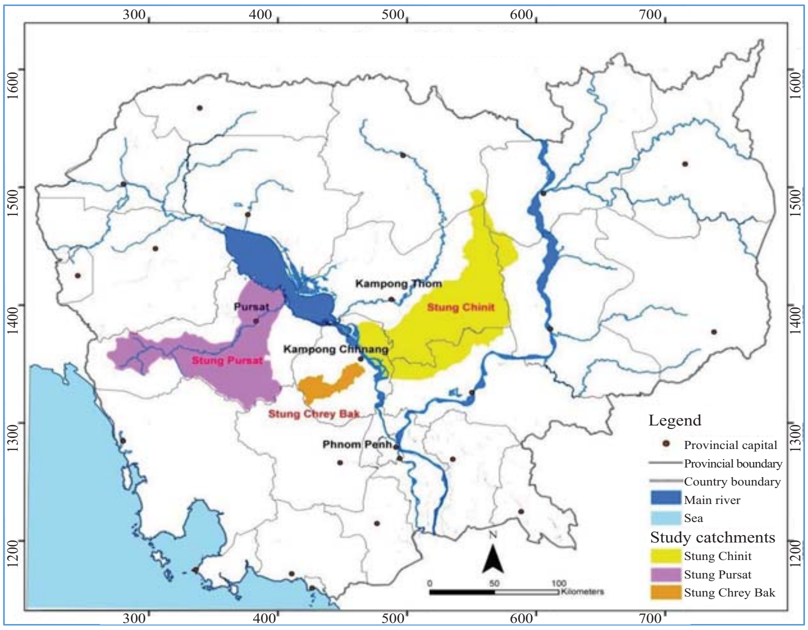
Exploring Climate Change Vulnerability and Adaptation in the Tonle Sap: A Tale of Three Catchments

Background

The Tonle Sap Basin is undergoing accelerating and significant hydrological change, as confirmed by the AusAID-funded "Exploring Tonle Sap Futures" study (Keskinen et al. 2011). The study demonstrates that changes in the Tonle Sap flood pulse and water regime over the next 30 years are more likely to be caused by infrastructure developments than by climate change. However, climate change will compound this situation and add further uncertainty to the future of water in the Basin. Unless issues related to water security and climate resilience are adequately addressed, it will become increasingly difficult to sustain food and energy security, ecosytem services and poverty reduction. Effective strategies and action plans to deal with these challenges will require both accurate and reliable water resources assessment (MOE 2013) and ongoing qualitative vulnerability assessment.

Figure 1: Location of study sites



Source: Chem and Kim 2013

Assessment reports on vulnerability to climate change in the Tonle Sap Basin exist; however, the absence of location-specific vulnerability assessments is one of the biggest failings hampering risk management and adaptation resilience at local level. Lack of specificity means that adaptation responses might be insufficient to mitigate or to keep pace with climate change.

In response, the central part of a three-year program of participatory action research, aiming to increase community adaptive capacity, deliver evidence-based decision making and promote adaptive governance that serves local priorities (Sam and Pech 2015), was assessment of local vulnerability to climate in three of the Tonle Sap's most at-risk catchments: Stung Chinit, Stung Pursat and Stung Chrey Bak (Sam et al. 2015) (Figure 1). Specifically, the assessment looked at (1) how climate change affects the vulnerability of men and women differently, and (2) how these vulnerabilities vary across topography (upstream and downstream areas).

This article summarises the main findings of that vulnerability assessment. Before setting out the results, we define some important terms and briefly describe the research design, data collection and data analysis. Then we present the key findings, first the indices for each component of vulnerability followed by the overall vulnerability index. The final section concludes and offers suggestions for further study.

Some key terms defined

Exposure is "the nature and degree to which a system is exposed to significant climatic variations" (IPCC 2001, 987).

