COMMUNITY-BASED VULNERABILITY ASSESSMENT AND RISK MAPPING FOR ADAPTATION PLANNING IN TERAI ECO-ZONE, NEPAL

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ABSTRACT

Communities have already felt the impact of climate change on their livelihoods. Since the risk of increased negative impacts is high, communities need to understand the climate change patterns, the likely impacts and measures to mitigate the negative impacts. This study was undertaken to assess climate change vulnerability, assess the associated risk and map it, and use these information to prepare adaptation plan. It was found that communities can assess the climate change vulnerability, and map the associated risks. They can prepare their adaptation plan to mitigate the likely negative impacts, and access resources from the local government to implement their action plan. This study has recommended that the community based climate change vulnerability assessment and risk mapping for adaptation planning tools and methodologies developed by this piloting study should be used by the local governments in their regular planning process to address the climate change issues at the community level.

Key words: climate change, vulnerability, exposure, sensitivity, adaptation, risk

INTRODUCTION

It has been a realized fact that the global climate pattern has changed. Temperature in Nepal has increased in the range of 0.060C to 0.120C per year in the mountains and hills and by about 0.030C in the Siwalik and Terai regions in the period of 1971-94 (Shrestha et al, 1999). There has been 15 days overall decrease in the rainy days (Timisina, 2011) whereas more than 100 mm seasonal rainy days have increased (Sherpa, 2009). Warmer temperatures have increased the prevalence of vector-borne diseases such as malaria, Kala-azar, Japanese Encephalitis and water-borne diseases such as cholera and typhoid (Regmi et al, 2006). As a result, people's livelihood has been negatively impacted. The effect of climate change is relatively high on poor people as their capacity to respond to such effects is low. The changed pattern of climate has created a need to adjust livelihoods and development strategies. It needs both capacities of the local people and conducive policy environment. Communities need appropriate tools and methodologies for this purpose.

In order to support Government of Nepal (GON) to develop such tools and methodologies, Asian Development Bank (ADB) commissioned a detailed study. The study was carried out by a consortium of Centre for International Studies and Cooperation (CECI), Practical Action (PA), International Union for Conservation of Nature and Natural Resources (IUCN), World Wildlife Fund (WWF) and National VDC Association Nepal (NAVIN). CECI conducted the study in Terai eco-zone, PA conducted in lower foothill, WWF in mountain and IUCN in hill eco-zones. This paper is based on the study conducted by CECI in Dhanusha (representing Terai eco-zone) for piloting of the developed tools and methodologies.

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The objectives of this study were to:

- assess the vulnerability of the community to climate change, and
- assess risks due to climate change for the preparation of adaptation plan for the study community

METHODOLOGY

CONCEPTUAL FRAMEWORK

Vulnerability: Vulnerability in general is a situation of helplessness. It is defined in various forms as per the subject under consideration. It is defined as a likelihood of injury, death, loss, disruption of livelihood or other harm in an extreme event, and/or unusual difficulties in recovering from such effects (Wisner et al, 1994). Whereas ISDR (2004) has defined vulnerability as "a set of conditions and processes resulting from physical, social, economical, and environmental factors, which increase the susceptibility of a community to the impact of hazards". In a simpler term IPCC (2001) has defined vulnerability in the context of climate change as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Hence, 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. By following IPCC's definition, vulnerability in this study is measured as follows.

$$V = E \times S \times \frac{1}{A} \qquad (1)$$

where; **V** = Vulnerability, E = Exposure: is the nature and degree to which a system is exposed to significant climatic variations (TAR, IPCC). Exposure, in this study, is the character, magnitude and rate of climate variation at local level. Hence, the more the local climate has changed or deviated from its historical condition or trend, the more the value of exposure will be; the more the value of E means the more the system is exposed to a new climate leading to high vulnerability.

