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Assessing the community vulnerability to natural disasters and climate change in the mountainous region of Pakistan

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Abstract

It is maintained that mountainous communities are more susceptible to climatic changes and natural hazards owing to their weak socio-economic conditions and direct reliance on natural resources. This study was aimed at assessing the vulnerability and capacity of community living in mountains of District Mansehra of Khyber Phktonkhawa (KPK) province of Pakistan. A questionnaire was developed to collect data from three tehsils of district Mansehra. This questionnaire was designed to assess the six dimensions of vulnerability i.e. demographic vulnerability, socio-economic vulnerability, and physical vulnerability, vulnerability due to impacts of previous disasters, mitigation and adaptation capacity, and vulnerability due to climate change. In order to compare the vulnerability of each tehsil, a vulnerability index ranging from 0 (low) to 1 (high) was developed. This vulnerability index inferred that Balakot (0.61) was highly vulnerable, and Oghi (0.43) & Mansehra (0.39) were medium vulnerable. It was observed that fragile topography along with poor demographic and socioeconomic conditions played a vital role in making Balakot highly vulnerable to future disasters. Community empowerment and disaster risk reduction initiatives at grass root level are much needed to reduce vulnerability and enhance people's resilience.

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Introduction

Concept of vulnerability makes contacts with multiple disciplines such as disaster management organizations, climate change organizations, academia, and development organizations. This multidiscipline nature of vulnerability led to various definitions of vulnerability (Fellma, 2012).

Intergovernmental Panel on Climate Change defines the climate based vulnerability as the degree of susceptibility of a system, place and person and incapable of dealing with effects of changing climate (2007). Vulnerability is a function of the exposure and sensitivity of a system to its adaptive capacity (Ludena *et al.*, 2015; Martin *et al.*, 2017). Vulnerability in context of poverty and development is a cumulative measure of human wellbeing that incorporate social, economic, political and environmental exposure to a range of detrimental shocks or stresses (Adger and Kelly,1999).United Nations-International Strategy for Disaster Reduction (2004) characterizes the vulnerability as, the conditions established by physical, environmental, economic and social factors, which enhance the tendency of a community of being harmed by hazards. These factors are major dimensions of vulnerability assessment in current research (Gentle and Thwaites, 2016; Aryal *et al.*, 2018).

Communities living in mountains are especially at risk, as they are highly reliant on natural resources for their livelihoods, highly exposed to natural disasters, and marginalized (Malek *et al.,* 2015*;* Fuchs *et al.,* 2017). Increased glacier melting and increasing temperature at higher elevations are providing the evidence that mountain ecosystems are turning out to be hotpots of climate change (Gentle and Maraseni; 2014; Arias *et al.*, 2016; Aryal *et al.*, 2016). Consequences of these changes may have very severe impact on mountain ecosystem and communities, as well as downstream communities (Macchi, 2011). It has been a growing opinion that climate change has resulted in alteration in biological and physical systems (Intergovernmental Panel on Climate Change, 2007), such as decrease in size of glaciers, changes in amount and frequency of precipitation, variation in cultivation and harvesting seasons, changes in flowering and fruiting pattern, emergence of pests, and movement of distribution ranges in flora and fauna in order to adjust the variation in environmental conditions *(*Lama and Devkota,2009; Keilerand Fuchs, 2016; Keating *et al.,* 2017).