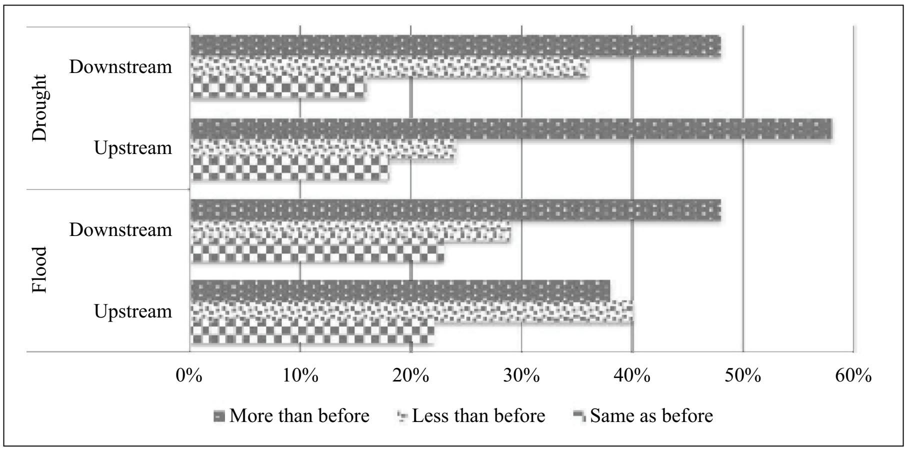
Sensitivity is "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli" (IPCC 2001, 993).

This article was prepared by Sam Sreymom, head of Environment Unit, CDRI. Full citation: Sam Sreymom. 2016. "Exploring Climate Change Vulnerability and Adaptation in the Tonle Sap: A Tale of Three Catchments." *Cambodia Development Review* 19(4): 5-12.

Adaptive capacity is "the combination of the strengths, attributes and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities" (IPCC 2012, 556).

Vulnerability is "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC 2007, 883).

Figure 2: Local perceptions of changes in flood and drought frequency in the last 10 years



Source: Field survey 2014

Research design

The study used a mixed quantitative-qualitative participatory approach which included a two-stage survey of 907 and 900 households involving 191 and 180 female-headed households, respectively, 18 focus group discussions, three provincial workshops, a provincial and a national validation workshop. To get an overview of the local situation and context, collected data on access to disaster information, emergency prepardeness, perceived risks and vulnerabilities was validated against secondary data on risk information, water and food security, poverty reduction and sustainable livelihoods.

Following Piya et al. (2012), we used descriptive and inferential statistics to analyse the three elements of vulnerabilty (exposure, sensitivity and adaptive capacity) and produce a vulnerability index. Indices for all three elements were calculated using principal component analysis. This is done by normalising the values of each indicator and subtracting the mean from the observed values divided by the standard deviation. The normalised variables are then multiplied with the assigned weights to construct the indices for exposure, sensitivity and adaptive capacity (Piya et al. 2012). Then the household vulnerability index is estimated as:

$$\text{vulnerability} = \text{exposure} + \text{sensitivity} - \text{adaptive capacity}$$

The overall vulnerability index simplifies interhousehold comparison within the study areas. A high vulnerability index value indicates high vulnerability, but this does not mean that a negative index value indicates that the household is not vulnerable at all. These index values allow a comparative ranking of the sample households. Analysis of variance (ANOVA) was carried out to compare mean values across the study areas and between female and male-headed households.

Key findings

Exposure

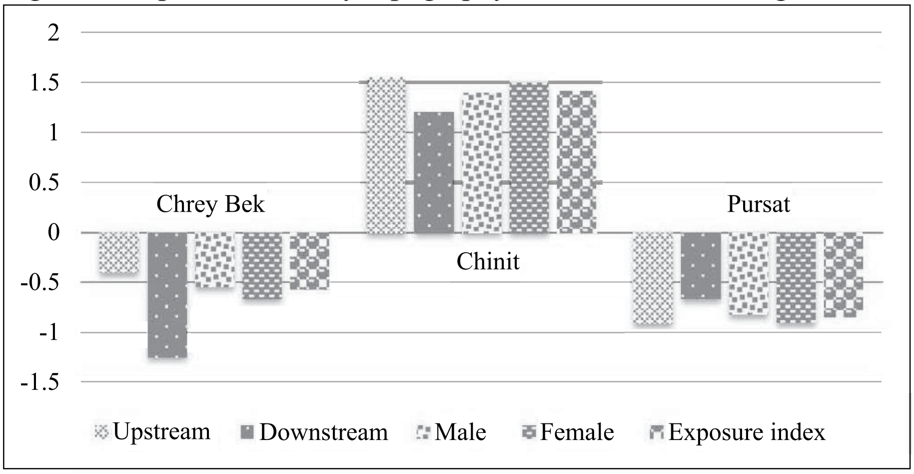
Local people reported suffering more damage from drought than from flood; overall, around half of them observed that floods (41 percent) and drought (55 percent) have become more frequent in the last 10 years (Figure 2). The results show variation between upstream and downstream effects. Rapid flooding events (mountain or flash floods) were thought to be occurring more often by 48 percent of downstream and 38 percent of upstream respondents, whereas 40 percent of

