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Vulnerability Assessment of Climate Change Impacts on Water Resources at Community Level in Hilly Areas of Nepal

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Abstract—*The study was carried out on six water supply schemes in Bajhang and Jajarkot districts (three schemes from each district) of Nepal. From present and historic status, the climate change impacts, on each water supply systems have been observed to assess the vulnerability. Vulnerability assessment was done with the help of primary and secondary data. Primary data were collected from the localities by group discussion and the quality of data was completely dependent on knowledge of the native people. The three indices were proposed to assess the vulnerability status of climate change impacts on water resources with water consumer communities. These indices were based on 25 indicators (Eight for exposure; seven for sensitivity and 10 for adaptive capacity) which were selected for each water supply scheme. The data were tabulated and the sub-indexes were calculated as the average of the indicator values. Vulnerability index was calculated according to the definition of IPCC (Intergovernmental Panel on Climate Change) i.e. as the ratio of, the product of sensitivity and exposure index, to the adaptive capacity index. The vulnerability calibration index of both the districts showed a very low adaptive capacity of the community which increases vulnerability in these areas. The result obtained from the vulnerability assessment analysis may serve as an important evidence for the decision and policy makers for further planning, and it aids in water management strategies too for reducing impacts on climate change. These findings can be applied to other water supply schemes in the hilly regions for effective adaptation strategies to climate change.*

Keywords*: Adaptation; Climate change; Exposure; Impact; Sensitivity; vulnerability.*

1. INTRODUCTION

Water is the most important element of life [32]. It is responsible for sustaining life on the Earth and provides multiple economic benefits directly and indirectly to the society. Nepal is wealthy nation in terms of water resources, however, in past few decades; availability of fresh water has been slowly decreasing. This is caused by uncontrolled population growth, misuse and unequal distribution of the water resources. Drying and depletion of water resources is also due to a frequent and more intensive climate change hazards which have adverse affect on the water supply systems [8]. Climate change is a global issue, its impacts differ from region to region, country to country, sector to sector and community to community [2, 14].

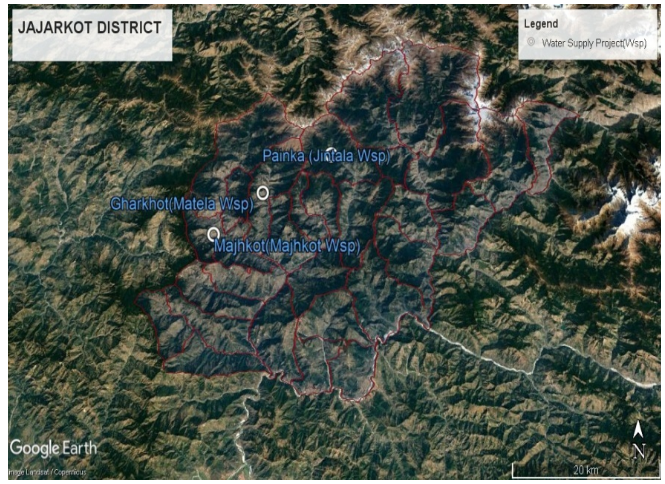
The water resources system is very sensitive to climate change [34]. It can be defined as the ‘‘whole made from connected hydrologic, infrastructure, ecologic, and human processes that involve water” [5]. Vulnerability is defined as ‘‘the degree to which the system is susceptible and is unable to cope with adverse effects of climate change” [3]**.** According to the Second Assessment Report of Intergovernmental Panel on Climate Change (IPCC) vulnerability can also be defined as “the extent to which climate change may damage or harm a system [33]. Vulnerability is the level to which a system reacts adversely to the occurrence of a hazardous event [28]. Thus, it is a term commonly used to describe a weakness or flaw in a system; its susceptibility to a specific threat and harmful event. The vulnerability to climate change to which it is exposed is determined by sensitivity and adaptive capacity of the system [12, 13, 21]. The direct measurement of vulnerability is misleading and challenging [11] so data on proxy variables are often used. The most commonly used approach is the index-based method [4]. The water system can have natural, ecological, biophysical, social, or socio-ecological perspective [29]. Thus, vulnerability can be explained by a combination of social factors and environmental risk, where risk derives from physical aspects of climate-related hazards exogenous to the social system [35, 10]. Management of water supply systems which are vulnerable to climate change impact need development of such tools which can assist the water managers to plan and act accordingly [25]. 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 [30].