The topography of mountainous areas with their climatic conditions make communities more vulnerable e.g. active landslides, riverbeds or river streams at foothills etc. Impact of climate change and natural hazards will be more prominent in resource-deficient mountainous community, as they have poor socio-economic conditions due to remoteness (Bryan *et al.,* 2012). There is high level of correlation between poverty and vulnerability to natural disasters (Willis *et al.,* 2014*).* It has been established that poor people lies in the most vulnerable category from natural disasters (Vermeulen *et al.,* 2011; Mallari *et al.,* 2016*;*Hufschmidt and Glade, *2010*; Birkmann *et al.,*2013). Keiler and Fuchs (2016) and Keating (2017) also pointed out that poverty has negative influence on adaptive capacity of community; Poor communities have less resources and lack of ability to adapt. Poor are compelled to live in marginalized area, as they have no other option to settle (Kaplan *et al.,*2009).In fact, it is believed that vicinity to an extreme natural hazards combine with low income or social status ended up in devastating consequences *(*Ciurean *et al.,*2013).In the past, center of attention of vulnerability assessment was limited to analysis of stressors i.e. climate change, earthquake, flood etc. and their overall impacts. With the growing time, vulnerability assessment approach has developed with investigation of system under stress or threat, and its capacity to react *(*Fontaine and Steinemann, 2009).

In this study, multiple dimensions or components of vulnerability have been investigated to assess the vulnerability of mountainous community of district Mansehra, KPK Pakistan. These examined dimensions of vulnerability are demographic vulnerability, socio economic conditions, quality and

type of physical infrastructure (Physical vulnerability), impacts of previous disasters, mitigation and adaptation capacity, and vulnerability due to climate change (Herman-Mercer *et al.*, 2016). Vulnerability of any area can be measured by using different approaches; Vulnerability and capacity assessment (VCA) is such a tool which is most popularly used for the collection and analysis of data to recognize the risk and vulnerability of community to hazards(Macchi, 2011; Gentle and Mazarseni, 2012). According to International Federation of Red Cross and Red Crescent Societies (IFRC, 2003; 2006a,b,c,d), VCA is participative process to determine risks and capacities at local and national scale, this can provide in-depth picture of community hazards. Using VCA, an index ranging from 0 to 1 for each assessed component was developed, 0 representing the least vulnerable and vice versa. Current study has major objective to identify the root causes of local peoples' vulnerability by assessing the factors associated with the exposure to climate change and natural hazards. Further capacity assessment of mountainous communities was carried out to judge their coping strategies. A tehsil-level comparison was also conducted to recognize and rank vulnerability status based upon their cumulative index score.

Materials and methods

Study Site

This study was conducted in District Mansehra of KPK province of Pakistan. It has a spread over an area of 4,579 sq. km. The area is dominated by high mountains, with an elevation ranging from 200 m to 4500 m asl.