Exposure to climate change in this study was assessed over various parameters such as temperature, rainfall, hazards, proxy indicators (plants and animals), and physical changes over the last 30 years. Exposure was analysed at two levels – community level (focus group discussion) and household level (household survey). For each parameter, various indicators were considered

S = Sensitivity: is 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. damages caused by an increase in the frequency of flash floods, landslides, duration of drought, etc. Sensitivity in this study is the effect of local climate change and related hazards on local biophysical and socioeconomic systems. This means, a highly sensitive system therefore will be more impacted compared to low sensitive system even with a same level of climate change hazards. It indicates that more climate sensitive system is more vulnerable too.

A = Adaptive Capacity: is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences as indicated by IPCC (TAR). Adaptive capacity of a system helps the system to adjust to climate change and moderate the impacts of climate change. The more a community (system) is endowed with resources, has access to and control over resources, the more the community has the capacity to adjust to climate change and moderate the impacts of climate change. Community or individual resources are assessed through assessment of livelihood assets.

Risk: Risk is defined as the combination of the probability of an event and its negative consequences (MoEST, 2012). By following NHRA (2010) methodology, risk in this study was assessed as:

$$R = H \times D \times M \qquad (2)$$

where; 'R' is risk, 'H' is temporal probability of a hazard, 'D' is damageability (vulnerability) and 'M' is the value of element at risk.

ANALYTICAL FRAMEWORK

There were several parameters considered to analyse the determinants of vulnerability. On the basis of literature and consultation with the experts and related stakeholders (including technical workshops in the Ministry of Science, Technology and Environment (MoSTE)), this study considered the following parameters as presented in Table 1.

Table 1. Parameters and indicators used in assessing vulnerability components

Parameter	Indicators used
Exposure	
Temperature	Hot days/ summer season; cold days/ winter season
Precipitation	Monsoon rainfall ; winter rainfall
Indicator Plants	Flowering and fruiting behaviour of indigenous plant; appearance and disappearance of species
Hazard	Drought; flood
Livelihood activities	Changes in sowing/ harvesting and storing practices of indigenous crops
Physical information	Volume of water in water bodies
Sensitivity	
Agriculture and food security	Loss of agriculture Lands/ productive land/ paddy field; loss of crop production
Forest and biodiversity	Forest coverage; forest biodiversity loss
Human settlement and infrastructure	Community settlement and Infrastructure
Water resources	Fresh water springs; natural springs /water bodies
Health sub sectors	Water related disease, other diseases
Adaptive capacity	
Human	Demographic situation such as - education and literacy, skills and labor; knowledge and awareness on climate change
Natural	Water for drinking and irrigation; land (khet land); forest
Social	Social institutions (formal/informal); service provider
Financial	Financial institutions (cooperatives); income
Physical	Infrastructure services; information/ communication source

ASSESSMENT INDEX

The assessment was carried out by developing indices. Exposure, sensitivity and adaptive capacity were measured in 1-4 scale with the value of 1 for low, 2 for moderate, 3 for high and 4 for very high perception of the community (PAC, 2010). Hence the maximum possible value of vulnerability was 16 [$(V=E\times S\times 1/A) = (4\times 4\times 1/1)$] and the minimum possible value was 0.25 [$(V=E\times S\times 1/A) = 1\times 1\times 1/4)$].

When all values of E, S and A are in whole numbers, there will be 64 possible combinations of V within the range from 0.25 – 16.00. The value of V was further classified into 4 categories: index 0.25-1 representing low, 1-2 representing medium, 2-4 representing high, and 4-16 representing very high. For further analysis of risks, one important crop during winter (wheat) and one important crop during rainy season (paddy) were considered in this study. In order to obtain the value of agricultural crops, crop productivity and price of the commodity were collected from the community people.

SELECTION OF STUDY AREA

For piloting the methodological approach, Dhanusha was selected in the Terai eco-zone. As per the local people and district stakeholders consulted, among 101 VDCs of Dhanusa, Mukhiyapatti Musharniya was reported as one of the most vulnerable VDCs. The test community was selected through rigorous consultations with the stakeholders. The project VDC (Mukhiyapatti Musharniya) was identified by the participants of the district level consultative meeting and group discussions. Three clusters namely Mukhiyapatti (Ward 1), Belhitol (Ward 4) and Musarniyatol (Ward 9) within the selected VDC were selected for gathering detail information. The study site was situated at the lowest elevation in south-eastern part from the district headquarters at an elevation range of 42m to 56m asl. There are three rivers namely Simara, Jamuni and Bighi flowing through this VDC. Being located at the lowest elevation and criss-crossed by three rivers, the selected location was very much prone to flood hazard during the rainy season and drought during summer. Appropriateness of the selected VDC and the clusters was further discussed and verified in a district level workshop facilitated by the DDC. The main indicators such as high climate related hazards, transportation facilities, marginalized community settlements and low food sufficiency were used to identify the test sites and were endorsed by the district level workshop.