2. MATERIALS AND METHODS

There is wide range of methodological frameworks and approaches that have been developed for vulnerability assessment. Among them community based vulnerability assessment (CBVA) is mostly preferred and adapted by various researchers [14, 16, 20, 23]. Our study has also applied the participatory approach for the vulnerability assessment of climate change impacts on water resources at community level. Three village development committees (VDCs) with three water supplies were selected from each two districts for the case study. Altogether 6 focus group discussions (FGDs) with total participants of 120 (42% female and 58% male) were organized in the selected sites with the interactions of water consumer communities in terms of climate change impacts faced by the communities in the past. During the discussions, different tools like historical timeline, seasonal calendar, climate hazard ranking, and prioritization of the hazards were used to understand the exposure, sensitivity, adaptive capacity. These three indices proposed with sub-indices based on 25 indicators (Table 1: Eight for exposure; seven for sensitivity and 10 for adaptive capacity) which were selected for each water supply scheme to assess the vulnerability status of climate change impacts on water resources with water consumer communities. The data were tabulated and the sub-indexes were calculated as the average of the indicator values. Vulnerability index was calculated according to the definition of IPCC (Intergovernmental Panel on Climate Change) i.e. as the ratio of, the product of sensitivity and exposure index, to the adaptive capacity index. The research is based on information provided by community for the determinants of vulnerability i.e. exposure, sensitivity and adaptive capacity. Thus study was focused with the local water consumer community's livelihood dealing with the impact based on their experiences and knowledge on climate change impacts in water resources.

2.1 Study areas

The study was carried out in two districts of Nepal, namely Jajarkot and Bajhang. Jajarkot is one of the distant and less developed upper hill district of Bheri zone which expands over 28˚36'40" to 29˚7'39" N latitude and 81˚49'18" to 82˚34'56" E longitude[7, 31]. It covers an area of 2,230 sq. km and has a population of 171,304 within 30,468 households [6]. Bajhang is a hilly-mountainous district of Seti zone which expands over 29° 29″ north to 30° 9″ northern latitude and 80˚ 46″ east to 81° 34″ eastern longitude [9]. It covers an area of 3,422 sq. km and has a population of 1, 95,519 within 33,786 households. It is one of the poorest districts of the country with 56.8% people living below the poverty line [6]. The study sites in Jajarkot district were located in Painka VDC (Jintala Water Supply Project), Majhkot VDC (Majhkot Water Supply Project) and Gharkhot VDC (Matela Water Supply Project). Similarly, the study sites of Bajhang district were Pipalkot VDC (Panaalekhola Water Supply Project), Jaya Prithivi Municipality (Rithapata Water Supply Project) and Bhatakhola VDC (Tilachaur Water Supply Project) see in Figur 1.



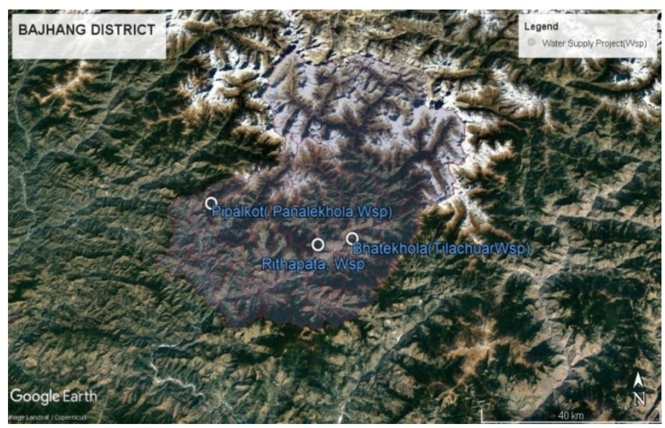


Figure 1: Districts maps with Wsp

Table 1.1: List of indicators (sensitivity, exposure and adaptive capacity) used for calculations

