

Socio-environmental and industrial vulnerability analysis of the communities in the Shiwalik region of Indian Himalayas foothills

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ABSTRACT

Socio-environmental vulnerability assessment in mountain landscapes depends upon multiple human-induced factors such as GHGs emissions from industry, transport, agriculture, and other vital economic sectors. However, there is a knowledge gap on choosing suitable indicators to assess socio-environmental vulnerability that addresses altitudinal variations. The present study was conducted to systematically analyze essential components of social vulnerability of an industrial area of the Shiwalik region of Indian Himalayan foothills by evaluating the role of industrialization under the climate change threat. Moreover, this study also attempts to identify guidelines for adaptation mechanisms which directly or indirectly governs the livelihood of communities of Shiwalik Himalayas. We identified the various dimensions of vulnerability such as exposure, sensitivity, adaptive and coping capacity based on existing literature and prevailing situations of the study area. We collected data on the indicators in a questionnaire-based survey of 96 randomly selected households to adjoin industrial regions. The findings suggested that the communities were more vulnerable to the ongoing activities of industrialization. Industrialization, climate change, and their enhanced role in climate change vulnerability among these local communities were linearly correlated. Besides, industrial establishment in the selected area has led to various problematic impacts such as deterioration of air quality through industrial emissions like GHGs emissions, waste generation mostly untreated, further causing severe health and environmental problems. The rising of health-related issues, especially respiratory diseases, was more prominent in the studied areas. This study will help policymakers formulate effective strategies to reduce social and environmental vulnerability due to enhanced industrial activities and establishment in the Shiwalik region of the Indian Himalayan foothills.

Introduction

Variability in climate is a self-regulatory phenomenon occurring naturally. Since the periods of formation of Earth's atmosphere have been both heating and cooling history and it has induced changes in ecological and social systems (Folland et al., 2001; Salinger, 2005; Carter and Makinen, 2011; IPCC, 2014; Pandey and Bardsley, 2015). However, the Earth's climate system is expanding the frequency and intensity of strange changes to the past millennium. The changes detected in the 20th and 21st centuries are primarily due to human activities (IPCC, 2013; Mann et al., 1999). The spatial pattern and threat posed by climate change and related vulnerabilities are particularly viable for mountain communities (Caesar et al., 2011; Pandey and Bardsley, 2015). The mountains have specific features and unique ecology and the environment, i.e., marginality, fragility, remoteness, and high dependency on natural resources and agro-ecosystems (Bhatta et al., 2015;

Gerlitz et al., 2016; Tsering et al., 2010). The increased frequency of extreme events such as floods, droughts, earthquakes, landslides, excessive cloudbursts, and abnormality in rainfall poses severe threats to the Himalayan community in addition to industrialization (Berrang-Ford, Ford, & Paterson, 2011; McEvoy, Matczak, Banaszak, & Chorynski, 2010; Satendra et al., 2014). These phenomena have exaggerated the vulnerability of social and ecological systems in the region (Nandargand Dhar, 2011; Shrestha et al., 2012). The Himalayas are the most extensive, most fragile, and young mountain systems (Tsering et al., 2010). This region lies in one of the poorest regions in the world (Hunzai et al., 2011), with a physically and biologically convoluted and diversified mountain system. The Himalayas are endowed with significant natural resources that support valuable ecosystem services and livelihoods for economically marginalized communities from mountains to plains (Gerlitz et al., 2017; Sandhu and Sandhu, 2015). Mountain communities are among the poorest and most vulnerable worldwide.

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The vulnerability of the Himalayan mountain communities is due to the remoteness of access, unsustainable development, and the over-exploitation of local natural resources (R. Pandey et al., 2017; Shukla et al., 2016; Gerlitz et al., 2016; Nandy et al., 2011).

Various researchers have assessed the vulnerability of different sectors in the Himalayas towards climate change, such as community (Pandey and Jha, 2012); water (R. Pandey et al., 2015); socio-environmental systems (Pandey et al., 2016a,b); and vulnerability of livelihood (Gerlitz et al., 2016).

The increase in extreme events in the past two decades dominates the increased socio-environmental vulnerability of the Himalayan community (Gupta et al., 2019; R. Pandey et al., 2017, 2016a; R. 2015; Pandey and Bardsley, 2015; Pandey and Jha, 2012; Panthi et al., 2015).