SAMPLING AND DATA COLLECTION

The households in the community were fairly homogenous from the climate change impact perspective. Hence, by following the central limit theorem, a total of 30 households were deemed sufficient for this study (Saxena, 2005, Kothari, 2008). This sample was equally distributed over three clusters in the selected VDC (Mukhiyapati Musharniya). Likewise, there were three focus group discussions conducted (one in each cluster) to ensure the inclusion of marginalized groups and in the discussion and mapping existing and probable climate change risks. The required information was collected from household survey. Focus group discussions were held to prepare community level vulnerability index.

RESULTS AND DISCUSSIONS

VULNERABILITY ASSESSMENT

Exposure assessment results

The study community has highly perceived that the average summer temperature has increased while average winter temperature has decreased over time. Likewise, the study community has highly perceived that the monsoon rainfall intensity and number of rainy days has decreased in the study area. The time of rainfall has moderately deviated; initiation of monsoon is delayed by 1-2 months. Likewise, winter rain has become unpredictable and in some years there has been no rainfall at all. A number of indicator plants have shown changes in their flowering time - for example, early flowering of mango. In addition, appearance and fast multiplication of some weed species such as Jalkumbi (Water hyacinth) have also been observed. Hot-waves during summer, cold-waves during winter, drought and flood were the major hazards in Mukhiyapatti. The incidence of occurrence of drought and flood hazards has increased over time. The change in the climate pattern has affected the cropping practices of indigenous crops pushing cultivation time later. There has been noticeable decrease in the water-table. Based on the observations of changes noted on these indicators, exposure was ranked as low, medium, high and very high with an index of 1 to 4, respectively. The results of analysis are presented in Table 2. The result shows that the overall exposure of the study site to climate change is high.

Table 2. *Household level perception of exposure*

Parameters and indicators used	Perceived change	Score index
Temperature		3
Hot days/ Summer season (100% household sperceived that summer season increased by 1-3 months and 50% households perceived that hot days increased since last 5- 7 years)	3	
75% household perceived hot waves increased and early by one month (Jetha-Asar)	3	
74% household perceived days are colder though winter becoming shorter	3	
Precipitation		2
Monsoon rainfall (80.6 % household perceived that there the rainfall has almost decreased by 40 % than past)	2	
Winter rainfall (86.1% decreased and uncertain)	1	
50% perceived change in rainfall duration (shorter with high intensity)	3	
Climate induced disaster		3
Drought Event (95% perceived increased frequency and duration)	3	
Flood Event (all most all said every year flood and 86 perceived increased)	3	
Indicator plant		2
Paddy planting has delayed by three weeks to five weeks	2	
Appearance and disappearance of species (wide spreading of Jalkumbi)	2	
Average exposure index	High	10/4=2.5

SENSITIVITY ASSESSMENT RESULTS

- The major affected sector was agriculture and food security, human settlement and infrastructure, and health.
- Since, this is a very low lying area, flooding is a common phenomenon when there is rain. In addition, flooding takes place even when there is no rain in the community but it rains in the hills in the Ramechhap and Sindhuli districts.
- Frequency of flooding, level of inundation and the duration of submergence of crop have increased over time in the last 10 years.
- When there is no rain or less rain, drought occurs affecting the human health, crop and livestock.
- It was a bitter experience of the community that if there is no flood, there is drought in that year.
- The return period of hazards over time has decreased. The major hazard events noted by the communities were in the years 1987, 1996, 2002, and 2007 of drought and flood.

