Indicator Based Vulnerability Assessment of Chhayanath-Rara Municipality, Western Nepal

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ABSTRACT

The dense settlements at the eastern hills of Rara Lake are at higher risk of existing landslides. Seepage of water from the lake has increased erosion rates, exaggerating the threats to villages. People are worried due to the potential of inadvertent disaster, therefore it became necessary to estimate the vulnerability of the communities and inform concerned authorities. Setting this requirement as an objective, underlying influencing indicators were assessed. The vulnerability assessment was based on the scoring of the responses emanated from indicator-based household's survey. These scores were summed up to generate indices and also mapped with their true locations. Vulnerability scores ranged from 16.50 to 21.75 and were categorized into five classes after standardization. A moderate vulnerability was exhibited by 33.08% of households sampled. High and very high categories of vulnerability occupied 18.80% and 4.51% of households, respectively. Field observation showed solitary households built away from village clusters were highly vulnerable. Most households showed moderate vulnerability and characteristics like stones/mud-built houses, firewood as a primary fuel, decreasing forests and grasslands, increasing temperatures, and decreasing rainfall were major influencing indicators for higher vulnerability in the research area.

1. INTRODUCTION

Vulnerability is conceptualized as complex-multidimensional, dynamic, time and space-specific (Joseph, 2013). According to the definition provided by United Nations International Strategy for Disaster Reduction (UNISDR) the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard (UNISDR, 2009) give rise to vulnerability condition. This definition encompasses the two sides of vulnerability. First, the external side of risk, shock or stress to which individuals or households are subject to; and other is the internal side which is defenselessness, means lack of coping without damaging loss (Haki et al., 2004). Therefore it is vital to incorporate both the components in vulnerability assessments and consider the social system along with environmental changes. Vulnerability depends on economic, social, geographic, demographic, cultural,

institutional, governance, and environmental factors (Cardona et al., 2012). The strengths of the communities as well as the external factors that are crucial in shaping the capabilities of those communities. The vulnerability can be related to the susceptibility of the system in question to adverse consequences following hazard impact and the value placed on the system by society (Tapsell et al., 2010). Considering this definition the inclusion of the economic status of the individuals or communities is a must in vulnerability estimation. Vulnerability to environmental hazards means the potential for loss (Cutter et al., 2003). In the disaster risk management discourse, the need for a paradigm shift from quantification and analysis of hazard to identification, assessment, and ranking of vulnerability has taken center-stage (Joseph, 2013). Thus, at present times it is a must to assess the vulnerability to quantify the risk of a particular hazard. Such assessments in

mountainous countries like Nepal, where multi-hazards are prevalent, would be crucial for disaster management.

Nepal is prone to disasters due to the number of factors, both natural and human-induced, including adverse geo-climatic conditions, topographic features, environmental degradation, population growth, development practices that are not sustainable, etc. When the database of the Ministry of Home Affairs (MoHA) of Government of Nepal (GoN) from 1971 till 2016 was reviewed, it revealed landslides and floods among the top five hazards and are annual in nature unlike earthquakes (MoHA, 2018). The database of landslides (August 1993 to May 2002) of different countries for casualties and damage, by (Alexander, 2004), ranked Nepal as 12th considering only 4 events causing 203 deaths.

The report prepared by the Ministry of Environment (MoE) regarding vulnerability of climate change identified the Mugu District, where the study area is located, among very high vulnerable districts in Nepal (MoE, 2010). Also, the same study found that the district Mugu is very low in socio-economic and technologic adaptation capability, and in infrastructure adaptation capability. This means the district has the least adaptive capacity in Nepal which has an inverse relation with vulnerability. Mugu District was ranked 66th out of 75 districts in the human development index with the score of 0.397 and 5th district in the human poverty index with a score of 45.22 (Sharma et al., 2014). These figures from government and non-governmental institutions made it clear that there is a requirement of research at the grassroots level. Similarly, a social vulnerability analysis done by Aksha et al. (2019) showed that the district having moderate to high vulnerability contrasting to high vulnerability estimated by Gautam (2017). These two scientific pieces of research were carried out at the national scale so there is a need to find out what is the actual scenario at a local scale. Further, Aksha et al. (2019) insist that the drivers of vulnerability may vary at component and local scale which made the necessity to produce the local level vulnerability estimates and for particular hazards. The local level vulnerability assessment could find what would be the level of vulnerability for each household and/or individual peoples. Besides, such local-level analysis can find the major driving factors behind the high vulnerability of each household. Thus, this research was carried out in the headquarter of the Mugu District where landslide hazard is one of a

