Climate Change Vulnerability Assessment of Chisapani VDC of Ramechhap District

*Sanjeet Kandel, Ram B Khadka, Khimananda Sharma, Man Kumar Dhamala and Saroj Ghimire
Department of Environmental science, Pokhara University, Nepal
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*Corresponding author: Sanjeet Kandel, Department of Environmental science, Pokhara University, Madhyapurthimi-15, Bhaktapur, Nepal

Abstract

This paper presents the results of study carried out with the objective of identifying the vulnerable community at ward level of Chisapani VDC of Ramechhap District of Nepal. Vulnerability assessment framework with list of indicators and determinants was prepared and finalized on the basis of literature review of previous works and updated with village development committee (VDC) specific information. Adaptive capacity of each ward was calculated by averaging three indicators; socio-economic, infrastructural and technological indicators which were determined by predefined criteria whereas perceptions of respondents are the basis of exposure and sensitivity. Various research tools like household survey, community discussions, focus group discussions and key informant interview were done to collect primary data. The data were tabulated, standardized, normalized and the sub-indexes were calculated as the average of the indicator values. Based on the Vulnerability definition given by Intergovernmental panel in climate change (IPCC), the vulnerability index was calculated as the product of Sensitivity index, Exposure index and the inverse of Adaptive capacity index in Arc GIS 10. The vulnerability index for wards of Chisapani VDC has been categorized as Low (<0.25), Medium (0.25-0.50), High (0.50-0.75) and Very High (>0.75).

Keywords: Vulnerability; Adaptive Capacity; Exposure; Sensitivity

Abbreviations: VDC: Village Development Committee; GLOF: Glacial Lake Outburst Floods; CBVA: Community Based Vulnerability Assessment; WWF: World Wildlife Fund; IUCN: International Union For Conservation of Nature; NAVIN: National Association of Village Development Committees in Nepal; CBS: Central Bureau of Statistic; HDI: Human Development Index

Introduction

Nepal's climate and impacts of climate change are as diverse as the country's topography. Generally, flood, droughts, debris flows, vector and water borne diseases, forest fire and disruption of ecosystem are the major climate change impacts in the terai-churia regions. In the middle mountains, landslides, flash floods, drought, prevalence of insects and plant diseases, and forest fires. Rapid melting of glaciers, glacial lake outburst floods (GLOF), and landslides are the major climate change impacts in the high mountains MoEnv [1]. Assessments of vulnerability, carried out holistically, can provide an important guide to the planning process and to make decisions on resource allocation at various levels, and can help to raise public awareness of risks UNEP [2]. Such assessments can help to provide answers to basic questions such as that are vulnerable, where and why - answers which are essential when developing early warning systems to improve preparedness. Vulnerability to the impacts of climate change needs to be assessed, so that adaptation strategies can be developed and populations can be protected Sullivan and Meigh [3].

Vulnerability is defined here as a function of exposure to hazard, population density and the coping capacity of people over time UNEP [2]. According to McCarthy [4], vulnerability is the degree to which a system is susceptible to, and 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 change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Similarly ISDR [5] defines vulnerability as a set of conditions and processes resulting from physical, social, economic and environmental factors which increase the susceptibility of a community to the impact of hazards.

Watson [6] in the Second Assessment Report of IPCC defines vulnerability as "the extent to which climate change may damage or harm a system." It adds that vulnerability "depends not only on a system’s sensitivity, but also on its ability to adapt to new climatic conditions". The IPCC report, The Regional Impacts of Climate Change: An Assessment of Vulnerability Watson [6] argues that the vulnerability of a region depends to a great
extent on its wealth, and that poverty limits adaptive capabilities. According to the Second Assessment Report, vulnerability depends on the level of economic development and institutions. The report argues that socio-economic systems “typically are more vulnerable in developing countries where economic and institutional circumstances are less favorable” Watson [6]. The report continues that vulnerability is highest where there is “the greatest sensitivity to climate change and the least adaptability.”