Sensitivity	Exposure	Adaptive capacity
Runoff (discharge)	Duration of hot days	Population structure
Water source (no.)	Duration of cold days	Education and literacy
level of maintained	Monsoon duration	skilled human resources
Population density	Forest fire	Service providers
Population flux	Flash flood	access to various institution
Material used in construction	Landslide	access to fund

Design consideration for extreme climate events	Drought	House hold type (unity, individualist)
	Location of Asset	information and communication
		physical infrastructures
		construction material availability

3. RESULTS

A. Adaptive capacity: Adaptive capacity of each water supply project (Wsp) was calculated by averaging all 10 indicators. These indicators criteria were used to determine the adaptive capacity of water consumers' communities for each water supply project. The adaptive capacity of water supplies community ranged from 1.4 to 2.3. The adaptive capacity index was found to be highest in Rithapata Wsp i.e 2.3 and least in Tilachaur and Pannalkhola Wsp for Bajhang district. Similarly for Jajarkot district the adaptive capacity index was highest in Jintala Wsp i.e 1.7 and lowest in Majhkot Wsp (see in table 3.1).

B. Sensitivity: Sensitivity index was calculated by averaging seven indicators for each water supply project. The sensitivity index of water supply project ranged from 2 to 2.71. The highest sensitivity index was in Rithapata Wsp i.e 2.71 of Bajhang district and Majhkot Wsp i.e 2.29 for Jajarkot district respectively. The lowest sensitivity index was in Tilachaur Wsp at Bajhang whereas for the Jajarkot it was in Jintala Wsp(see in table 3.1).

C. Exposure: Exposure index was calculated by averaging eight indicators for each water supply project. Exposures were based on the perception of water consumer's communities and field observation. Forest fire, Flash flood, drought and landslide were the major exposure in water resources found for the communities of study area. The exposure index was found to be highest for Tilachaur Wsp in Bajhang district and in Matela Wsp in Jajarkot district respectively i.e. 3 (for both) whereas the exposure index was recorded to be lowest in Panaalkhola Wsp (2.6) for Bajhang district and Majhkot Wsp (2.71) for Jajarkot district respectively(See in table 3.1).

Table 3.1: Values of mean with standard error (Mean ± SE) of various major components of vulnerability

	Bajhang			Jajarkkot		
Vulnerability Component	**Ritha pata Wsp**	**Tilac haur**	**Panaal Khola Wsp**	**Jjntal a Wsp**	**Majh kot wsp**	**Matel a Wsp**
Adaptive capacity	2.3±0.15	1.4±0.16	1.4±0.16	1.7±0.15	1.5±0.17	1.6±0.16
Exposure	2.86±0.26	3±0.31	2.6±0.37	2.86±0.26	2.71±0.29	3±0.38
Sensitivity	2.71±0.85	2±0.7	2.14±0.65	2±0.31	2.29±0.36	2.15±0.34

D. Vulnerability

Vulnerability assessments was done to identify and understand the most vulnerable water consumers communities of Water supply projects based on ranking the components of Adaptive capacity, Exposure, and Sensitivity. The vulnerability calibration index of both the districts showed a very low adaptive capacity of the community which increases vulnerability in these areas (See in table 3.2). The highest vulnerability was at Tilachaur Wsp (Bajhang) and Majhkot Wsp (JaJarkot) whereas the value was calculated to be least for Rithapata Wsp in Bajhang and Jintala Wsp in Jajarkot district.