The “vulnerability” concept has evolved from the social sciences (Wisner and Luce, 1993). It reflects the degree to which a system is susceptible to adverse effects caused by a specific hazard or stressor (IPCC, 2014). It has emerged as a critical consideration in adaptation options to climate change (Birkmann, 2007; Cutter, 2003; Eakin and Luers, 2006). Identification of vulnerable hotspots and understanding the process and roots of vulnerability is a common concern to govern, allocate and prioritize resource distribution are prime concerns for policymakers (El-Zein and Tonmoy, 2017). The vulnerability studies, particularly in the Himachal Pradesh, of Indian Himalayan state, are restricted to disaster vulnerability and resilience studies (glacial lake outburst flood risks) (Allen et al., 2016) and earthquake (Pandey et al., 2015), and forest ecosystems and climate change vulnerability (Upgupta et al., 2015), the vulnerability of current farming systems (Chauhan et al., 2019b; Chauhan et al., 2019a). No systematic study is available on communities’ socio-environmental and industrial vulnerability adjoining Himachal Pradesh’s industrial area.

Evaluating industrial areas under the current threat of climate change may provide a framework for assessing the community vulnerability and pathways for creating an environment to cope with the aggregate conditions due to the simultaneous industrial emission of climate change. The present study attempts to assess the socio-environmental vulnerabilities within individual households of an industrial area in the Himalayan foothills. The vulnerability assessment undertaken in this study will provide the database on the highly vulnerable landscapes and communities towards industrialization. The study will drive the state mechanisms for allocating resources by prioritizing assistance for the most vulnerable households and communities.

Materials and methods

Profile of study region

Himachal Pradesh is the northern state of India that covers the mountainous landscape. This state is located between 30° 22' 40" 105 N to 33° 12' 40" N and 75° 45' 5" E to 77° 15' 14" E. This state is bordered by Uttar Pradesh, Jammu, and Kashmir, Haryana, and Punjab. The total population is 6.8 million people of India's 1.7% of the land. It is predominately an agricultural state where 71% of the total population generates income from agriculture contributing to 9.4% of total State Domestic Product (SDP) (Census of India, 2011; Chauhan et al., 2020). The biophysical and socioeconomic characteristics of Himachal Pradesh are presented in table 1. In this state, the Himalayan range ranges at lower altitudes (≤ 1000 m a.s.l.) known as the Foothills and outer Himalayan zone), a subtropical climate. Areas at middle altitude (1000–1500 m a.s.l.) known as the Siwalik and Lower Montane Zone with a humid subtropical climate. The study was carried out in the south-western region of the Solan districts, Himachal Pradesh. The focus of the study area is rural settings near the industrial area in the district (Fig. 1). Solan covers a geographical area of 1936 sq. km. lies between 30° 44' 53" to 31° 22' 01" north latitude and 76° 36' 10" to 77° 15' 14" east longitude (ISFR, 2019). According to the Indian state of forest report,

Table 1

Bio-physical and socioeconomic characteristics of Himachal Pradesh.

Bio-physical and socioeconomic parameters	Description
Geographical area (km ²)	55,673, (1.69% of whole country)
Population	6864,602
Number and name of districts	12
Number of total villages in these districts	20,757 villages
Land use	4576
Permanent pastures & other grazing land	1511.3
Fallow land (current and other than current)	22
Land under miscellaneous tree crops and groves not included in net area sown	64
Net area sown	550
Climate parameters	
Annual temperature (minimum to maximum °C)	sub-zero to 35 °C
Average rainfall (mm) across the region	1800 mm

(Source ISFR, 2019; Census 2011).

2019 Solan district recorded 890.1 sq km of total forest cover with 41.44 sq km very dense forest 444.54 sq km moderately dense forest 404.31 sq km open forest. The elevation of the district ranges from 300 to 1350 m above mean sea level. The district has some parts of very low altitude and others of high altitude. The Severe winter season is the chief climatic feature in the district. The total Annual Rainfall in the district is 983.4 mm (ISFR, 2020).