Third Assessment Report of the IPCC defines vulnerability as: “the degree to which a system is susceptible to, or unable to cope with the 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 [4]. Vulnerability can thus be defined as a function of exposure, sensitivity, and adaptive capacity.

\[ \text{Vulnerability} = f(\text{exposure, sensitivity, adaptive capacity}) \]

In the IPCC report, exposure is defined as “the nature and degree to which a system is exposed to significant climatic variations”; sensitivity is defined as “the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli”; and adaptive capacity is defined as “the ability of a system to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences”. Those most vulnerable to the impacts of climate change are the poorest groups in climate vulnerable locations that have limited access to the resources, services and systems that would enable them to cope with and adapt to these impacts GoN [7]. Similarly, children are the ones who are hardest hit by climate change though they have least contribution to cause of climate change NDRC [8]. Adaptation to climate change requires public-health strategies and improved surveillance A Haines [9].

**Methodology**

This research is based on explorative as well as diagnostic approaches. This research has followed community based vulnerability assessment (CBVA), adapted by Practical Action Nepal, world wildlife fund (WWF), international union for conservation of nature (IUCN), and National Association of Village Development Committees in Nepal (NAVIN) MoEST [10,11] and methodology applied for the vulnerability mapping of Southeast Asia by Yusuf and Francisco [12]. This approach uses participatory case study methods for assessing vulnerability to better understand the nature of vulnerability of communities to climate change. The assessment begins with the system in question, in this case Chisapani VDC, and examines the conditions of community and of various factors that gives rise to its vulnerability and the interrelations between them. The determinants of vulnerability i.e. exposure, sensitivity and adaptive capacity are not assumed; rather they are calculated in the research based on information provided by community and available secondary data of the study area.

This research starts with the identification and finalization of criteria and indicators for vulnerability based on available data of the study area. After reviewing available information, additional necessary primary data are collected through household survey, focus group discussion and key informant interview. Collected data were then tabulated to prepare database to calculate indices for sensitivity, exposure and adaptive capacity. After this, maps were prepared for all criteria used to calculate all those indices. Finally, vulnerability map was prepared identifying and showing most vulnerable ward of VDC (Figure 1).

**Study area**

Chisapani Village Development Committee is the study site of this study. It lies in Ramechhap District in Janakpur Zone of Central Development Region of Nepal. This VDC lies at 27.4200N and 86.0600E. The VDC has total population of 3187 among them 1412 are male and 1775 are female. Total household number of this VDC is 686 CBS [13]. Chisapani VDC has northern boundary with Gelu and Chankhu VDC, eastern boundary with Manthali VDC (District headquarter) and Kathajor VDC, western boundary with Bhatauli VDC and Puraanagaaun VDC and southern boundary with Bhatauli VDC. The area of this VDC is 13.65 sq km. This VDC has altitudinal variation form 500 m to 1500m from sea level. The lowest elevation (500m) is at the bank of Tamakoshi in the eastern boundary of VDC while highest elevation (1500m) at south west of VDC.

**Sources of data**

Primary data were collected through house hold survey, key informant interview, formal and informal interviews, focus group discussions and through direct observation. Secondary data source of the population were village profile prepared by VDC and different statistical reports prepared by Central Bureau of Statistic (CBS).

**Data analysis and interpretation (Table 1)**

Each determinants from all the wards were aggregated and averaged and normalized to a scale of 0 to 1 range following the UNDP procedure adapted for human development index HDI UNDP [14] as,

\[ z_{ij} = \frac{x_{ij} - x_{i \text{min}}}{x_{i \text{max}} - x_{i \text{min}}} \]
Table 1: List of indicators and determinants used for calculation of sensitivity, exposure and adaptive capacity.