major problem (Budha et al., 2016). Also, the district is one of the remote areas of Nepal. The major objective to assess the vulnerability status of households and find the extent of influence by particular causative factors as household or individual is distinguished as the first level of social vulnerability (Dwyer et al., 2004) in the spatial scale of analysis. The inference drawn will provide the differences in results of national and local scale vulnerability assessment.

2. METHODOLOGY

2.1 Study area

The study area for this research is located in the Mugu District of western Nepal at the longitude of 82°6'E to 82°12'E and latitude of 29°30'N to 29°35'N. It included households from 10 villages of Chhayanath-Rara Municipality as shown in Figure 1. Most part of the experimental site makes the buffer zone of the Rara National Park. The study area comprised of uneven terrain and steep east-facing slopes with gradient ranged from 0° to 72°. It had an elevation difference from 1,622 m to 3,460 m.

Mugu Karnali River formed the border of the study area at the Northern edge as shown in Figure 1. The River is snow-fed and a major tributary of the Karnali River. Gumgadh River flowed in the Eastern part. Rara Lake is situated on the Western border. Here most water bodies, even small streams, were perennial. Minor gullies and streams become highly destructive in monsoon periods, due to steep gradients, making landslides a recurrent phenomenon (Budha et al., 2016).

2.2 Indicator selection

The flow chart shown in Figure 2 represents the different stages in the vulnerability assessment of this research. The first stage was to select indicators based on works of literature available. As vulnerability cannot be determined by a single factor, combinations of many indicators were considered for study (Dwyer et al., 2004). Indicators of social vulnerability for individual/household level were selected based on a literature review (Armas and Gavris, 2013; Cutter et al., 2003; Devkota et al., 2013; Dwyer et al., 2004; Ebert and Kerle, 2008; Tesso et al., 2012) and acknowledging the local conditions. 36 indicators selected for this study are listed into four major indicators as Social, Economic, Environmental and Institutional as shown in Table 2. This selection of indicators was based on the list of generally accepted
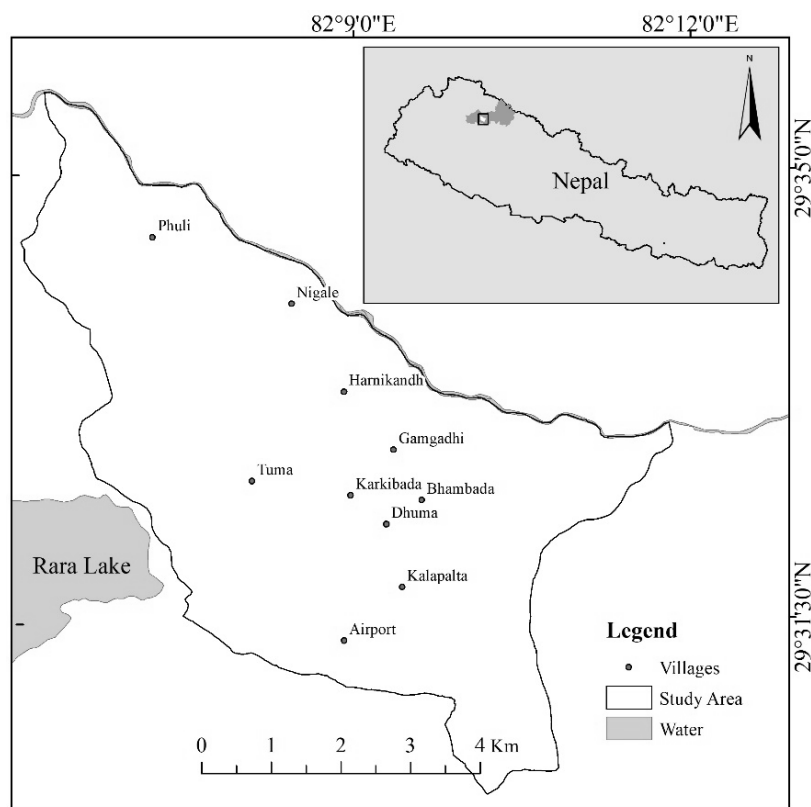
Figure 1. Location of the study area

criteria with considerations of data availability and quality, simplicity, quantitative, sensitivity (Dwyer et al., 2004) and response.