Table 1: Weights and average natural disaster frequency in the last 50 years

Natural disasters	Weight	Chrey Bak	Chinit	Pursat
Flood	0.42	4.50	5.33	4.67
Drought	-0.46	4.50	0.67	2.00
Thunderstorm	0.78	3.00	5.67	0.00

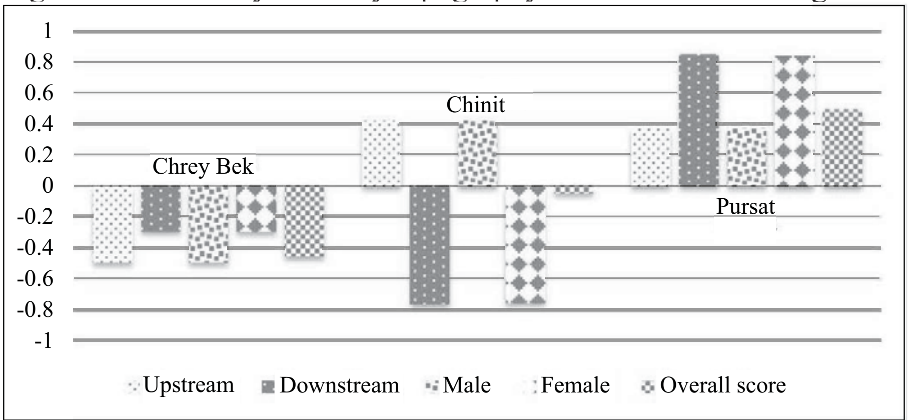
Note: Weight is the relative importance of a given variable on a scale of -1 to +1 (from least to most important).
Source: Data collected from provincial workshops in Kompong Chhnang, Kompong Thom and Pursat, 2014

Figure 3: Exposure index by topography and household head gender



Note: The higher the score, the higher the level of exposure to disaster risk
Source: Field survey 2014

Figure 4: Sensitivity index by topography and household head gender



Note: the higher the score, the higher the sensitivity to climate conditions
Source: Field survey 2015

upstream respondents felt that floods have been less frequent. Drought frequency was considered high: the perception of 58 percent of upstream and 48 percent of downstream respondents was that drought had become more common.

An exposure index, calculated based on the number of reported natural disasters, reveals that thunderstorm hazards pose the highest risk, followed by flooding and drought (Table 1). Among the three catchments, Stung Chinit experienced the most natural disasters, though drought is not a big problem there as the area is served by a modern storage reservoir and irrigation structures.

As seen in Figure 3, among the three catchments, inhabitants in Chinit have the highest level of exposure to disaster risk. In terms of topography, upstream dwellers in Chinit and Chrey Bak are more exposed to climate risk than their downstream counterparts, whereas the opposite is true in Pursat.

By gender, in both Pursat and Chrey Bak catchments, male-headed households are more exposed to climate risks than female-headed households; the opposite holds in Chinit.

Sensitivity

Overall, among the sensitivity indicators shown in Table 2, the share of natural resource income (from farming, fishing and forestry) in total household income contributes the most to climate risk. In contrast, wages from non-resource livelihood opportunities reduce dependence on climate-sensitive activities. The second biggest contributing factor to climate sensitivity is the land area affected, followed by the crop area affected.

Across the three catchments, people in Pursat have the greatest overall sensitivity to climate conditions, while the biggest difference in sensitivity rating is related to topography in Chinit (Figure 4). Upstream dwellers in Chinit are more reliant on resource-based livelihoods than those downstream and therefore have a higher level of sensitivity. In terms of gender, female-headed households in Chrey Bak and Pursat have higher levels of livelihood sensitivity than their male counterparts because they had lost larger areas of crops to disasters. The reverse situation is true in Chinit, where male-headed households depend more on resource-based income than female-headed households and are therefore more sensitive to climate hazards.