Table 3.2: Result of the vulnerability Calibration index of different water supply projects at Bajhang and Jajarkot districts

Vulnerability*					
Wsp					
Bajhang			Jajarkkot		
Ritha-pata	**Tilac-haur**	**Panaal-Khola**	**Jjntala**	**Majhkot**	**Matela**
3.37	4.29	3.94	3.87	4.14	4.03

* When V is equal to or less than 1, it indicates low vulnerability. When V is in between 1 to 2, the system is medium vulnerable; V is 2 to 4 means, system is in high vulnerable; when value of V is above 4, then the system is very high vulnerable.

4. DISCUSSION

The study was focused on vulnerability assessment based on the water consumers' community knowledge for the target system of water supply projects. According to Tiani *et al.*, 2015 also suggested to use a combination of participatory and analytical tools for understand the vulnerability dimensions [27]. There are very few study concentrated on vulnerability assessment of climate change impacts on water resources. In most cases climate change problems have not been deal with in water resource analysis, management and policy formulation [4]. The degree of vulnerability for the livelihood will depend on availability and accessibility of multiple factors [26]. Choice of several indicators was subjective according to our study goals and targets used in vulnerability assessment which was similarly mentioned in [11]. The vulnerability calibration index of both the districts showed a very low adaptive capacity of the community which increases vulnerability in these areas. The other study also shows similar result that vulnerability was increased due to the low level of the adaptive capacity of the water supply system in Kathmandu Valley due to the impact of climate change [1, 24]. The similar study areas shows that observed rainfall is at decreasing rate in different station of Jajarkot and Bajhang district. The temperature shows the increasing rate at Bajhang and nearby stations of Jajarkot districts respectively. Drying and depletion of spring water sources and frequent climate-induced hazards are caused due to changing rainfall patterns and temperature regime in these areas caused by the climate change [8]. While other study published by the climate change vulnerability mapping report shows that Jajarkot was ranked 9th in combined vulnerability and 34th rank in combined vulnerability index in Bajhang among the 75 districts of the country due to its low adaptive capacity of the district [18]. The study shows the high vulnerability in all water supply projects (See Table 4.1) due to less adaptive measures in both districts because of the inability of the water consumer communities to cope for climatic threats and hazards which they were facing in those areas. Similarly [17, 19, 22] studies shows that vulnerability to extreme climatic hazards increases due to widespread poverty with an additional burden to the poor people.

4.1 Reason vulnerable to climate change of all water supply projects

Water Supply Infrastructure (Asset)	Reasons why the all component is vulnerable to climate change
Source	Increasing trend of temperature and erratic rain fall reduce in discharge of source. Erratic rainfall and prolonged drought cause landslide, erosion, flash flood and river flood. This results in reduced in quantity and quality of water in these WSP which has significant impact on water resource for water consumers' communities.
Intake	Landslide, sediment and debris deposition caused damage in intake frequently in past periods. Due to lack adaption measure increases the vulnerability.
Distribution and transmission pipelines.	The pipelines were laid in fragile and land slide zone. Flash flood, landslide, and damage and collapse the pipelines, even sometimes blockage pipelines which increase the sensitivity in past days.
Reservoir tank	Accumulation of sedimentation in the tank, construction of tanks at the top of hill, loopy and fragile land increases the vulnerability of the reservoir tank. No any design consideration on to Protect against climatic threats

5. CONCLUSION

The vulnerability assessment of water resources systems plays a significant role in identifying, planning and adaptation measures to minimize the impacts of climate change. Our study has focused on the participatory approach involving the water consumer communities through their sharing of lifelong experiences, views, and opinions on climate change issues. Similarly, the water supply projects of the study area were identified with major exposures such as forest fire, flash flood, drought and landslide as major climate induced risks/ hazards. The vulnerability calibration index of both the districts showed a very low adaptive capacity of the community which increased vulnerability in those areas. The highest vulnerability was at Tilachaur Wsp (Bajhang districts) and Majhkot Wsp (Jajarkot districts). The result obtained from the vulnerability assessment analysis may serve as an important evidence for the decision and policy makers for further planning, and it aids in water management strategies too for reducing impacts on climate change. These findings can be applied to other water supply schemes in the hilly regions for effective adaptation strategies to climate change.