Household-level questionnaire development, a second step of the process (Figure 2), was based on the selected indicators. It was made sure that the response from the questionnaire would be as quantitative as possible so that expert judgment can be applied for scoring purposes. In the process of questionnaire formation, past works of literature on

hazard assessments were referred. The questionnaire was then scheduled for the household interview and data was accumulated. Data collected from each household were focused on the collection of specific information about each household (Rajesh et al., 2018). The information obtained includes their social status and economic conditions as well as the influences from the changing environmental conditions and level of support provided by nearby organizations.
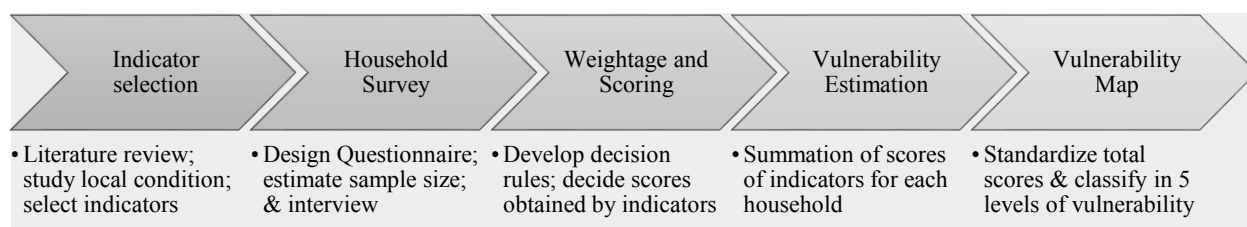

Figure 2. Flow chart for vulnerability assessment

2.3 Sample size for household survey

To estimate the sample size of the household formula by Arkin and Colton (1963) was used. The statistical relation for sample size (n) calculation is given in Equation 1.

$$n = \frac{N*Z^2*P(1-P)}{N*d^2+Z^2*P(1-P)} \tag{1}$$

Where; n=sample size, N=total number of household, Z=value of standard variate at 95% confidence level (1.96), P=estimated population proportion (0.05), and d=error limit of 5% (0.05).

The population database repository can be found at Central Bureau of Statistics (CBS) who conducts the national census for GoN. Total number of households in the experimental area was 1434 (CBS, 2011). Using Equation 1 sample size was calculated to be 133. Therefore, a household survey was carried out in 133 houses as a random stratified manner, considering the distribution in all villages.

2.4 Calculation and scoring of vulnerability

A vulnerability score (V^s) was obtained by adding the weighted values or individual scores assigned for each indicator. Calculation of V^s was done through Equation 2 (Ebert et al., 2009; Haki et al., 2004). V^s is based on the scores obtained by indicators which in turn was reliant on the response of the survey done. The approach was based on indicators' revealed vulnerabilities at ground level. After conducting the interview, their response for each indicator was classified into three options indicating low, moderate or high vulnerability. The scores were assigned, accordingly for each response, ranging from 0 to 1. Here 0 represents low vulnerability and 1 represents a high vulnerability. These scores were summed to obtain total scores which indicated the overall vulnerability of the households. Here, higher V^s resembled high vulnerability and vice-versa.

$$V^s = \sum_i^m v_i q_i \qquad (2)$$

Where; m is the number of factors, v_i is a weighted score (values ranging from 0-1), and q_i is the relative frequency or the amount of factor i.

The V^s for all houses was then standardized from 0 to 1. For standardization, the min-max standardization method (Briguglio et al., 2009) was used. Equation 3 transforms the values of the vulnerability score of individual households in a particular variable array so that they take a range of values from zero to unity.

$$SVI = \frac{V - V_{min}}{V_{max} - V_{min}} \qquad (3)$$

Where; SVI is a social vulnerability index, V is the total score for a study unit derived from Equation 2, V_{max} is maximum score value, and V_{min} is minimum score value.