In addition to the indicators in Table 2, the sensitivity index also takes into account water availability and supply. Rainwater and groundwater are the main sources of water for domestic use. In the wet season, about 40 percent of households use rainwater (2 percent in the dry season), 23 percent (36 percent in the dry season) draw water from dug wells and 18 percent (29 percent in the dry season) from tube wells. Few households (1.5 percent in the

Table 2: Mean values and weights for sensitivity indicators in the last 10 years

Indicators	Weight	Aggregate	Chrey Bak	Chinit	Pursat
Fatalities	-0.01	0.012	0.01	0.01	0.03
Land affected	0.20	1.09	0.45	1.14	1.68
Livestock affected	0.03	3.33	2.79	4.24	2.97
Crop area affected	0.10	0.76	0.68	0.69	0.90
% of resource income	0.69	46.14	36.41	44.94	57.07
% of non resource wages	-0.69	53.86	63.59	55.06	42.93

Note: Weight is the relative importance of a given variable on a scale of -1 to +1 (from least to most important).
Source: Field survey 2015

wet season and 2.4 percent in the dry season) are able to connect to a piped supply. Almost two-fifths (38.7 percent) of all survey respondents face water shortages for domestic use, and either bought water or paid to have it transported to their homes. Of those, 107 spent up to 10,000 riels/month on water in the dry season, 55 of whom also spent a similar amount on water in the wet season.

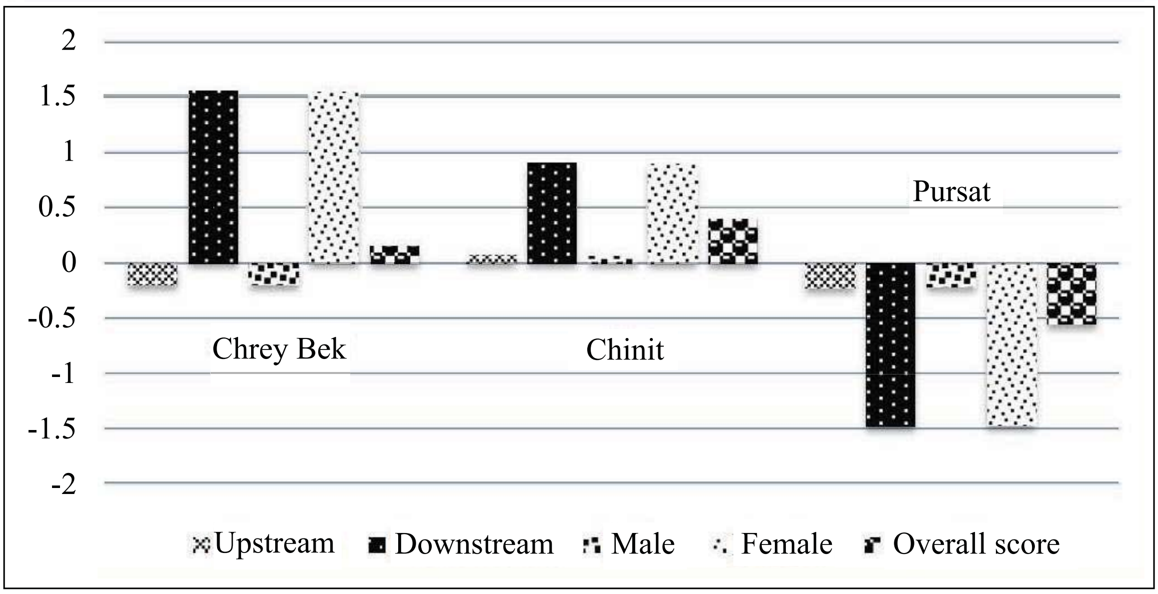
Farmers use different sources of water supply depending on the season. In the wet season 71 percent of farmers rely on direct rainfall to water their crops, nearly 16 percent get water from a natural stream and almost 9 percent use water from an irrigation canal. In the dry season, the largest number of farmers, nearly 35 percent, divert water from rivers to water their fields, about 24 percent take water from an irrigation canal, and about 19 percent use pond and lake water. Eighty-one percent of respondents said that the main water stress affecting their farming is either too much and/or too little water. The remaining 19 percent had no problems with water supply: 15 percent of downstream and 21 percent of upstream respondents reported having enough water to meet their needs.

Adaptive capacity

Adaptive capacity, whether to climate change, disasters or other shocks, is taken as the function of the ownership or availability of five types of livelihood assets: physical, financial, natural, human and social. Of these, in the study areas, the enhancement of adaptive capacity is most heavily influenced by human assets (Table 3), particularly education level rather than training, whereas the dependency ratio decreases adaptive capacity. Next are physical assets, of which a disaster-proof house contributes the most to better adaptive capacity, closely followed by mobile phone and radio by which people receive disaster alerts and information; land with a water supply is the least influential indicator in this category. Of the five livelihood assets, adaptive capacity improvement is least influenced by ownership or access to natural assets.