| Particulars     | Indicators                          | Determinants                                |
|-----------------|-------------------------------------|---------------------------------------------|
| Adaptive capacity | Socio-economic                      | House hold depending on Agriculture         |
|                  |                                     | Average annual income of HH                 |
|                  |                                     | Population with sufficient food supply      |
|                  |                                     | Number of socio-economic groups and organizations |
|                  |                                     | Literacy rate                               |
|                  | Infrastructural                     | Distance to nearest heath post              |
|                  |                                     | Number of Toilet                            |
|                  |                                     | Distance to VDC office                      |
|                  | Technology                           | Road density                                |
|                  | Human                                | Population density                          |
|                  |                                     | Population age distribution                 |
|                  |                                     | Women headed house hold                     |
|                  | Ecology                              | Forest per unit land area                   |
|                  | Exposure                             | Flood                                       |
|                  |                                     | Annual Frequency, geological state and people’s perception |
|                  |                                     | Landslide                                   |
|                  |                                     | Drought                                     |

Where $z_{ij}$ is the standardized determinants of type $i$ of region $j$; $x_{ij}$ is the unstandardized determinants of type $i$ of region $j$; $x_{max}$ is the maximum value of the determinants over the region $j$, and $x_{min}$ is the minimum value of the determinants over the region. The range for each determinants and indices were categorized as Low (<0.25), Medium (0.25-0.50), High (0.50-0.75) and Very High (>0.75).

Each of the normalized determinants were added and normalized again to generate indicators for each type of exposure, sensitivity and adaptive capacity. The indicators (Index of Adaptation capacity, Sensitivity and Exposure) were calculated in MS Excel using arithmetic average. Those indexes were then imported into the GIS layer of the ward of Chisapani VDC using in ESRI’s ArcView GIS. The Vulnerability Index was calculated using the following formula with the Field Calculator in the ArcView GIS.

Vulnerability Index = Sensitivity Index * Exposure Index * 1/Adaptive Capacity Index

Result and Discussion

a) Adaptive capacity: Adaptive capacity of each ward was calculated by averaging three indicators; socio economic, infrastructural and technological indicators which were determined by predefined criteria. A total of 11 criteria were used to determine the adaptive capacity of each wards of Chisapani VDC. The adaptive capacity of wards ranged from 0.301 in ward 8 to highest adaptive capacity in ward 6 with adaptive capacity index of 0.761, followed by ward 5 (0.711) and ward 4 (0.497). One ward i.e. ward no 6; had very high adaptive capacity and one ward, ward no 5 had high adaptive capacity and remaining 7 wards had medium adaptive capacity (Table 2).

Table 2: Score of adaptive capacity of 9 wards of Chisapani VDC.

| Ward no | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Adaptive capacity | 0.439 | 0.388 | 0.423 | 0.497 | 0.711 | 0.764 | 0.336 | 0.301 | 0.341 |

b) Sensitivity: Sensitivity index was calculated by averaging human sensitivity and ecological indices, among which human sensitivity was determined by population density, no of women headed house hold on each wards; while ecology sensitivity was determined by proxy determinant of forest cover per unit land surface of each wards. The sensitivity index of wards ranges from 0.114 in ward no 7 to highest sensitivity in ward no 1 with score of 0.684. Ward no 1 is highly sensitive to impacts of climate change with the sensitivity index of 0.684, followed by ward no 4 with index of 0.676, ward no 3 with index of 0.582 and ward no 8 with 0.505. Similarly, ward no 6 is least sensitive to impacts of Climate Change with the sensitivity index of 0.114. Remaining 4 wards are moderate sensitivity to impacts of Climate Change with medium rankings (Table 3).

Table 3: Score of Sensitivity index of 9 wards of Chisapani VDC.

| Ward no | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   | 9   |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| sensitivity index | 0.684 | 0.469 | 0.582 | 0.676 | 0.253 | 0.114 | 0.464 | 0.505 | 0.304 |

c) Exposure: Combined or total exposure was calculated from three different exposure observed and assessed during study. Scoring of exposures was basically based on the perception of local people. Flood, drought and landslide were the major exposure found for the people of study area. Individual exposure indices were averaged to calculate
combined exposure. The Exposure index ranged from 0.524 for ward no 2 to 0.296 for ward no 6, indicating that ward no 6 is least exposed to Climate Change whereas ward no 2 is highly exposed to climate change. Ward no 3 has high exposure index of 0.503. Other remaining 6 wards have medium ranking in terms of exposure (Table 4).