The standard scores obtained by each household were then categorized into five levels of vulnerability with 0.2 as a class interval as shown in Table 1. The vulnerability levels were very low, low, moderate, high, and very high, as shown in Table 1, with their score ranges as 0-0.2, 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1.0 respectively.

Table 1. Vulnerability classes for standardized scores

Range	Vulnerability Classes	Symbols
0.0-0.2	Very Low Vulnerable	VLV
0.2-0.4	Low Vulnerable	LV
0.4-0.6	Moderate Vulnerable	MV
0.6-0.8	High Vulnerable	HV
0.8-1.0	Very High Vulnerable	VHV

The standardized results can be compared with other similar vulnerability researches either of the same areas or different places, but it should be kept in mind the variety of indicators used in respective researches.

3. RESULTS AND DISCUSSION
3.1 Household vulnerability

The vulnerability score values ranged from a minimum of 16.5 to a maximum of 21.75 with the average score as 18.77. Figure 3 showed the number of households at different vulnerability levels based on standardized vulnerability scores. Most households' total score lies around average such that it would reflect moderate vulnerability while considering the overall area. 133 households were surveyed for vulnerability assessment where a maximum number of houses showed moderate vulnerability. As depicted in Figure 3, the numbers of households were 21, 37, 44, 25, and 6 as we move from very low, low, moderate, high, to very high vulnerability respectively. Therefore, 33.08% of houses showed moderate vulnerability with the average standard score of 0.43215. Data collected from the survey included household characteristics, landholding, crops and livestock variety, disaster occurrence, perception level, and different coping strategies pursued changing environmental conditions.

Households clustered as a large village illustrated household's vulnerability range from very low to high. These villages with clustered form include 500 families or above. Some of the clustered settlements were Gamgadhi, Bhambada, and Karkibada as shown in Figure 4. Very high vulnerable houses were found scattered and away from the clusters of the village and having a solitary status. Such families were generally minority casts and don't have enough resources to build houses in the main village. Those individual households were devoid of most

facilities while those in clustered villages were taking benefits of common services. The unequal distribution of resources and services can be attributed to their solitary nature of living and negligence from the government's side as more time and costs should be considered to make infrastructures accessible to those individual households.
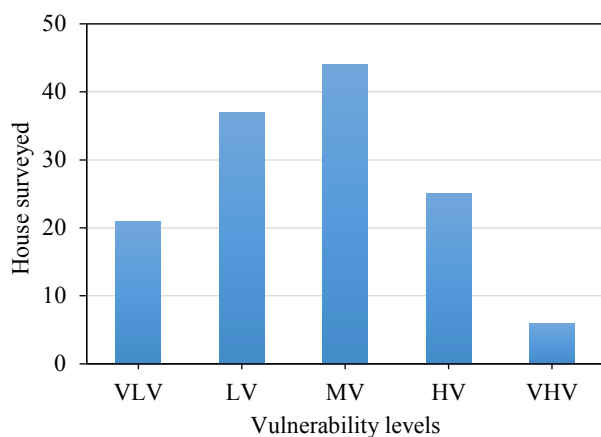

Figure 3. Vulnerability levels of household surveyed after standardization

In Figure 4 the scores of the individual household were interpolated so as to represent the spatial coverage of vulnerability. This further reflected that clustered villages and areas with high economic activities like Gamgadhi (subset image 1 of Figure 4) and Airport have a lower vulnerability. On the other side, a higher vulnerability was distributed where the villages are small and are away (subset image 2 of Figure 4) from headquarter Gamgadhi.