Among the three catchments, as Figure 5 shows, people in Chinit have the highest overall adaptive

Figure 5: Adaptive capacity index by topography and household head gender



Note: The higher the score, the higher the adaptive capacity.
Source: Field survey 2015

Table 3: Adaptive capacity index

Livelihood asset	Aggregate Index	Component indicator	
		Description	Subindex
Physical	0.55	Disaster-proof house	0.42
		Mobile phone and radio	0.39
		Land with water supply	0.21
Human	0.59	Education level	0.47
		Dependency ratio*	-0.03
		Training	0.28
Natural	0.07	Lowly fertile land	-0.12
		Natural water source supply	0.04
Financial	0.51	Household annual income	0.39
		Livestock standard unit	0.33
		Savings	0.022
Social	0.27	Membership in community-based organisation	0.10
		Access to credit	0.18

Note: Adaptive capacity is rated on a scale of -1 to +1 (from the least to the most influential); * calculated by subtracting the number of adults from the total number of family members.

capacity; this is largely due to their higher gross household incomes. Downstream dwellers in Chrey Bak and Chinit catchments have higher adaptive capacity than upstream dwellers because they own more of all five assets. The opposite is true for Pursat catchment, where people living in upstream areas own more physical, natural, financial and social assets and therefore have a higher adaptive capacity than people living downstream. In each study catchment, the differences between the adaptive capacities of upstream and downstream communities are statistically significant at the 1 and 5 percent levels.

Female-headed households in Chrey Bak and Chinit have higher adaptive capacities than male-headed households, though this result is not statistically significant. In Pursat on the other hand, male-headed households can access more resources and therefore have a higher adaptive capacity than female-headed households; the difference is statistically significant at the 5 percent level.

Disaster and severe weather warnings, and emergency preparedness, play important roles in enhancing adaptive capacity. One-fourth of all respondents said they had received flood, storm or drought warnings: radio was the main source of information for the majority (56.23 percent), followed by television (50.06 percent), word of mouth (39.14 percent) and local authorities (8.71 percent). As seen in Figure 6, around half of the respondents said they had not done anything to prepare for a major natural disaster, and only some 20 percent maintained an emergency food supply.