6. RECOMMENDATIONS

- Increase the awareness and training of efficient water management practices such as reducing water usage, promoting water storage throughout the year, multiple uses of water resources for different purposes.
- Priority should be given to design climate resilient water supply systems and awareness programmes should be made user friendly and aimed for target community.
- Linking of surrounding sources and connecting to same transmission pipe line, if possible, for minimizing water crisis in target areas.
- Building infrastructures in local institutions and government agencies for planning, designing and implementing source protection measures and management.
- Increase the expertise of the localites through technical and vocational trainings on water supply systems.
- Conducting Bio-engineering operations and promoting plantation to enhance natural filtration in the concerned areas.
- Implementation of spring management plans (Rainwater harvesting including the construction of ponds and trenches, plantations in recharge zones and source conservation).

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REFERENCES

[1] ADB, Technical assistance completion report, Enabling the Private Sector to Undertake Poverty- Focused Water Distribution and Strengthening of Institutional Reforms in Kathmandu Valley. Asian Development Bank, Kathmandu, 2008.

[2] Adger, W. N., Brooks, N., Bentham, G., Agnew, M., and Eriksen, S. New Indicators of Vulnerability and Adaptive Capacity. Technical Report 7, Tyndall Centre for Climate Change Research, University of East Anglia, Norwich, 2004.

[3] Adger, W.N. Vulnerability. *Global Environment Change*. 16, 3, 2006, pp. 268–281.

[4] Bates, B. C., Kundzewicz, Z. W., Wu, S., and Palutikof, J. P. *Climate Change and Water.* Intergovernmental Panel on Climate Change Secretariat, 2008.

[5] Brown, R., Rouholahnejad, E., Rahman, K., Abbaspour, K., and Lehmann, A. Climate change and agricultural water resources: a vulnerability assessment of the Black Sea catchment. *Environmental Science and Policy*, 46, 2015, pp. 57–69.

[6] CBS, National Population and Housing Census. Kathmandu: Central Bureau of Statistics, 2011.

[7] Chapagain, S. A report on GIS based analysis of landslides in Jajarkot District: GIS Mapping and Terrain Analysis, 2017.

[8] Chhetri, R. and Adhikari, S. The Impacts of Climate Change on Water Resources in Hilly Areas of Nepal. *I-manager's Journal on Future Engineering and Technology*, 13, 3, 2018, pp. 42-49.

[9] Dhruba G. C., Cheng, S., Bhandari, J., Xiaojie, L., and Xu, Zengrang. Multidimensional poverty in bajhang district of Nepal. *Pakistan Journal of Agricultural Sciences, Faisalabad, Pakistan,* 52, 4, 2015, pp. 1127-1133.

[10] Eakin, H. and Luers, A. L. Assessing the vulnerability of social-environmental systems, *Annual Review of Environment and Resources*, 31,1, 2006, pp. 365–394.

[11] Hinkel, J. Indicators of vulnerability and adaptive capacity: towards a clarification of the science–policy interface. *Global Environment Change*, 21, 1, 2011, pp. 198-208.

[12] IPCC. Climate change 2001: Impacts, Adaptation and Vulnerability, Summary for Policymakers, WMO, 2001.

[13] IPCC. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Parry, M. L., Canziani, O. F., Palutikof, J. P., Linden, P. J. v. d. & Hanson, C. E. (eds.). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2007.

[14] Kandel, S., Khadka, R. B., Sharma, K., Dhamala, M. K., and Ghimire, S. Climate Change Vulnreability Assesment of Chisapani VDC of Ramechhap District. *International Journal of Environment Science and Natural Resource*. 1, 3, 2017, pp.1-6.

[15] Kasperson, R. E, and Kasperson, J. X. Climate change, vulnerability and social justice. Risk and vulnerability programme. Stockholm Environment Institute, Stockholm, 2001.

[16] Maharjan, S. K., Maharjan, K. L., Tiwari, U., Sen, N. P., and Yildiz,F. Participatory vulnerability assessment of climate vulnerabilities and impacts in Madi Valley of Chitwan district, Nepal, *Cogent Food and Agriculture*, 3,131008, 2017, pp.1-20.