Sampling of households and data collection methods

The present study was conducted to explore the climate change social vulnerability of communities living in an industrial area by evaluating the role of Industrialization under the current threat of climate change. It also attempts to identify guidelines for adaptation mechanisms, which directly or indirectly governs the livelihood of communities of Shivalik Himalayas. A paper-based survey, based on understanding and knowledge was conducted in the region to obtain data about the role of industrial settlement and climate change for adaptation planning in Himalayan mountain communities (Tribbia and Moser, 2008; Theoharides et al., 2009; Archie et al., 2012; R. Pandey et al., 2017). The conceptual framework on mountain-specific socio-environmental vulnerability based on biophysical and social system indicators of all three dimensions of vulnerability (exposure, sensitivity, adaptive capacity) was developed (Fig. 2). We defined the functional relationships among the exposure (E), sensitivity (S) and adaptive and coping capacity (A), and different dimensions of vulnerability among the communities in various ways as per the earlier studies focused on the Himalayan landscape (Brooks et al., 2005; IDEA, 2005; Kaspersen et al., 2005; IPCC, 2014; Pandey and Jha, 2012).

The opportunities generated by Industrialization facilitate resources, which helps these communities cope with the current environment. This study discusses the changes in the region and associated coping mechanisms of these communities by adjusting the natural to artificial resources under the opportunities and impacts of Industrialization with the current climate regime. The information revolves around the various dimensions of climate change and initialization, leading to a social vulnerability in the region. The household survey was conducted in randomly selected villages within the industrial area of the chosen community in the Solan district. Five households per village were surveyed (total $n = 96$). The household survey was conducted in 11 randomly selected villages within each of the Solan districts. Although the demographic background of the sample might not have been representative of the entire population in each, the sample size covered various income and education levels. We selected relevant indicators for vulnerability assessment as per the guideline of peer-reviewed studies and own experience, which were further used to compute socio-environmental vulnerability. These indicators covered the household's biophysical parameters and socioeconomic parameters and represented

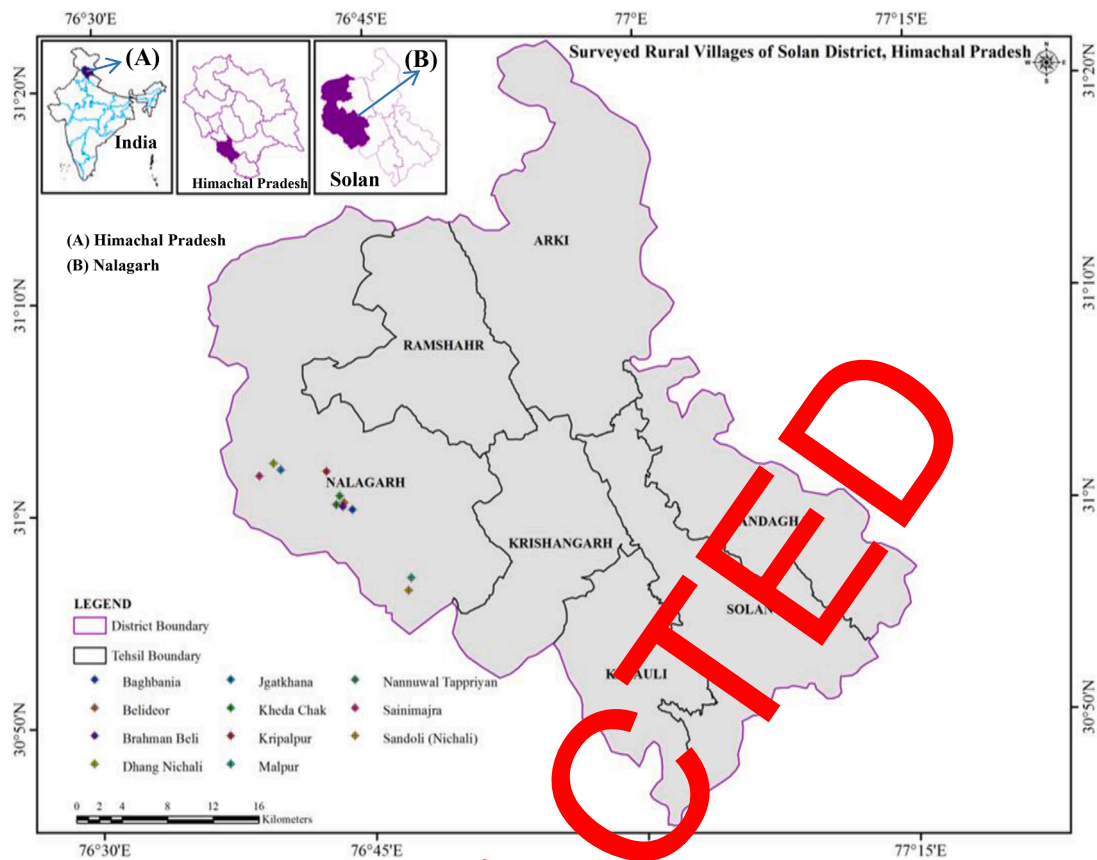


Fig. 1. Location of Nalagarh taluka in map of Solan district, Himachal Pradesh. Point indicates the location of surveyed villages.