Figure 6: Preparation for disaster

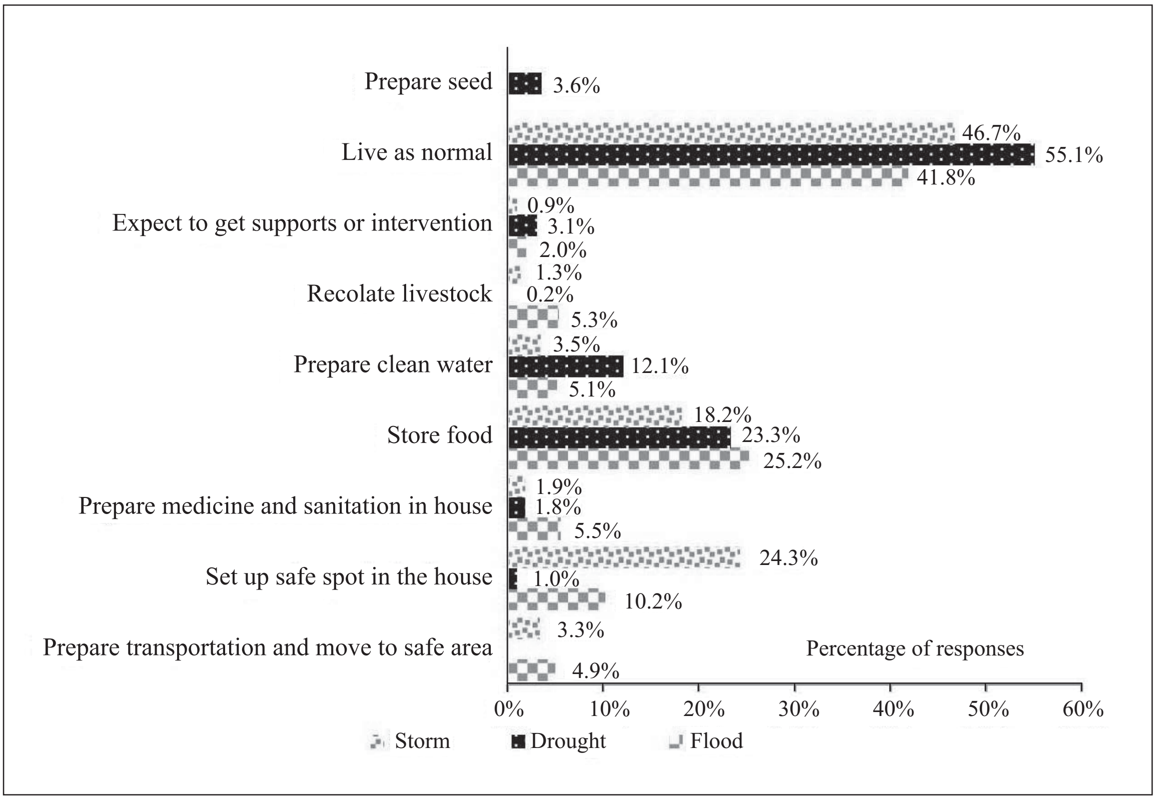


Table 4: Ranking of alternatives if current livelihoods are destroyed by disaster (%)

Livelihood source	1st	2nd	3rd
Shift to another natural resource activity	4.99	0.00	4.00
Shift to livestock cultivation	5.49	1.28	4.00
Shift to farming	1.37	1.28	0.00
Seek employment locally	12.97	10.26	0.00
Migrate to find work	6.73	15.38	8.00
Start own business	3.49	9.62	8.00
Borrow money/food from others	4.74	**37.82**	24.00
Depend on help from others	2.24	9.62	**44.00**
Not sure	**40.40**	5.13	0.00
Other	17.58	9.62	8.00
	100	100	100

Similarly, few respondents had tried different farming practices or crops to build resilience to weather variability or climate change. Owing to habit and water-related constraints, 93 percent of rice and crop farmers were growing the same crop varieties using the traditional cropping calendar. Many of those who had not changed their crops despite flood and drought damage said they did not have the expertise to select and grow different crops nor enough information about the crop varieties that can improve their resilience.

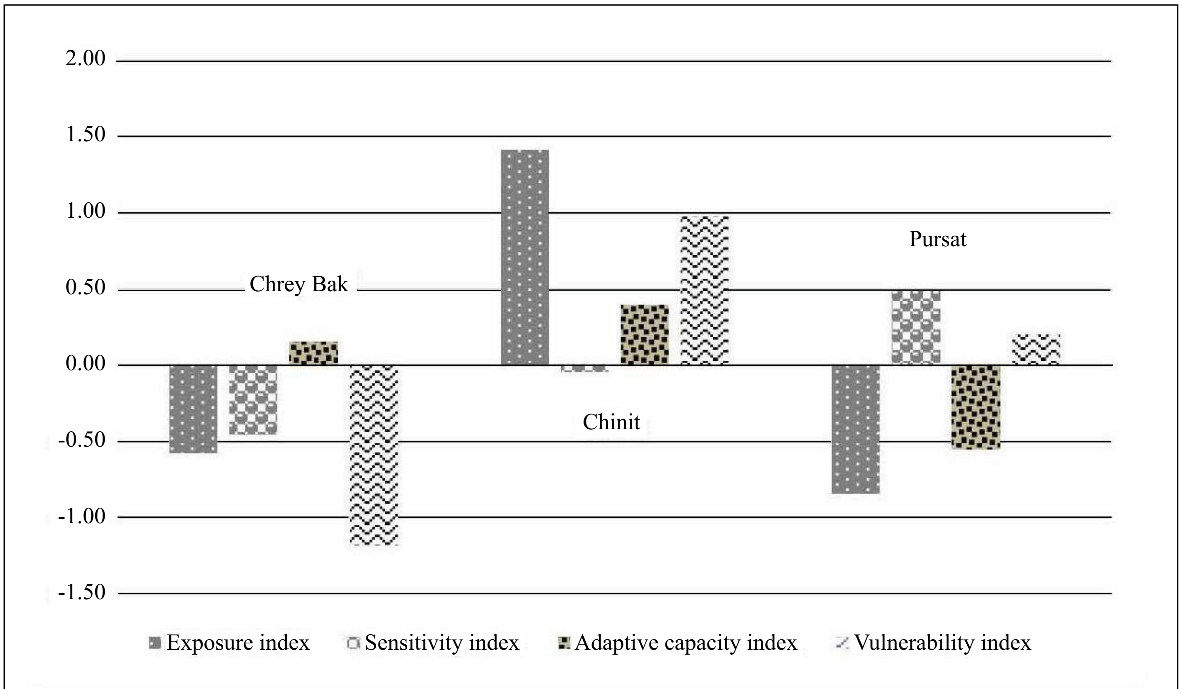
Another element of adaptive capacity concerns people's coping strategies when disaster has destroyed their livelihoods. Respondents ranked "not sure what to do" as their first option, followed by "borrowing money" and "depending on help from others" (Table 4). The continued dependence on climate-sensitive natural resources suggests a lack of self-help or self-reliance. It can be therefore be inferred that local people have no alternative livelihoods at all, thus contributing to their high level of vulnerability.