Moreover, the moderate vulnerability in a higher number of households showed similar results as concluded by Aksha et al. (2019) but causative factors for higher vulnerability can be different. As the higher vulnerability being the outcome of solitary nature some families, considerations by government authorities to bring them in the mainstream so that they can get enough supply of all the services that are provided in other clustered villages. Here, further researches needed to be carried out about the ways to make those individual households inclusive.
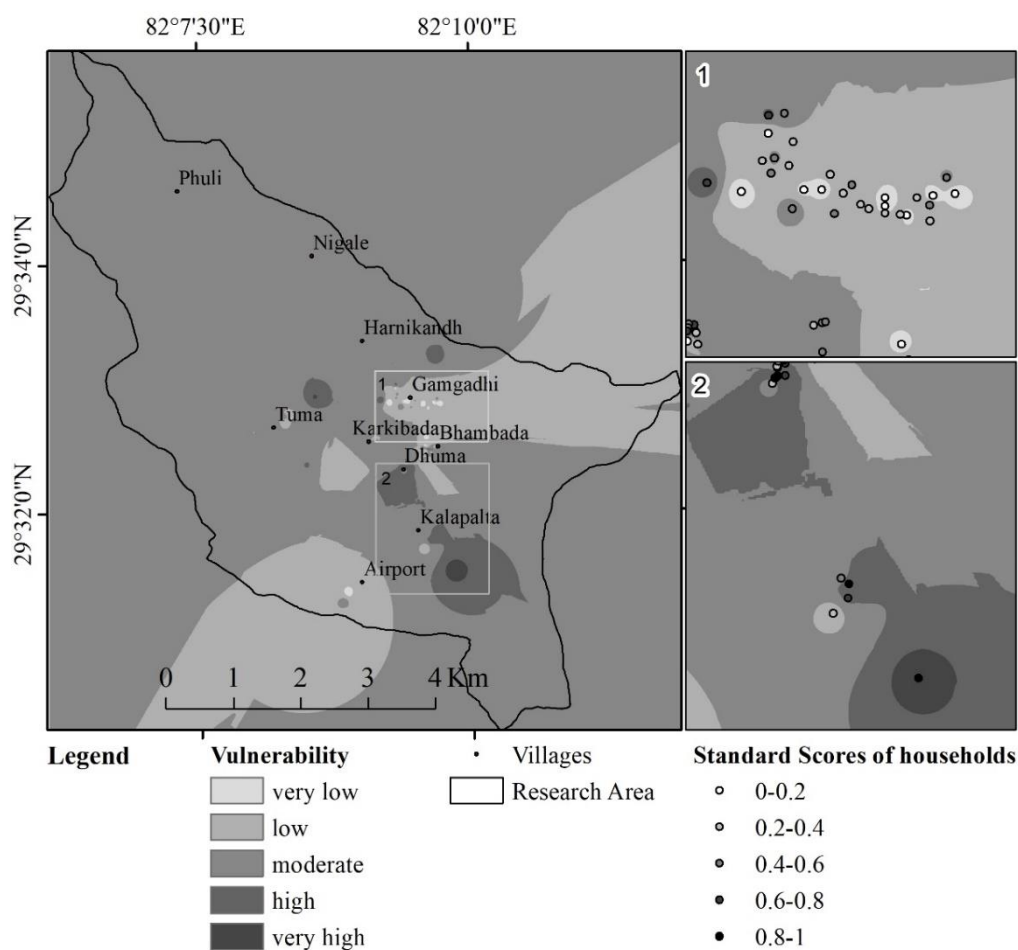

Figure 4. Spatial distribution of the vulnerability in the research site with representations: 1 as low vulnerable area, and 2 as a highly vulnerable area

3.2 Indicators producing high vulnerability

The responses that influence higher vulnerability for each indicator are shown inside parenthesis for each indicator in Table 2. The percentages indicate the number of responses out of 133 households for each indicator that indicated high vulnerability. The higher the percentage the higher was its contribution in very high vulnerability.

For example, indicator 1 in Table 2 shows 12.78% of respondents had females as heads of the family indicating lower influence in high vulnerability. In the case of economic vulnerability variables in Table 2, indicator 23 is producing high vulnerability as most of the peoples are generating income from a single profession and they don't tend to change higher income-generating businesses. This indicates lesser diversity in occupation and in case of catastrophic events they may not have alternatives for their livelihood. Lack of perennial cash crops like fruits and less diversity in livestock also inflicts high vulnerability. Decreasing grasslands and decreased agricultural productivity were indicators among environmental vulnerability variables that were perpetrating the high vulnerability of peoples. Lack of institutional or governmental support, as well as insignificant community-level activities for hazard control, were also contributing to increased vulnerability of the locality.