The results of sensitivity analysis are presented in Table 3. The result shows that the sensitivity of the study site to climate change is high.

Table 3. Household level perception of sensitivity

Parameters and hazards	Indicators used	Perceived change	Score index
Agriculture & food security			3
Flood	Loss of agriculture - (>25% paddy production decreased	3	
Drought	Wheat and lentil production decreased by about 50%	3	
Forest & Biodiversity			2
Drought	Forest coverage (decreased)	2	
Flood	Forest biodiversity loss (only a few species seen)	2	
Settlement & infrastructure			3
Flood	Community settlement and Infrastructure (damaged)	3	
Water Resources sub sectors			2
Flood	Fresh Water Springs (quality deteriorated	2	

ADAPTIVE CAPACITY ASSESSMENT RESULTS

The adaptive capacity assessment results are presented in Table 4. Result shows that the adaptive capacity of the Mukhiyapatti community was at medium level. Because of the inverse relationship of the adaptive capacity with the vulnerability, the higher level adaptive capacity reduces the level of vulnerability.

Vulnerability assessment results: Having the index values of exposure, sensitivity and adaptive capacity, the vulnerability index of the community to climate change was estimated by using Equation 1. The estimated index at the household level was 2.4. It indicates that vulnerability is perceived at high level. Among the households surveyed, 69 percent households felt that they are highly vulnerable followed by 17 percent medium and 14 percent very highly vulnerable.

Table 4. Household level perception of adaptive capacity

Parameters and indicators used	Criteria	Perceived change	Score index
Human			2.7
Demography	Dependent population (33% below 5 years and 17% above 60 years	3	
	Education (literacy more than 50%)		
Education and literary	Literacy (> 55% literate in which 15% with secondary education)	2	
	Awareness on climate change (30% respondents heard about climate change)		
Skill labour	Profession (10-30% with diverse profession)	3	
Natural			2.3
Water	Drinking (Tube well in almost all houses) and irrigation from shallow tube well (50% houses)	3	
Forest	Forest (very thin community forest, some patches of private forest) little available of fodder	1	
Land	Khet land mostly rainfed	3	
Social			3.0
Social institutions	Affiliation to social institutions (54% Household affiliated to formal and informal institutions)	3	
Service Providers	Number (5 GO, 15 NGO and 7 CBOs are working	3	
Financial			2.0
Financial institutions	Number (2 Banks, 2 Cooperatives and 3 saving and credit groups)	2	
Physical			2.5
Infrastructure for services	Access (Almost all have access to drinking water, school, road and bridge Infrastructure for services)	3	
Information/ communication source	Access (mobile telephone 59% mobile, TV -11% and radio- 63% no newspaper available)	2	
Average adaptive capacity index		High	12.5/5=2.5

RISK ASSESSMENT AND MAPPING

Hazard assessment results

Among several climate change induced hazards, communities made a pair-wise comparison of hazards and concluded that floods and droughts were relatively more serious hazards in Mukhiyapatti. The temporal probability for hazard was estimated from the hazard specific historical time line provided by the community members. In case of Mukhiyapatti, this was estimated for two major hazards (flood and drought) identified and prioritized by the community (Table 5). In the year 2002, there was a flood in the rainy season and then there was no rain for the whole of the autumn, winter, spring and summer.

Table 5. Temporal probability of hazard during paddy crop in the field

Hazard	Severity	Period	Return period (years of incident)
Flood	Highly dangerous	Flowering	5-10 yrs (1989, 1996, 2002, 2009)
	Slightly - moderately dangerous	Booting	2-5 yrs (1987, 1989, 2007, 2009
Drought	Extreme	Flowering	About 6 yrs (1995, 2002)
	Severe	Booting	About 2 yrs (2004, 2006, 2010)

Damageability assessment results

Flood was mostly during the time of heading and flowering of paddy crop and some during booting. When there is a flood during booting, the paddy crop is submerged for 4-7 days and when it is during heading and flowering, the crop is submerged for about 10-15 days. Crop damageability at these various stages and period of submergence is presented in Table 6. Likewise, drought is mostly during winter and pre-monsoon period. Wheat is at the stage of flowering and ripening. Damageability of wheat crop at these various stages of growth is presented in Table 7.