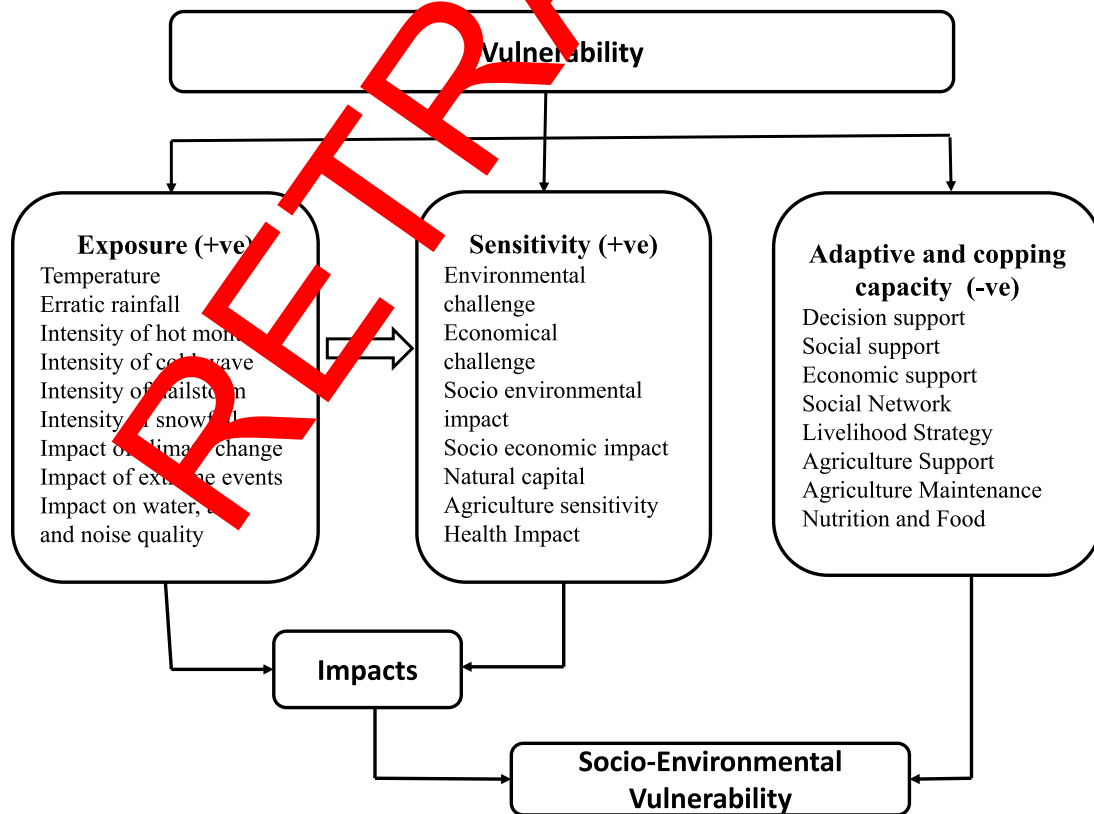


Fig. 2. Conceptual framework of the approach for vulnerability assessment (modified from Füssel and Klein, 2006).

Table 2

Indicators used for describing different components of the exposure (E), sensitivity (S) and adaptive capacity (AC) dimensions of vulnerability and the nature of their functional relationship explanations and sources to vulnerability.