Table 2. Share in the higher vulnerability of each indicator

Ind.	Vulnerability Indicators	%	Ind.	Vulnerability Indicators	%
Social Vulnerability Variables			*Economic Vulnerability Variables*		
1	Head of the Household (female)	12.8	19	Income (less than average)	53.4
2	Occupation (depending on only one occupation)	73.7	20	cash reserve (no)	24.8
3	Family size (small than the average size of six)	35.3	21	access to credit (no)	41.4
4	Dependent population (age group: infant, 6-12, & above 60)	34.9	22	access to information (no)	3.01
5	Education (illiterate and less than grade 2)	11.3	23	changed profession (no)	95.5
6	No of relatives (less than three)	45.9	*Environmental Vulnerability Variables*		
7	Involvement in social activities (no)	53.4	24	Forest (decreasing)	100
8	non-working people in family	68.0	25	Grassland (decreasing)	97.0
9	House type (stone/mud and wood)	94.7	26	Agriculture (decreasing)	91.7
10	roof type (wood)	68.4	27	Productivity (decreasing)	97.0
11	Cooking (firewood only)	92.5	28	Settlement (increasing)	87.2
12	Standard (low)	48.9	29	Hazards (increasing)	42.9
Economic Vulnerability Variables			30	Temperature (increasing)	96.2
13	Land holding (only one plot or no)	37.6	31	Rainfall (decreasing)	91.7
14	Land availability (lower than average of 5.48 no. of plots)	57.1	32	Landslide occurrences (observed in their surroundings)	89.5
15	cultivation (less than 2 crops or non-cultivating)	27.1	33	Landslide damage (two or more items)	62.4
16	perennial crops (nil)	72.2	*Institutional vulnerability variables*		
17	having 1 or less variety of livestock	56.4	34	Landslide control practices (nothing had done)	53.4
18	Food Sufficiency (only up to six months)	31.6	35	Control practices at household and community level (no)	80.5
			36	Institutional support (no support GoN and organisations)	62.8

The following sections present the discussion of each indicator's influence on vulnerability.

3.2.1 Social indicators

Indicators like occupation, non-working population, house type, and cooking fuel (shown as in 2, 8, 10, and 11 in Table 2) showed very high vulnerability among social indicators. Average working to non-working ratio was found to be 1:2 in the study area but most jobs done were to sustain the daily life requirements. Almost all houses had access to electricity but almost 92.5% of houses surveyed use firewood as a primary fuel for cooking. This indicated a lack of petroleum fuels in the area and the pressures on existing forests are greater. 125 houses were made from stone and mud with 91 having wooden roofs. KC (2013) found that; with the increase in 1% of

permanent housing in Hills and Mountains of Nepal there was a 1% decrease in deaths due to landslides had flood hazards. In the research all houses were permanent. Some researchers consider large families as more vulnerable than smaller ones (Dwyer et al., 2004). In contrast, there are fewer human resources to work in crop fields in families with 4 or 5 members which in turn will decrease productivity making them more vulnerable. As mentioned by Sujakhu et al. (2019) households headed by females increased vulnerability but in this research area, the share of household head was only 12.78% by females showing less influence of the indicator. From the field survey, it was found that 118 respondents were literate but most of them didn't have higher education. This will reduce the coping capacities of people towards hazardous conditions. 46.6 percent of respondents showed involvement in social activities which seems they like to work in cooperation with one another. This is obligatory when adverse condition prevails.

3.2.2 Economic indicators

Indicators like land availability, perennial crops, less livestock diversity, and less diversity in the profession showed inflicting high vulnerability. Here, properties, income, and assets were noted during the survey. 18 people in the study area didn't possess any land and 16 of which were from headquarter of the municipality. On the other side, 83 peoples have land properties in two or more areas where food crops and cash crops can be grown depending upon the existing land conditions. This increased the diversity of crops which helps in sustaining livelihoods throughout the year. All families who depend on agriculture had cultivated manually, and used animal manure as primary fertilizers, depended upon rain and nearest stream for irrigation and had their own seed stocks. This reflects the lack of modern technologies, the use of which could increase productivity and hence reduce vulnerability which is also found by Sujakhu et al. (2018) that access to information and education can reduce vulnerability.