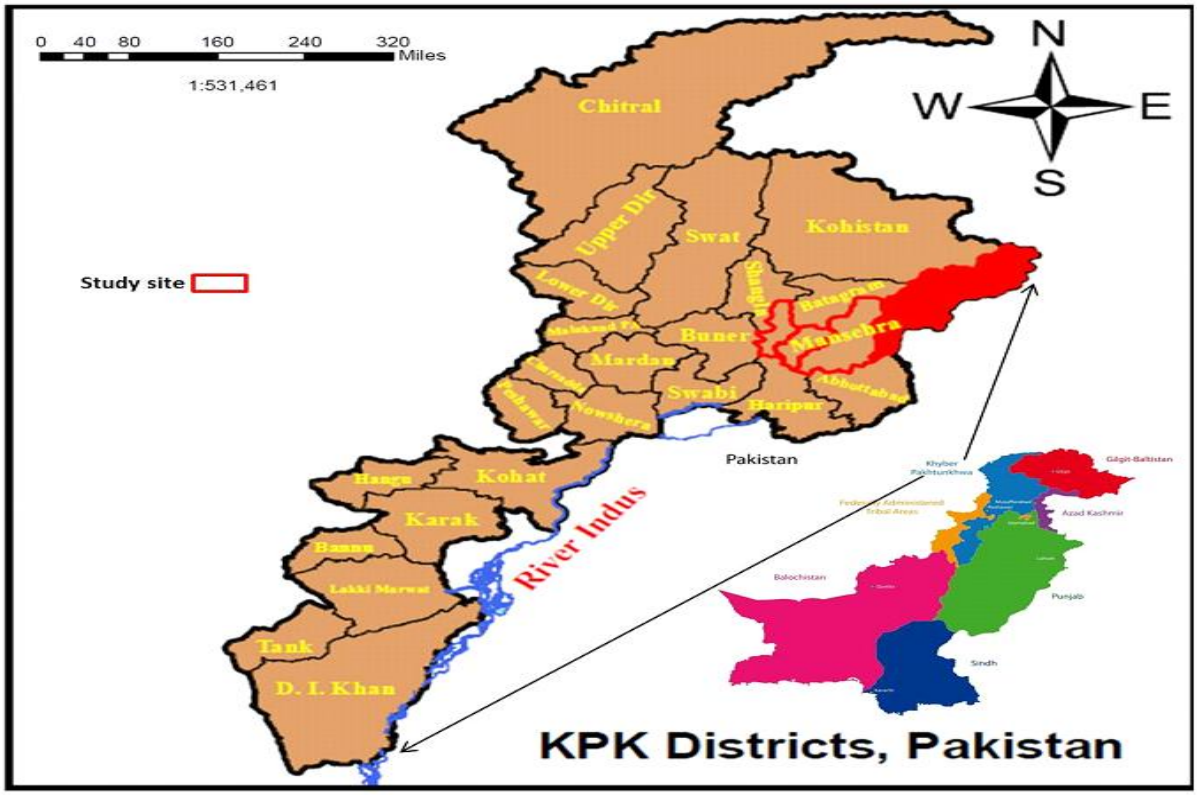

Fig. 1. Map of study area showing District Mansehra (red outline) in KPK Province (blue color) of Pakistan with three major Tehsils.

The slopes and peaks of these mountains are rich with flora and fauna (Earthquake Reconstruction and Rehabilitation Authority, 2007). Total size of households currently is 239,275 with estimated population of 1,556,460 (Unpublished). District Mansehra was most affected by the Kashmir syntax Earthquake in 2005. The area has then become a popular research site due to its disaster prone nature.

District Mansehra has three tehsils; Balakot, Mansehra and Oghi (Fig. 1). Among the three tehsils, Balakot was the worst affected in earthquake 2005; many thousands deaths and injuries were reported (United Nations Development Programme, 2007).

Almost all the houses and schools were destroyed. Balakot lies in the red zone of seismology according to measured Iso-seismal map of this region and it has active fault line (Zare and Paridari, 2008).

Data Collection using VCA

To apply VCA tool, a semi-structured questionnaire was developed through extensive literature review. Questionnaire had six sections, and total 50 items were developed. First section inquired demographic characteristics of the households. Second section of the questionnaire was consisted of socio-economic information. Third section of questionnaire was comprised of information about infrastructure and building structure of their houses. Fourth section was about the impacts of previous disaster on their livelihoods. Fifth section gathered data about adaptation and mitigating capacity of community to cope with adverse effects of natural disasters. Last section of questionnaire dealt with the climate change and its impacts on community living.

Pilot study

A Pilot study was conducted for pre-testing of questionnaire. In this, few questionnaires were used to interview the households of Balakot city. This study helps to check the validity and relativity of questions to the particular area. After this pre-testing, some modification was done in final questionnaire to be conducted in field survey of the study.

Main Survey Design

From each tehsil of Mansehra district, one major village was chosen for gathering household data. A total of hundred (100) households from each Tehsil were randomly selected for the questionnaire interview this makes an aggregate sample size of 300. Head of the household was interviewed considering that they are living in the area from last 20 years. Living span of interviewee was considered so that they should have observation of changing climate (Adger *et al*., 2013).

Scoring procedure

Six factors or components which contribute to vulnerability were assessed through the questionnaire. These components are demography, socio-economic factors, physical factors, impact of past disasters, mitigation and adaptation capacity, and climate change. Further, these components were consisted of some variables. Variables in each component of questionnaire were given the vulnerable status ranges from 0 to 1, 1 being the highest vulnerable, and 0 as the least vulnerable.