Dimensions	Component	Indicator	Explanation	Source	
Adaptive capacity(AC)	Decision support	Age dependency	Ratio of working population (18–54 years) to nonworking population (0–18,>55 years) is age dependence ratio and higher the ratio more would be vulnerability	(Ali and Erenstein, 2017; Amusa	
		Gender	Females are more vulnerable (male=2; female=1)	Pandey et al., 2015; Hahn et al., 2009; Pandey and Jha, 2012)	
		Education	Higher education increases adaptive capacity	(Gbetibouo et al., 2010)	
	Social support	House type	House structure		
		Electricity	Electricity availability		
		Sanitation facility	Sanitary facilities at household These improve adaptive capacity		
	Economic support	Land	Agricultural land	(Pandey and Jha, 2012)	
		Livestock	Livestock in adult cattle units (ACU)		
		Household items	Household items represent household strength in addressing adversities		
	Social network	Major energy source	Better quality fuel is an indicator of finances and health		
		Drinking water sources and accessibility	Availability and accessibility of drinking water source indicate hygiene and labor requirements		
		Assistance from others	Providing or receiving assistance and practicing community agriculture lead to better capacity	(Pandey and Jha, 2012)	
	Livelihood strategy	Community cultivation			
		Occupation	Better and more occupations provide better income and support for household well-being leading to better adaptive capacity	(Hahn et al., 2009)	
		New activity			
	Farm support	Change in livelihood			
		Coping activities under different extreme events (change in sowing/planting/harvesting season, irrigation pattern)	Adjustment in sowing/planting or harvesting time to cope with weather and extreme events increases adaptation to	(Sridevi et al., 2014)	
		Change in cropping pattern/rotation	Change would lead to better adapt.		
	Farm maintenance (AC)	Introduction of new crop			
		Fertilizer use	Household with better farm production resources have higher productivity and thus better adaptive potential	(Pandey et al., 2016b)	
		Manure use			
Exposure (E)	Nutrition & food (AC)	Pesticide use			
		Adjustment for water scarcity			
		Adjustment for irrigation water			
	Hot months (E)	Scarcity of grass			
		Months on food availability	Food availability, good nutrition and better health lead to improved labor and thus strengthen the household, capacity	(Pandey et al., 2018)	
		Food production			
	Erratic rainfall (E)	Food sufficiency months			
		Temperature (E)	Temperature	Changes in temperature influence household livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)
		Hot months (E)	Hot months	A greater number of hot months influences household livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)
	Hailstorms (E)	Erratic rainfall	Erratic rainfall influences household livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)	
Hailstorms		Hailstorm intensity and frequency influence household livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)		
Impact of severe events (E)	Drought	Severe events can deprive households of resources and livelihoods, making them vulnerable	(Gerlitz et al., 2016; Pandey and Jha, 2012)		
	Cloudburst		(Gerlitz et al., 2016; Pandey and Jha, 2012)		
	Landslide		(Gerlitz et al., 2016; Pandey and Jha, 2012)		
Cold wave (E)	Cold spells	Long cold spells influence household livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)		
	Snowfall (E)	Snowfall	Change in snowfall can alter household production processes and influence livelihoods, exposing them to new situations	(Gerlitz et al., 2016; Pandey and Jha, 2012)	

(continued on next page)

Table 2 (continued)

Dimensions	Component	Indicator	Explanation	Source
Sensitivity (S)	Impact of extreme events (S)	Agriculture productivity	Extreme events decrease agricultural productivity and	(Gerlitz et al., 2016; Pandey and Jha, 2012)
		Water availability	water availability and thus create challenges for household	
	Human wellbeing (ecological, challenges, economic challenges) (S)	health	livelihoods	(Pandey and Jha, 2012)
		Fire	Increases in these environmental and economic challenges	
		Cloudburst	will have negative effects on ecology, economies and	
		Land fragmentation	human wellbeing, making the community more sensitive.	
		Climate Change		
		Tourism		
	socioeconomic impact (s)	Road construction		(Pandey and Jha, 2012)
		Hydro construction		
	Socio-environmental impact (S)	Wildlife conflict		(R. Pandey et al., 2017)
		Economic impact	Negative economic impact (income) in a region directly affect sensitivity	
	Natural capital	Environmental impact	Negative environmental impacts in a region directly affect sensitivity.	(R. Pandey et al., 2017)
		Fuelwood collection	Extraction of fuelwood and fodder from forest places extra	
	Agriculture sensitivity	Fodder collection (forest)	pressure on forest, leading to forest degradation, and thus increase sensitivity.	(Gbetibouo et al., 2010)
		Fodder collection (farm land)		
		Fodder collection (community land)		
		Soil fertility	Loss of soil fertility; excess soil erosion and impairment of	
		Soil erosion	microclimates, such as loss of soil moisture, has impacts on	
		Microclimate	farm productivity and increases sensitivity	
	Human capital (health)	Number of months for water sufficiency	Increased water sufficiency, lowered ground water levels	(R. Pandey et al., 2015)
		Ground water level	and surface water lead to water scarcity and thus	
		Shortage of water	increase sensitivity	
		Insect incidence	Increases in insects and pests and in human diseases	
		Disease Incidence	increase sensitivity	

prevailing characteristics of the social and ecological systems.