As the study area is located in district headquarter the income level from the questionnaire interview was found to be higher with an average monthly income of Nepalese Rupees (NRs) 21,676.7 (~200$). Likewise, the average expenditure per month was revealed as NRs 13,804.5 (~125$). There were banking facilities in headquarter so that people can do savings. 42.1% of people had the cash reserve, 58.6% of people had access to credit and 97% had access to information. The facilities of headquarter can be reached from every part of the study area within one day. Thus, the access banking facilities and savings of people can be useful in hazardous conditions. These indicators have less contribution to the higher vulnerability of the area.

3.2.3 Environmental indicator

Most of the indicators of environmental vulnerability variables indicate high vulnerability. Most of the respondents said that the forests and grasslands were decreasing whereas settlements had the opposite trend. The main reasons behind these were depicted by the respondent as population growth, need of the wood for building construction and fuel, road access to district, lack of awareness, lack of proper management and so on. Many trees in Mugu district have fire scars deep within their cones, an indication that forest fires have been periodic over at least the past 70 years (Nightingale, 2010) which can be one reason for a decrease in forest stands. The farming trend was also found to be decreasing as many youngsters were attracted to other employments making higher food deficit in houses. Lower-income from agriculture became a push factor towards other jobs.

It was reported by 128 respondents the temperatures were increasing in the last 10 years while 122 respondents felt decreasing precipitation at the same time period. These climatic conditions were thought to be a playing role in climatic hazards like drought, hailstorm or climate-induced hazards like landslides. Climate change had increased the vulnerability by increasing disaster risk, adding stress on natural protectors of hazards, and undermining livelihoods that provide resilience against disaster (MoHA, 2013). Mugu District is prone to multi-hazards; of which major are earthquakes of 500 year return period, rainfall-induced landslides, and disease/outbreaks (Nepal Hazard Risk Assessment, 2010). Also, the district falls into the very high category for drought risk/exposures with indices ranging from 0.563 to 1; where decreasing precipitation and increasing temperatures were proxy indicators (MoE, 2010). Also, climate change and variability are expected to affect the frequency of heavy rainfall and wildfires that enhance the potential for landslide occurrence (Alcantara-Ayala et al., 2017). Thus, it can be concluded that adverse environmental changes were imposing adverse conditions on the livelihoods of people and hence inflicting high vulnerability.

3.2.4 Institutional indicators

Though the study area was located in the district headquarter institutional support was negligible in different phases of the disaster cycle. Inadequate institutional support was noted from this survey as 62.78% responded to this. Post-disaster remedies were major activities of some institutions like the Red Cross and Natural Calamity Relief Fund at District Administrative Office (DAO). While, one village named Bhambada; was involved in the construction of gabion walls, tree plantation, and awareness as pre-disaster measures to reduce vulnerability. People were found not reporting the disaster loss as the compensation from DAO was relative to a smaller amount. 80.45% of respondents said they do nothing to control landslides at the household/community level. As there exist lengthy processes to acquire financial and logistic support, it was difficult for communities to conduct hazard mitigation practices at the community level. The National Adaptation Programme of Action (NAPA) prepared by GoN lists out the factors that exacerbate vulnerability to climate-related disasters. The factors include inadequate institutional guidance and land-use regulation, failure to implement building codes, inadequate public awareness, and limited access to early warning systems (NAPA, 2010). As the installation of early warning systems and skill development for disaster risk management reduces the vulnerability of households (Bista, 2019), this can be an important step to lowering vulnerability.

Thus, it is recommended to diversify livelihood options, increasing crop productivity by using modern technology, intensify the governmental services and work for environment protection in order to lower the vulnerability. Exploring mitigation measures can be further research steps in order to find suitable options to reduce vulnerability.