Table 4: Score of exposures (Landslide, Drought, Flood and Combined) of 9 wards of Chisapani VDC.

| Ward no | Standardized score (Landslide) | Standardized score (Drought) | Standardized score (Flood) | Total exposure |
|---------|-------------------------------|-------------------------------|--------------------------|---------------|
| 1       | 0.38                          | 0.64                          | 0.06                     | 0.360         |
| 2       | 1.00                          | 0.57                          | 0.00                     | 0.524         |
| 3       | 0.86                          | 0.65                          | 0.00                     | 0.503         |
| 4       | 0.00                          | 0.95                          | 0.00                     | 0.317         |
| 5       | 0.44                          | 0.89                          | 0.00                     | 0.444         |
| 6       | 0.00                          | 0.89                          | 0.00                     | 0.296         |
| 7       | 0.25                          | 1.00                          | 0.00                     | 0.417         |
| 8       | 0.55                          | 0.42                          | 0.27                     | 0.411         |
| 9       | 0.00                          | 0.00                          | 1.00                     | 0.333         |

d) Vulnerability: The Vulnerability Index was calculated using the following formula with the Field Calculator in the ArcView GIS.

\[
\text{Vulnerability Index} = \text{Sensitivity Index} \times \text{Exposure Index} \times \frac{1}{\text{Adaptive Capacity Index}}
\]

Exposure specific vulnerability was first calculated for each of the exposure identified in the study area.

e) Flood vulnerability index: The flood vulnerability index ranged from 0.89 for ward no 9 to 0.00 for ward no 2, 3, 4, 5, 6 and 7, indicating most of the wards i.e. six wards are not vulnerable to flood. Ward no 9 is highly vulnerable to flood followed by ward no 8 which is moderately vulnerable to flood.

f) Drought vulnerability index: Ward no 9 is least vulnerable to drought with the index of 0.06, followed by ward 6 with vulnerability index 0.10. Ward no 7 is very highly to drought followed by ward no 4 while ward no 1 and 3 are highly vulnerable to drought. Ward no 2, 5 and 8 are moderately vulnerable to drought. Refer to annex III for detail.

g) Landslide Vulnerability index: Ward no 3 is most vulnerable to landslide with highest landslide index of 1.00, while ward no 9 is least vulnerable to land slide with index of 0.00. ward no 1 and 2 have very high landslide vulnerability index followed by ward no 7 and 8 with high landslide vulnerability index. Similarly ward no 4 have moderate index and ward no 5 and 6 have low index.

h) Combined vulnerability index: Combined vulnerability index of study area ranges from 0.059 for ward no 6 to 0.722 for ward no 1. The study revels ward on 1 as most vulnerable ward with high vulnerability index (0.722) followed by ward no 3, 7, 8 and 2 with 0.719, 0.706, 0.687, 0.649 and 0.623 respectively. Ward no 9 have medium vulnerability index i.e. 0.466 and ward no 5 have low vulnerability index of 0.176 (Table 5) (Figure 2).

Table 5: Score of vulnerability (exposure specific and combined) of 9 wards of Chisapani VDC.

| Ward No | Drought vulnerability | Landslide vulnerability | Flood vulnerability | Combined vulnerability |
|---------|-----------------------|-------------------------|---------------------|------------------------|
| 1       | 0.666                 | 0.796                   | 0.074               | 0.722                  |
| 2       | 0.476                 | 0.908                   | 0.000               | 0.623                  |
| 3       | 0.640                 | 1.001                   | 0.000               | 0.719                  |
| 4       | 0.858                 | 0.483                   | 0.000               | 0.649                  |
| 5       | 0.213                 | 0.160                   | 0.000               | 0.176                  |
| 6       | 0.096                 | 0.035                   | 0.000               | 0.059                  |
| 7       | 1.000                 | 0.593                   | 0.000               | 0.706                  |
| 8       | 0.483                 | 0.704                   | 0.363               | 0.687                  |
| 9       | 0.498                 | 0.000                   | 0.997               | 0.466                  |

Figure 2: Map showing ranking of vulnerability of Chisapani VDC.

