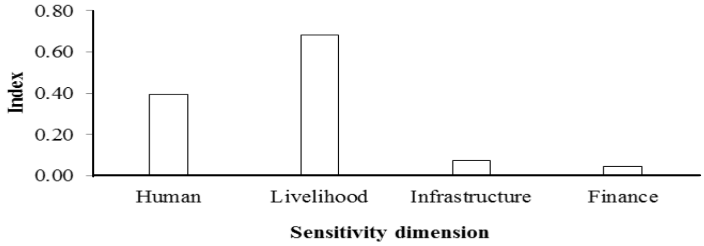

Fig. 2 Comparison of sensitive indicators to climate change in the KPS province

Adaptive Capacity

Fig. 3 compares adaptive capacity dimensions which finally be composed into adaptive capacity index. The values on top of the bar are the mean of the dimension, meaning that the higher the value, the higher adaptive capacity. The graph illustrates that the human component of adaptive capacity is twice as significant as the other components (infrastructure, economics and technology). It can be interpreted that labor is the best way to handle shock. Other factors, such as the level of social capital, play an insignificant role compared to other determinants.

By disaggregating adaptive capacity index (ACI) into highland (N=200) and lowland (N=400), the means of ACI of lowland and highland commune are at 0.77 and 0.83 with the standard deviations of 0.11 and 0.09 respectively. The independent samples test shows that the group means of the lowland and highland are significantly different as the p-value is 0.00 (less than 0.05). Based on this statistics, we can conclude that highland community is statically lower than lowland communes.

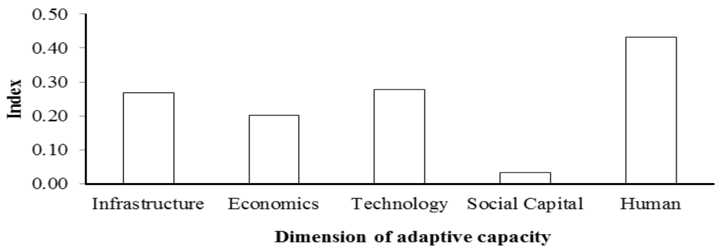

Fig. 3 Comparison of adaptive capacity of household in the KPS province

Vulnerability assessment

Figure 4 also presents the index of hazard, sensitivity, adaptive capacity by disaggregating the index value into topographical areas (highland and lowland) based on household data. Both areas experienced hazards to a similar degree. Given the index value of hazards is low, the main hazard is drought, which is considered the most serious hazard among the three hazards studied in this paper (drought, windstorms and flash floods).

There is a slightly variation between highland and lowland areas in term of adaptive capacity index value. However, it is concluded that the highland area is more vulnerable than the lowland area because of a lower adaptive capacity and higher sensitivity to climate stimuli. It is worth noticing here that livelihood of households who are heavily depending on paddy rice is more vulnerable than those with raising livestock and having engaging in non-agricultural activities.

Fig. 5 shows a comparison of households with the vulnerability index categorized into low and high vulnerability. The graph shows that 43% of households are in the medium vulnerability category with 19% and 7% in the high and very high vulnerable categories respectively. By lumpsumming these three categories it was found that there are 67% of household in the KPS province that are potentially impacted by hazards, while the rest are in the low vulnerability category.

From a qualitative point of view, natural disasters, particularly drought, have resulted in insecurity amongst communities. Due to losses in rice production, some people turn to theft in order to support their families. The FGDs disclosed this had happened in the Prekdey village (Rolang Chork commune, Somrong Tong district). FGDs in the Chrok Trach village (Morha Sang commune, Phnom Srouch district) confirmed that some families were in hardship because of the drought and did not have enough money for their children go to school. Some families, often the ones who had suffered the most difficulties and who experienced serious damage to rice production from drought, had decided to sell their properties and migrate other places, especially to Phnom Penh. Moreover, the FGD in the Krang Troak village (Kok commune, Borsedth district) reported that some families experienced increased domestic violence between husbands and wives which was attributed to stresses caused by drought that damaged their rice production.

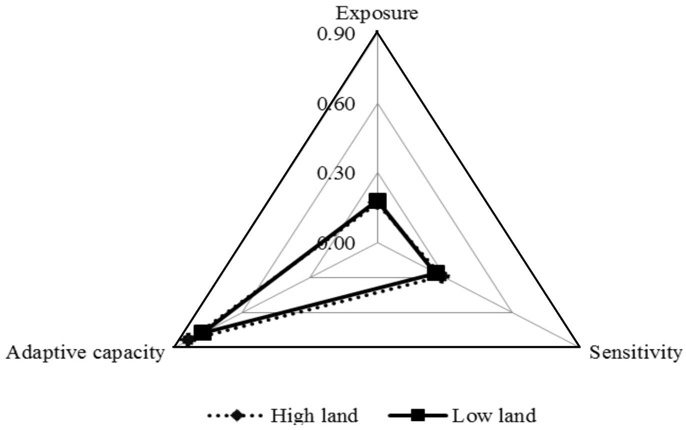

Fig. 4 Vulnerability comparison of high and lowland households of the KPS province (1999-2010)

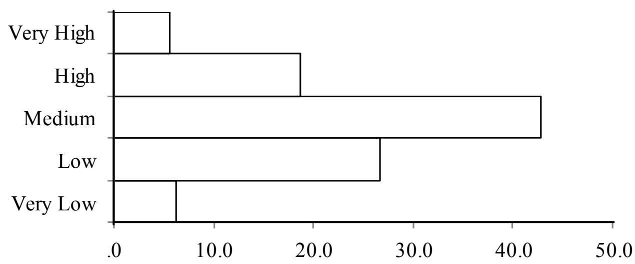

Fig. 5 Vulnerability Index by Households

Adaptation identification

In this study, the practices of adapting to drought were determined through a household survey, FGDs and expert recommendations. Some farmers stated they did not employ any adaptive practices, while others protected their paddy rice from drought impacts by pumping water from nearby water bodies such as ponds or wells and/or changing to drought-resistant practices (for example by planting a short-duration rice variety). Some farmers also increased the amount of fertilizer they used in order to maximize their yield, especially during years when drought occurred.

The key informant interviews also found that participants believed that modern crop varieties should be and in some cases have been introduced to areas which experience frequent and/or severe drought. This is one of the primary interventions of the Department of Agriculture at the provincial level through their line authorities. While establishing a supplemental irrigation scheme is a long-term drought mitigation strategy, providing ad hoc water pumping to local community is a must during drought spells. The practice of water pumping has been used throughout Cambodia, especially in Kampong Speu province, with the assistance of the Department of Water Resources and Meteorology. Although it would involve many different government agencies, the next urgent drought mitigation intervention should be increasing farmers' knowledge about farming techniques including Systematic of Rice Intensification (SRI) and improving general education.

CONCLUSION

Cambodia is highly dependent on agriculture, therefore it is vulnerable to climate stimuli such as flood and drought. Every province in Cambodia is vulnerable to climate change to some degree, however some are more affected by flood and others by drought. This research found the Kampong Speu province is prone to drought, with many residents reporting they experienced drought impacts almost once every two years.

This empirical study reconfirmed that the present vulnerability of households in Kampong Speu is high due to high sensitivity, low adaptive capacity and low exposure factors, and the study identified that 67% of this province is in the medium to very high vulnerable range. People have adapted to drought, but their practices are not productive. Therefore, enhancing adaptive capacity is very critical, including promoting more drought-resistant crops, (perhaps, as suggested in the literature, on a small scale) implementing an irrigation scheme, and improved knowledge about how to use farming techniques to mitigate drought.

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