3.3 Vulnerability from different sectors

It can be observed in Table 2 that for social, economic, environmental, and institutional indicators the average percentages of scores causing high vulnerability becomes 53.31, 45.45, 85.56, and 65.54, respectively. This revealed that social and economic indicators in the study area were illustrating vulnerability in a moderate way whereas environmental and institutional sectors had a greater share in causing higher vulnerability which is also clarified in Figure 5. Results in this research were contrasting to that of Aksha et al. (2019) where social and economic sectors contributed to higher vulnerability. Here, the findings show that changing environmental conditions and the accessibility/distribution of facilities as prime causative factors of high vulnerability which is contrasting to that of Gautam (2017).

Figure 5, represents the share of a single sector in low, moderate or high vulnerability. Social and economic sectors show that their contribution to high vulnerability is minimal as compared to economic and institutional vulnerability. Among environmental and institutional sectors high vulnerability is depicted as 72.63 and 64.66% respectively (Figure 5). In social sectors percentages of moderate vulnerability were found higher whereas in economic sectors percentages of low vulnerability were greater.

Thus, when a single sector was considered it was found the environmental and institutional having their greater share leading to higher vulnerability. Measures to strengthen the institutional capacity and assurance of their presence in each village can be a topic to research in this case.
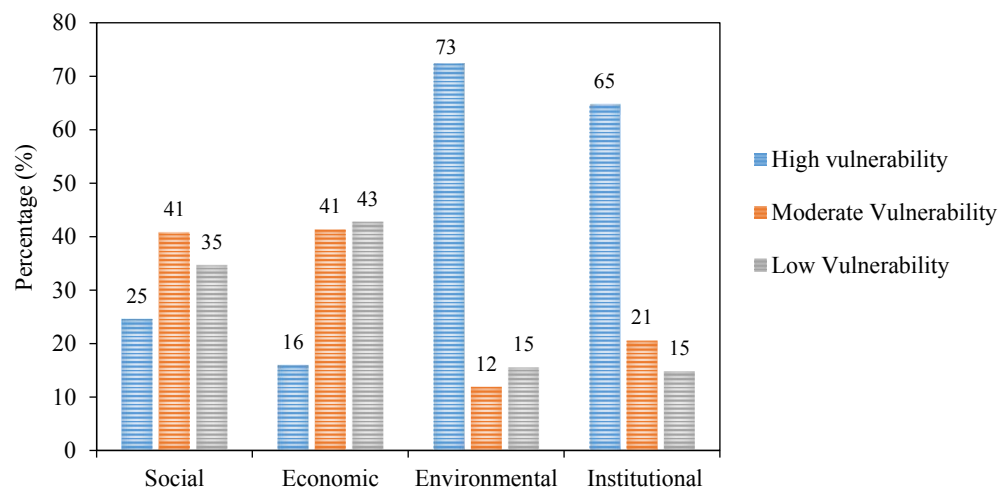

Figure 5. Contribution of a sector to vulnerability (three levels of vulnerability)

4. CONCLUSION

As the research was conducted at a local scale and use revealed circumstances for each indicator, directly from households, the vulnerability status of the people residing in headquarter of Mugu District was presented in a more accurate way. Most households reflected the moderate vulnerability and the results are quite contrasting to that of national-level assessments done by other researchers. Other vulnerability assessments showed the Mugu District as high to very high vulnerable districts. The findings showed that changing environmental conditions and the accessibility/distribution of facilities as prime causative factors. The common findings are that the isolation of an individual from the core community makes it more vulnerable such that it would be difficult and costly to provide services to people located in remote areas. Based on the inferences of this research, the reduction of vulnerability can be possible when access to infrastructures and the services are provided to all households. The isolated households should be provided with opportunities for integration in the core community to increase their capacities. Further researches in other parts of the Mugu District can provide a state of vulnerability whole district.

Besides, vulnerability is a critical issue needed to be addressed during the disaster cycle and vague inferences can lead to faulty management practices. The findings showed that results done at a local scale can be different from that of national-level studies and thus there is the necessity of local-level vulnerability assessment for precise results and fair disaster risk management. Further researches should be carried out to explore livelihood opportunities, mitigation options, and ways to effectively link governmental services to isolated areas.

ACKNOWLEDGEMENTS

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