Table 6. Extent of damage to paddy crop when it is submerged (%)

	Duration of submergence and damage percentage (Ismail et al, 2009)			
Stage of growth of paddy crop at the time of	4 days	8 days	12 days	16 days
Booting	17	40	60	88
Heading and flowering	14	29	65	100
Ripening	10	30	75	100

Table 7. Estimation of drought damage on wheat (percentage) (CECI, 2010)

Description	Extreme drought	Severe drought	Moderate drought
Winter drought	50	30	10
Pre-monsoon drought	65	55	35

ASSESSMENT OF VALUE OF ELEMENT AT RISK

Estimation of area being impacted

Out of the total area I the surveyed clusters (950 ha), 400 ha was affected more (>50% paddy damaged in flood) and 333 ha was affected relatively less (<50% paddy damaged in flood). Whereas, when there was drought, 333 hawas affected more (>50% wheat and lentil damaged by drought) and 400 ha was affected relatively less (<50% wheat and lentil was damaged by drought).

<u>Estimation of value of element at risk</u>: The price of the selected crops (paddy and wheat) in the year 2009/10 was as presented in Table 8.

Table 8. Crop productivity and price (2009/10)

Crop	Productivity (Mt/Ha) (MOAC, 2009)	Price (Rs/Mt) (MDD, 2009)
Paddy	3.6	14,200
Wheat	2.4	17,500

RISK ASSESSMENT RESULTS

Estimation of value of hazard risk: The estimated values of hazard risks are presented in Tables 9 and 10.

Table 9. Value of drought hazard risk in wheat

Wheat area that could be impacted	580 hectare
Drought season	Pre-monsoon
Type of drought	Moderate that occurs in two years
Extent of drought damage/ loss	35%
Crop productivity	2.4 Mt/ha
Price	Rs 17,500/Mt
Value of drought risk = Hazard * Damageability % * Value of element at risk = (1 – ½) * 35/100 * (580 * 2.4 * 17,500) = Rs 4,263,000	

Table 10. Value of food hazard risk in paddy

Paddy area that could be impacted	950 hectare (60% damage in 500 Ha and 40% damage in 450 ha)
Return period of the flood	Five years (moderately dangerous)
Stage of paddy at the time of flood	Flowering
Duration of crop submergence	8 days
Paddy productivity	3.6 Mt/ha
Price	Rs 14200/Mt
Value of flood risk = Hazard * Damageability % * Value of element at risk =[(1-0.2)*60/100*(500*3.6*14200)]+[(1-0.2)*60/100*(450*3.6*14200)] = Rs 12,268,800 + Rs 7,361,280 = Rs19,630,080	

Table 11. Drought hazard risk assessment in wheat

Potential income when no risk	= 580 ha * 2.4 mt/ha * Rs 17,500/Mt = Rs 24,360,000
Value of drought risk	= Rs 4,263,000
Percentage of drought loss over the total potential income when no risk	= 17.5%
Level of risk	Medium

Table 12. Flood hazard risk assessment in paddy

Potential income when no risk	= 950 ha * 3.6 mt/ha * Rs 14,200/Mt = Rs 48,564,000
Value of flood risk	= Rs 19,630,080
Percentage of flood loss over the total potential income when no risk	= 40.42%
Level of risk	Very high

Mapping risk: After completing the estimation of value of risk, the level of risk for flood and drought in Mukhiyapatti was mapped (Figure 1). In this map, darker colour indicates higher level of risk, medium dark colour indicates medium level risk and light colour indicates low level of risk. Higher level flood risk is seen in areas with lower level drought risk in the same location and vice-versa.