[17] Maraseni, T. N. Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environmental Science & Policy*, 21, 2012, pp. 24–34.

[18] Ministry of Environment. Climate Change and Vulnerability Mapping for Nepal, Kathmandu, 2010.

[19] Mirza, M. M. Q**.** Climate change and extreme weather events: can developing countries adapt? *Climate Policy,* 3, 3, 2003, pp. 233–248.

[20] MoEST. Community Based Vulnerability Assessment Tools and Methodologies and Risk Mapping**.** Kathmandu: Ministry of Environment Science and Technology Government of Nepal, 2012.

[21] NERI, Burden sharing in the context of global climate change: a north-south perspective. NERI Technical Report No. 424. Roskilde, Denmark: National Environmental Research Institute, 2002.

[22] Pandey M. R., Shah, S., Paudel, P. R., and Sharma, B. Assessment of Trends of Climate and Vulnerability of a Mountain Community to Climate Change Induced Hazards in Nepal: A Case Study of Gaurishankar Conservation Area. *Lasbela University Journal of Science and Technology,* 5, 2016, pp. 191-198.

[23] Practical Action, WWF, IUCN Nepal, CECI Nepal & NAVIN. Review of community vulnerability assessment methods and tools, 2010.

[24] Regmi, B. and Adhikari, A. Human Development Report 2007/2008: Fighting climate change: Human solidarity in a divided world. Human Development Report Office, 2007.

[25] Sharda, V. and Srivastava, P. Value of ENSO-forecasted drought information for the management of water resources of small to mid-size communities. *Trans. ASABE*, 59, 6, 2016, pp 1733–1744.

[26] Smit, B., Pilifosova, O. Adaptation to climate change in the context of sustainable development and equity. In Mc Carthy, J. J., Canziani, O., Leary, N. A., Dokken, D. J. and White, K. S., eds, Climate Change 2001: Impacts, Adaptation and Vulnerability. IPCC Working Group II. Cambridge: Cambridge University Press, 2001, pp. 877-912.

[27] Tiani, A. M., Besa, M. C, Devisscher, T., Pavageau, C., Butterfield, R., Bharwani, S., and Bele, M. Y. Assessing current social vulnerability to climate change: A participatory methodology (Working Paper No. 169). Center for International Forestry Research (CIFOR), Bogor, Indonesia, 2015.

[28] Timmerman, P. Vulnerability, Resilience and the collapse of the society, Environmental monograph 1, Toronto: Institute of Environmental Studies, University of Toronto, 1981.

[29] Tonmoy, F. N., El-Zein, A., and Hinkel, J., 2014. Assessment of vulnerability to climate change using indicators: a meta-analysis of the literature. *Wiley Interdisciplinary Reviews: Climate Change*, 5, 6, 2014, pp. 775–792.

[30] UNEP. Assessing Human vulnerability due to environmental change: Concepts issues methods and case Studies, 2002.

[31] United Nations Development Action Framework (UNDAF) District Profile: Jajarkot, UNRCHCO, 2013.

[32] Vorosmarty, C. J., McIntyre, P. B., Gessner, M. O., Dudgeon, D., and Prusevich, A. Global threats to human water security and river biodiversity. *Nature*, 467, 7315, 2010, pp. 555–561.

[33] Watson, R. T., Zinyowera, M. C., Moss, R. H., and Dokken, D. J. The Regional Impacts of Climate Change*:* An Assessment of Vulnerability. Cambridge University Press, Geneva, Europe, 1997, pp. 1-16.

[34] WECS. National Water Plan (2002-2027). Kathmandu: Water and Energy Commission Secretariat, Government of Nepal, 2005.

[35] Wisner, B., Blaikie, P., Cannon, T., and Davis, I. At Risk: Natural Hazards, People's Vulnerability and Disasters, 2nd edn. Routledge, New York, 2004.