Vulnerability

The calculation of a vulnerability index reveals that, overall, Chinit catchment is the most vulnerable and Chrey Bak the least vulnerable (Figure 7). This result is statistically significant at the 1 percent level. The vulnerability index, however, does not take into account predicted future impacts of climate change. Although Chinit has the highest adaptive capacity score, when the scores for the three components are combined, it turns out to be the most vulnerable.

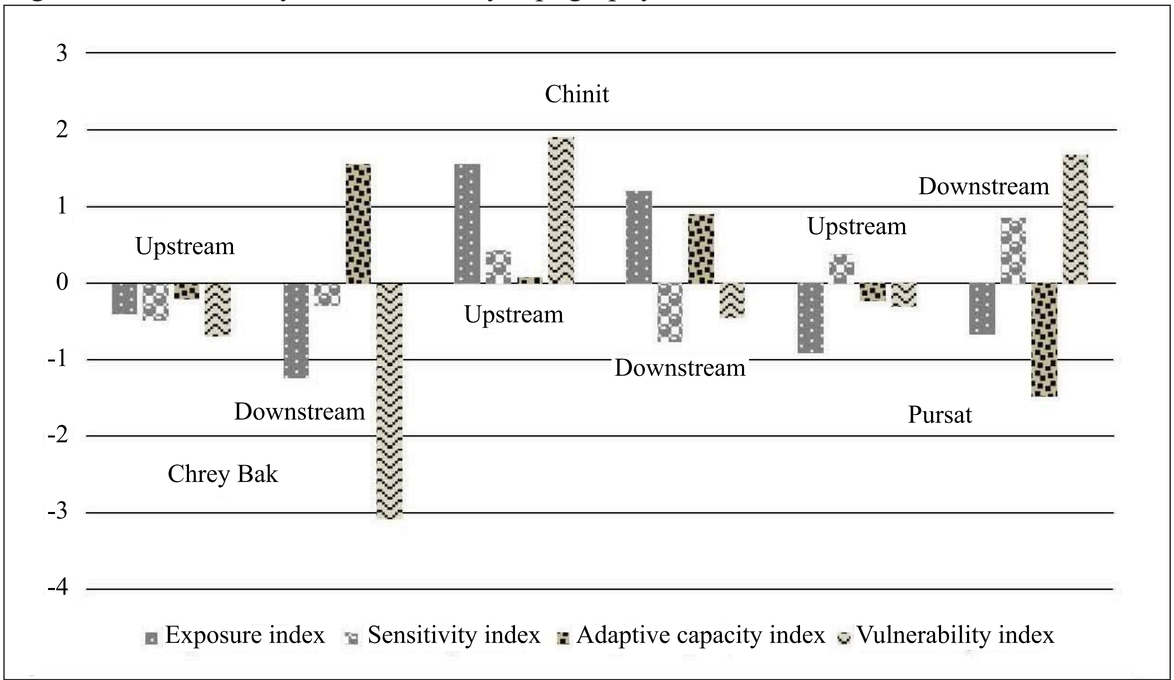
Vulnerability levels differ significantly between upstream and downstream areas in the three catchments. In Chrey Bak, upstream dwellers are more vulnerable than those downstream

Figure 7: Vulnerability index scores



Note: The results are statistically significant at the 1 percent level.

Figure 8: Vulnerability index scores by topography



Note: The results are statistically significant at the 1 and 5 percent level.

(Figure 8). Although the level of exposure is lower upstream, low adaptive capacity creates higher vulnerability. This result is statistically significant at the 1 percent level. A similar result is found for Chinit catchment, where, due to high exposure and sensitivity, communities in upstream areas are also more vulnerable than those downstream. The opposite holds for Pursat catchment, however; because of high sensitivity, downstream reaches are more vulnerable than upstream parts. This result is also statistically significant at the 1 percent level.

Regarding differences in vulnerability related to household head gender in the three catchments, the results show that female-headed households in Chrey Bak and Chinit, due to their slightly higher adaptive capacity, are less vulnerable than male-headed households. However, these results are not statistically significant.