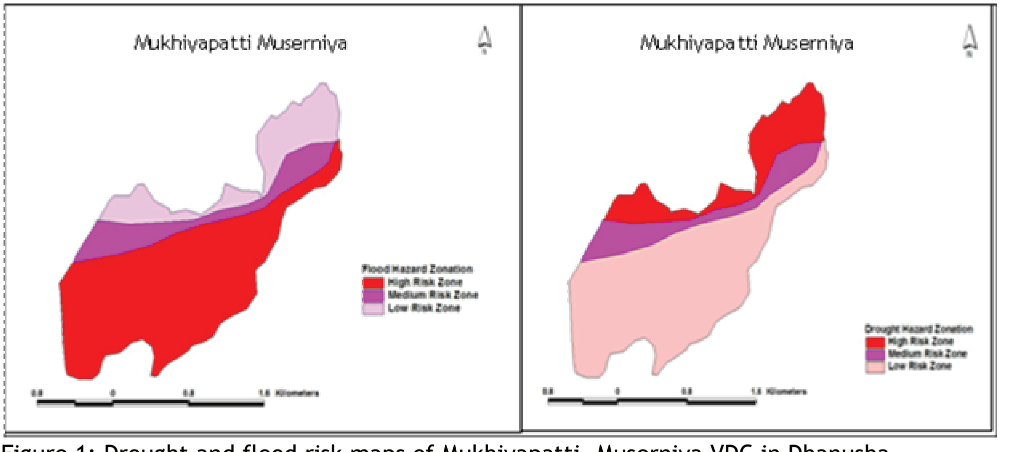

Figure 1: Drought and flood risk maps of Mukhiyapatti, Muserniya VDC in Dhanusha

Risk management system: There was already an existing committee called as Disaster Risk Management Committee (DRMC) promoted by CECI. There were seven such committees in various VDCs promoted in 2007-08 at the community level (cluster level). These committees are also called as Upkar Committees. These are community-based organisations having their executive committee members elected democratically. The main purpose of the committees is to look after the overall activities of disaster and adaptation to climate change hazards. The committees have plan of action for risk mitigation and disaster management. The plans are implemented through their own fund named "Community Disaster Fund". The fund is further supported by the DDRC and other I/NGOs working in the district. Feasibility of this model was discussed and was endorsed by the community people for further replication in other areas.

ADAPTATION PLANS

After the assessment of vulnerability and the risk, adaptation plan was prepared. The followings were the stepwise process to prepare an adaptation plan.

Identification of actions to be undertaken: In view of the major flood and drought hazards, communities identified the following actions to be undertaken to minimise the hazard risk and adapt to the problem in the long-run.
Major action to adapt to increasing flood hazard risk

- Construction of dam along all three rivers
- Plantation of trees along the river basin along all three rivers
- Cultivation of flood tolerant variety of paddy
- Raising the plinth height of tube-well for drinking water

Major action to be undertaken to adapt to increasing drought hazard risk

- Installation of shallow tube-well for irrigation
- Cultivation of zero tillage lentil in paddy field before the harvest of paddy

PREPARATION OF ACTION PLANS

Institution mapping: The community reviewed the related institutions in the neighbourhood and in the focus group and diagrammed the institution.

Action plan for adaptation: In consultation with the communities about the adaptation needs, the doable intervention activities and the supporting institutions available, the action plan for adaptation was developed.

Cost-benefit analysis of action plans: In consultation with the communities, the associated cost of the proposed adaptation action plan was estimated. The expected benefit was assumed to be represented by the estimated loss due to flood or drought hazard risk. A simple ratio of undiscounted[1] benefit-cost was estimated. The estimated ratio (4.3) showed that the adaptation action plan was profitable to implement. In fact, these benefits are received over several years after construction of dam, plantation of trees and installation of shallow tube-wells.

CONCLUSIONS

Climate change has affected livelihoods of the people. The risk of increased negative impacts is high. In order to minimise the risk, communities need to understand the climate change patterns, the likely impacts on livelihoods and measures to moderate the negative impacts. This study was able to show that communities can assess the climate change vulnerability, assess the level of associated risk and map it, prepare the adaptation plan to moderate the likely negative impacts and access resources from the local government to implement their plan. In light of the findings of this study, it is recommended that the community based climate change vulnerability assessment and risk mapping for adaptation planning tools and methodologies should be used by the local government in their regular planning to address the climate change issues at the community level.

[1]This is used here to make it community friendly and not to confuse with the complicacy of discounting process

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