Vulnerability index of each variable (VI_v) was calculated by following formula.

$VI_v = Vf_1 \times PRD_1 + Vf_2 \times PRD_2 +$ and so on

Where Vf_1 and Vf_2 are vulnerability factors for category 1 and 2 of variable, respectively. Vf can vary depending on the categories of each variable e.g. Vf_1, Vf_2, Vf_3 .....

PRD_1 and PRD_2 are percentage responses in decimal for category 1 and 2 of variable, respectively. Percentage responses in decimal (PRD) can be PRD_1, PRD_2, and PRD_3.....

$$VI_v = \sum_{i=1}^{n} (Vfi \times PRDi)$$

Where,

Vf_i = Vulnerability factor for *ith* category of variable. Vf_i can be any value ranging from 0 to 1 depending upon the category of variable.

PRD_i = Percentage response in decimal for *ith* category of variable.

n = number of categories of variable.

Vulnerability index of each component (VI_c) was calculated by following formula.

$$VI_c = \frac{Sum\ of\ vulnerability\ indices\ of\ all\ the\ variables\ in\ that\ component}{number\ of\ variables\ in\ that\ component}$$

Components can be demography, socio-economic, physical, impact of past disasters, and mitigation and adaptation capacity, and climate change.

Overall vulnerability index for each tehsil (VI_t) was calculated by following formula.

$$VI_t = \frac{Sum\ of\ vulnerability\ indices\ of\ all\ the\ components}{number\ of\ components}$$

A scale was developed to rank the vulnerability index of each tehsil (Fig. 2). According to this scale, population having vulnerability score less than 0.25 was ranked as least vulnerable (L). Population having vulnerability score in the range of 0.25 -0.50 was ranked as medium vulnerable (M). Community having vulnerability score above 0.50 was ranked as high vulnerable (H).

Results and discussion

Demographic vulnerability

Results indicate that Balakot is demographically more vulnerable as compared to other tehsils, as demographic vulnerability index of Balakot (0.42) is higher than Mansehra and Oghi (Table 1).

Table 1. Demographic Vulnerability Index.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
No. of family members living in a household	0.57	0.40	0.38
No. of children per household	. 061	0.41	0.42
No. of household members above 60 years	0.31	0.22	0.23
No. of women per household	0.53	0.33	0.28
No. of disabled person	0.11	0	0.01
Vulnerability index for components	0.42	0.27	0.26

Table 2. Socioeconomic Vulnerability Index.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
No. of earning members per household	0.79	0.74	0.83
Estimated monthly income	0.65	0.38	0.46
Source of income	0.49	0.25	0.23
Highest educational attainment	0.60	0.37	0.38
No. of school age children enrolled	0.54	0.61	0.68
No. of unemployed members of age 18+	0.25	0.08	0.08
Access to safe drinking water	0.74	0.36	0.24
Access to health facilities	0.74	0.36	0.48
Vulnerability index for components	0.60	0.39	0.42

Large family size and ratio of dependent population, such as Children, elderly, disabled persons, and women were key components in this category which were higher in Tehsil Balakot. The dependent population increases the vulnerability because they demand special attention in the time of crises, adding to it, fewer resources were documented which indicates higher poverty. Similar findings were given by Gentle and Marasani 2012 where large household more dependency made Nepalese in Jumla district more vulnerable.

Socioeconomic Vulnerability

Socio- economic vulnerability was high for Balakot (0.60) relative to Mansehra (0.39) and Oghi (0.42) (Table 2).