Conclusion and further research

This participatory assessment of climate change vulnerability in Stung Chrey Bak, Stung Pursat and Stung Chinit finds that local people in the three catchments have low to moderate adaptive capacity, high sensitivity to water availability for domestic use and farming, and high exposure to frequent thunderstorms, flooding and drought. It can therefore be concluded that communities in the three catchments are highly vulnerable to the impacts of climate change.

Efforts to build adaptive capacity should pay greater attention to natural and social assets, which have so far been largely neglected in the field of disaster management. Social assets including access to credit, saving groups, seed banks, local networks and community-based organisations should be built up and expanded.

Adaptation and disaster preparedness measures have been slow to operationalise, to the point that the motivating effects of even extreme weather events quickly fade. This emphasises the urgent need to equip rural households with the knowledge, skills and means required to undertake adaptation and mitigation responses. At the same time, the need for early warning alerts and disaster information could readily be met through mobile phone messaging which is a fast and economically feasible way to reach the most people.

Upstream dwellers in Chinit and Chrey Bak catchments are more vulnerable than those downstream. Frequent droughts and flash floods combined with low adaptive capacity heighten vulnerability in upstream areas, and downstream reaches are susceptible to river and flash floods and dry-season drought. However, people living downstream, especially near the Tonle Sap Lake, have adapted better to climatic stress. Regardless of location, without much expansion in alternative livelihood options, improving household adaptive capacity is beyond the means of most households. Thus more attention must be paid to initiatives that can support crop diversification, sustainable productivity increases such as in integrated rice-fish/duck systems, growing vegetables as cash crops, and local off-farm job creation.

An interesting, though non-significant, finding is that female-headed households in Chrey Bak and Chinit catchments, due to their slightly higher adaptive capacity, are less vulnerable than male-headed households. Given that uncertainty about the intensity of climate change is high, efforts must focus on improving overall adaptive capacity. Even so, the survey results highlight the importance of investing in women and encouraging women's greater participation in decision making as an essential element of climate change response. This can be achieved through the provision of social, emotional, financial and technical support, not only from government agencies and NGOs but also from their own communities and local networks. The results highlight that special attention should be paid to the situation of female-headed households in Pursat catchment.

This study serves as a baseline for assessing the vulnerability of local people to climate impacts and disaster risks. A follow-up study in the same locations using the same sample size would complement and consolidate the study findings. The resulting panel data would broaden understanding of household and community vulnerabilities and their potential resilience capacities. Future vulnerability and adaptation assessments should use simple but tangible indicators so that the multidimensional aspects of vulnerability are measured in a comprehensive and robust way.

References

Chem Phalla and Kim Sour. 2013. "Climate Change and Water Governance in Cambodia." PowerPoint presentation at IDRC Asia Regional Partners meeting, Kathmandu, Nepal, 19-20 June.

IPCC (Intergovernmental Panel on Climate Change). 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability". Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge; New York: Cambridge University Press.

IPCC. 2007. *Climate Change 2007: Impacts, Adaptation and Vulnerability". Contribution of Working Group II to the Fourth Assessment Report* of *the Intergovernmental Panel on Climate Change*. Cambridge: University Press.

IPCC. 2012. Annex II: Glossary of Terms." In *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change*, edited by C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen,M. Tignor and P.M. Midgley, 555-564. Cambridge; New York: Cambridge University Press.

Keskinen, Marko, Matti Kummu, Aura Salmivaara, Someth Paradis and Hannu Lauri. 2011. *Exploring Tonle Sap Futures Study*. Aalto University and 100Gen with Hatfield Consultants Partnership, VU University Amsterdam, EIA and Institute of Technology of Cambodia.

MOE (Ministry of Environment). 2013. "Synthesis Report on Vulnerability and Adaptation Assessment for Key Sectors Including Strategic and Operational Recommendations." Phnom Penh: National Committee on Climate Change, MOE.

Piya, Luni, Keshav Lall Maharjan and Niraj Prakash Joshi. 2012. "Vulnerability of Rural Households to Climate Change and Extremes: Analysis of Chepang Households in the Mid-Hills of Nepal." Presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguacu, Brazil, 8-24 August.

Sam Sreymom, Kim Sour, Nong Monin and Sarom Molideth. 2015. "Vulnerbability Assessment in the Three Catchments." In *Climate Change and Water Governance in Cambodia: Challenges and Perspectives for Water Security and Climate Change in Selected Catchments,* edited by Sam Sreymom and Pech Sokhem, 56-88. Phnom Penh: CDRI.