The community of the study area identified the drought, landslide and flood as major climate change induced risks/hazards, though the spatial distribution of these risk were not even. Settlement in sloppy terrain are subjected more to land slide where as settlement in lower elevation and near to river bank are prone to flood. Problem of drought was reported all over the study area but was more in settlements in higher elevation and sloppy terrain [15-23].

Adaptive Capacity of ward no 6 and 5 are high which is justifiable because accesses to various services and infrastructure (road, education, drinking water, alternative source of income, economic conditions, sanitation, health facility etc) are often higher in those wards. Adaptive capacities of remote and marginal wards i.e. ward no 7, 8 and 9 are therefore
low in most of the cases. Similarly, ward no 1 and 4 are highly sensitive because of comparatively high population density and least forest area per unit land, where as ward no 5 and 6 are least sensitive because of least population density and high forest cover per unit land area.

Ward no 2 and 3 have very high exposure to the landslide which is justifiable because most of the settlements in these wards are in sloppy terrain, while ward no 9 is least exposed to landslide because of plane and stable terrain. Most of wards i.e. except ward no 9 and 8 are highly exposed to drought because of scarce water source where as ward n 9 and 8 are less affected by drought because these ward are close to Tamakosi River. At the same time ward no 9 and 8 are most exposed to flood because the settlements in these wards are at the bank of Tamakosi River. Overall vulnerability thus calculated identifies ward on 1 as most vulnerable ward with high vulnerability index followed by ward no 3,7,8,4 and 2. Ward no 9 have medium vulnerability index ward no 5 have low vulnerability index.

Conclusion

The overwhelming scientific evidences and data collected so far clearly reveal that climate change is a tangible reality which has widespread implications for agricultures, water resources, forestry, and human health as well as social, economic and political system. Nepal’s fragile and diversified geological condition, sensitive ecosystem and diverse nature of climate have exposed its natural and human (social) system to threats and impacts of climate change. Chisapani VDC, the study area, is a typical Nepalese rural hilly area having agriculture as a major source of income, poor economic condition and low human development indicators in terms of in terms of education, health, roads and other physical infrastructures. The VDC has area of 13.65 sq km with the altitudinal variation from 500 m to 1500 m from sea level. This variation in altitude along uneven distributions of physical infrastructure results variations in vulnerability to CC in small study area.

The temperature and rainfall trend analysis carried out on the basis of data obtained from nearest meteorological stations, clearly reveals that rainfall and temperature pattern in the study area are undergoing through some visible changes. It is concluded that the trend analysis of temperature data shows the positive trend where as the trend of annual precipitation has negative trend. Similarly, the community of the study area identified the drought, landslide and flood as major climate change induced risks/ hazards. Settlement in sloppy terrain are subjected more to landslide where as settlement in lower elevation and near to river bank are prone to flood. Problem of drought was reported all over the study area but was more in settlements in higher elevation and sloppy terrain.

Adaptive capacity of each ward was calculated by averaging three indicators; socio-economic, infrastructural and technological indicators which were determined by predefined criteria. Adaptive Capacity of ward no 6 and 5 are high while adaptive capacities of remote and marginal wards i.e. ward no 7, 8 and 9 are low. Ward no 1 and 4 are highly sensitive to climate change impacts where as ward no 5 and 6 are least sensitive because of least population density and high forest cover per unit land area. Ward no 2 and 3 have very high exposure to the landslide because of the settlements in sloppy terrain, while ward no 9 is least exposed to landslide because of plane and stable terrain.

Most of wards i.e. except ward no 9 and 8 are highly exposed to drought because of scarce water source where as ward n 9 and 8 are less affected by drought because these ward are close to Tamakosi River. Ward no 9 and 8 are most exposed to flood because the settlements in these wards are at the bank of Tamakosi River.

Ward no 1 is most vulnerable ward with high vulnerability index followed by ward no 3,7,8,4 and 2. Ward no 9 have medium vulnerability index ward no 5 have low vulnerability index.

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