Table 3. Physical Vulnerability Index.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
Land ownership	0.54	0.12	0.16
House ownership	0.12	0.12	0.16
Existence of building codes	0.83	0.92	0.82
Roof structure	0.38	0.09	0.35
Wall structure	0.56	0	0.04
Overall condition of house	0.50	0.16	0.32
Is house made on steep slopes	0.70	0.16	0.16
Physical condition of public school	0.50	0.08	0.24
Distance of nearest public health facility	0.69	0.24	0.50
Road condition	0.78	0.16	0.12
Open spaces around buildings	0.68	0.68	0.64
Vulnerability index for components	0.57	0.24	0.31

Table 4. Vulnerability Index for Impact of Previous Disasters.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
Household members affected from which disasters(past 10 years)	0.83	0.08	0.16
No. of death in previous disasters (past 10 years)	0.29	0.008	0.008
No. of injured in previous disasters (past 10 years)	0.33	0.01	0.04
No. of missing person in previous disasters	0	0	0
Frequency of earthquake occurrence	0.81	0.37	0.30
Frequency of landslide occurrence	0.65	0	0
Frequency of flood occurrence	0.70	0.24	0.28
Frequency of cyclone	0.10	0	0
Most affected member in family by disaster	0.69	0.08	0.14
Is school damaged in previous disasters	0.96	0	0.44
Is house damaged in previous disasters	0.98	0.28	0.48
Cost of damage on assets from past disasters	0.64	0.04	0.16
No. of days to go back at work after previous disaster	0.86	0.19	0.34
No. of days to go back to normal life	0.86	0.15	0.37
How long it take to initiate or provide emergency and relief services	0.92	0.86	1
Vulnerability index for components	0.64	0.15	0.24

In this case, more unemployed adults, less income sources coupled with less education attained were major factors to increase people's vulnerability. Socio-economic conditions of Balakot community were very poor; most of population belonged to poor class having income less than 15000 rupees per month. Mostly people were laborer. They were unable to meet the expenses of physical mitigation to avoid the adverse impacts of disasters. Most of households in Balakot had no access to safe drinking water and health facilities.

These poor socio-economic conditions affect their ability to cope with adverse effects of natural events, because access to water, sanitation and health facilities encapsulate the resources of community to which people can turn in at the time of disaster. These results endorse the statement made by Busby *et al.*,(2010)that communities having low level of literacy rate, deprive of access to clean water and health facilities are more likely to be at risk of being harmed. Similar findings were reported by Bryan *et al.*, 2013.

Table 5. Vulnerability Index for Adaptation and Mitigation Capacity.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
Provision of training on risk management	0.88	1	1
Availability of early warning system	0.97	1	1
Did you get any warning in last disaster	1	1	1
Adequacy of first aid and rescue facilities	0.67	0.44	0.57
Availability of evacuation center	0.90	0.80	0.72
Vulnerability index for components	0.88	0.84	0.85

Physical Vulnerability

Physical vulnerability of infrastructure and building was higher for Balakot (0.57) as compared to Mansehra and Oghi (Table 3).Physical features, such as location, type of infrastructure and houses, are important part of vulnerability assessment. Most of houses in Balakot were located on steep slopes. Land sliding was common phenomena in Balakot. Balakot had poor quality of houses as compared to Mansehra and Oghi. Most of roads were in poor condition.

These results are in line with the views *of* Kohle *et al.,* (2007*),* as vulnerable location along with poor physical infrastructure have enhanced the vulnerability of Balakot relative to other communities.

Table 6. Vulnerability Index for Climate Change.

Variables	Vulnerability index of variables		
	Balakot	Mansehra	Oghi
Change in temperature observed over last 10-20 years	0.86	1	0.80
Effect of temperature change on income	0.65	0.52	0.52
Seasonal variation in flowering and fruiting pattern	0.39	0.08	0.28
Impact of climatic variation on food production	0.67	0.68	0.46
Change in food diversity	0.28	0.24	0.32
Change observed in harvesting season	0.35	0.16	0.52
Change observed in amount of annual rainfall	0.74	0.81	0.73
Impact of change in rainfall on agricultural production	0.80	0.76	0.64
Change observed in glacier melting	0.64	0.60	0.76
Change observed in snow pattern	0.54	0.54	0.62
change observed in tree pattern	0.16	0.08	0.20
Vulnerability index for components	0.55	0.49	0.53

Impact of past disasters

Impact of previous disasters has been used as an indicator to assess the vulnerability of communities of Balakot, Mansehra and Oghi (Table 4). Index for impacts of past disaster was high for Balakot (0.64), as compared to Mansehra (0.15) and Oghi (0.24). As Balakot is located on fault line, small scale earthquakes often occurred. In earthquake 2005, Balakot was damaged adversely. Higher number of deaths and injuries were recorded in Balakot as compared to Mansehra, and Oghi. The results of current study showed that almost all households were affected by the earthquake and currently people were living in temporary shelters provided by other Governments to Pakistan. Balakot is highly vulnerable, as the case study conducted by Crowards (2000) revealed that if an area had faced more number of deaths and injuries in previous disaster, it

will be higher vulnerable to future disasters also.

Adaptation and mitigation capacity

Almost similar response was found for mitigation and adaptation capacities of all the three tehsil. Vulnerability indices for mitigation and adaptation capacities were 0.88, 0.84, and 0.85 for Balakot, Mansehra, and Oghi respectively (Table 5). Results indicate that all of three communities are at high risk due to lack of mitigation and adaptation capacity.

Table 7. Ranking of vulnerability of each tehsil.

Tehsil	Demographic vulnerability	Socio-economic vulnerability	Physical vulnerability	Impact of past disasters	Mitigation and adaptation capacity	Climate change	Overall vulnerability	Ranking of vulnerability
Balakot	0.42	0.60	0.57	0.64	0.88	0.55	0.61	H
Mansehra	0.27	0.39	0.24	0.15	0.84	0.49	0.39	M
Oghi	0.26	0.42	0.31	0.24	0.85	0.53	0.43	M

H = 'High vulnerable', and M = 'Medium vulnerable.'

They have received no training on disaster or risk management. There was no early warning system available. First aid and rescue services were not satisfactory. Evacuation center were not available and neither community was aware.

Climate change and its impacts

Vulnerability indices to climate change were higher for Balakot (0.55), with Oghi (0.53) and Mansehra (0.49). Phenomenon of climate change has been observed in study area as an increase in temperature, increase in glacier melting and change in precipitation were the common perception of people about climate change.

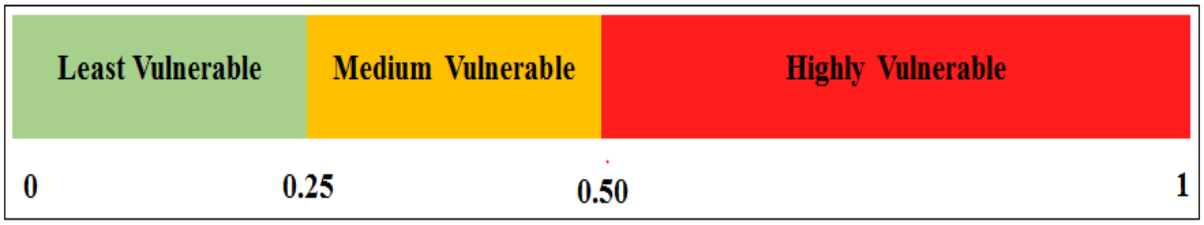

Fig. 2. Vulnerability index scale highlighting status of vulnerability according to scores.

This change in climate was equally affecting the communities of Balakot, Mansehra, and Oghi (Table 6).

Comparative vulnerability analysis in three Tehsil

Overall vulnerability of each tehsil was calculated by taking the average of vulnerability score of all the six components (Table 7).

The overall vulnerability of each of tehsil was ranked into three categories i.e. high, medium, and low. A scale was developed to rank the vulnerability index of each tehsil (Fig. 2).

According to this scale, Balakot community was ranked highly vulnerable, as its index score was 0.61. Both Mansehra and Oghi were ranked as medium vulnerable, as their scores were 0.39 and 0.43 respectively.

Demographic characteristics, socio-economic conditions, physical location and infrastructure of houses and buildings, exposure to more disasters, lack of mitigation capacities, and continuously changing climatic conditions has increased the overall vulnerability of community of Balakot relative to communities of Mansehra and Oghi (Fig. 3).

Vulnerability scores of Mansehra and Oghi are very close to each other, as they have almost similar type of demographic, social, economic, physical, and climatic conditions. Difference of Balakot community with other two communities is visible in demographic and socio-economic conditions.

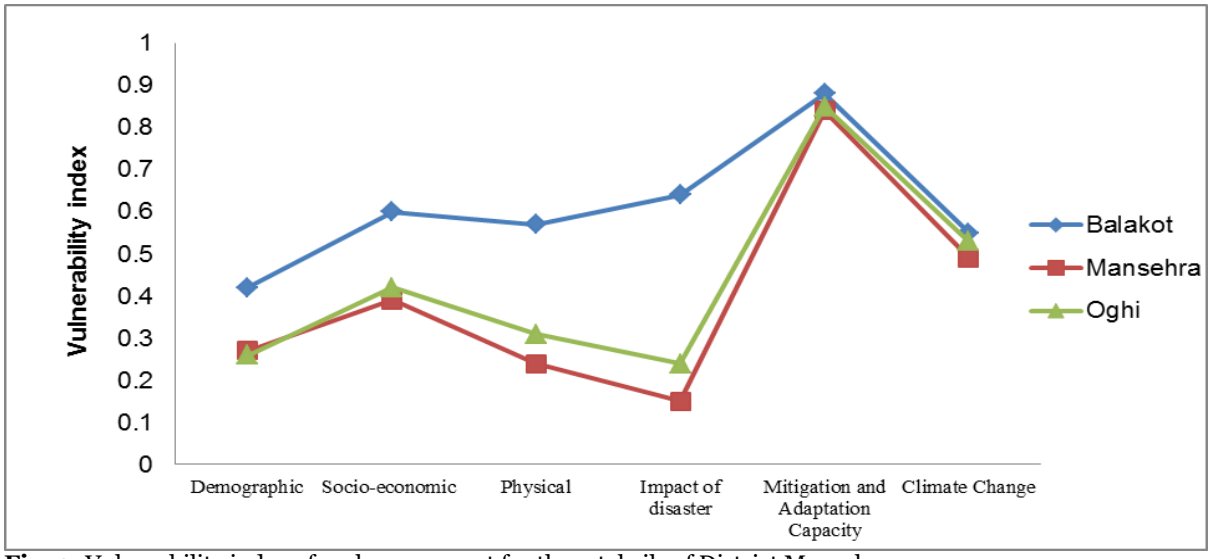

Fig. 3. Vulnerability index of each component for three tehsils of District Mansehra.

Poor condition of houses and physical infrastructure further increase the gap between Balakot and other two communities. Further, Balakot is situated at fault line, which makes it more prone to disasters. Lack of mitigation and adaptation capacities increases the vulnerability of each community, as none of communities have developed any capacity to cope with future disaster.

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Conclusion

This study has concluded that vulnerability and adaptation capacity of different communities vary according to their socio-economic and demographic conditions. Communities living on steep slopes are more prone to have natural disasters in future, therefore to enhance their resilience education and awareness in needed. Although all selected tehsils were equally vulnerable towards climate change as they had no mitigation and adaptation capacity. It is further suggested the management of Disaster must shift from reactive to preventive approach by creating awareness among masses of disaster-prone areas like Balakot. Availability of early warning system should be ensured for timely evacuation and safeguard belongings.

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