The indicators were aggregated, depending on their association, into 24 components representing the three dimensions of vulnerability with different components for adaptive capacity (i.e., decision support, social support, economic support, social network, livelihood strategy, farm support, farm maintenance, nutrition, and food) for exposure (temperature, hot months, rainfall, hailstorms, impact of these changes, cold spells, snowfall, impact of extreme events, water quality, air quality, visibility); and for sensitivity (human wellbeing (environmental challenges), human wellbeing (economic challenges), socioeconomic impact, socio-environmental impact, natural capital, farm sensitivity, human capital (health)). Every indicator was normalized for further processing and assessing vulnerability, as suggested in previous studies (Hahn et al., 2009; Pandey and Jha, 2012; Zurevec et al., 2017). The listing of selected indicators is given in Table 2.

The primary data are of greater significance as the study has investigated the perception and strategies of the community about climate change. Thus, village and household schedules were used as a primary tool for data collection. Most of the survey respondents were heads of household as they are well aware and have more knowledge about their region. Data were processed and analyzed through IBM SPSS and MS Excel software for frequency distribution, central tendency, and interpretation (using bar charts, column charts, pie charts) to highlight the various sections of the communities. A participatory rural appraisal (PRA) approach (Macchi, 2010) has been used for ascertaining quality household-level data. To ensure the sample did not exclude households with low literacy levels, researchers allowed for oral responses in addition to written ones. Most survey respondents were considered head-of-household acquainted with the prevailing mechanisms and livelihood options befitting local customs.

Results and discussions

Household characteristics

In this study, males were found to be the spokesperson in the family. The 86% of household respondents were reported male while 14% contributed from the female, which reflects that men are consistently the family's spokesperson. The maximum and minimum age of the household respondent was 70 and 30 years old, respectively, with a mean age (50.06 ± 1.15 years). The mean of the family size was reported the 5.6 ± 0.23 . In this region, education status was poor among the household. A minimal number of the households were educated up to a bachelor's degree (15%). Illiterate families were approx 10%, primary schooling (22%), high school (34%), and intermediate (22%).

The economic status of the households was assessed on the basis of house types i.e., pakka, semi-pakka, and kaccha. We reported three general housing types in villages such as pakka, semi-pakka, and kaccha. Pakka houses were made of brick and concrete and denoted a higher economic status. Semi-pakka houses were reported to be constructed in the same fashion as pakka without a solid surface roof. Semi-pakka houses represent less economic status than pakka houses. Kaccha houses were built using mud and wood. The proportions of pakka, semi-pakka, and kaccha houses were 91%, 7%, and 1% in the region. This analysis has shown tremendous wealth in this region. Besides, it was reported that this region has 100% accessibility of electricity with 24 h availability.

Further, the possession of the toilet inside the house was very high, i.e., 94%, due to households' higher inclination towards sanitation. Most families were reported to be dependent upon more than one profession for their subsistence and livelihood support. There were varieties of occupations reported among households. The occupations include self-

employed such as business, transportation, contractors, etc., as their primary profession (36%), followed by agriculture (25%), service (23%), shopkeeper (9%), and wage labor (6%). So we could say that the professional diversity in the study area is good due to employment opportunities. The possession of livelihood assets like television, refrigerator, cooler, motorized vehicles, etc., was reported in most households. In addition, resources obtained from community forests were also reported better in this area. Most families were notified to collect wood and cow-dung cakes for utilizing as the cooking energy source. However, slightly over a quarter of respondent households occasionally use liquid propane gas (LPG) for cooking purposes. It was fascinating to report that only one family in this area used biogas as a cooking energy source. Most of the households were reported to be making dung cakes from the waste of their livestock. A few families purchased fuelwood from local shops.

Moreover, it was also reported that households also collect fuelwood from the nearby forest. Tap water is the primary source of drinking water in this region; 84% of households were using tap water supplied by the government. Other water sources such as hand pumps or underground water and open sources (lakes, ponds, etc.) exist in this area.

Perception about industrialization and climate change

The challenges and opportunities of climate change were discussed deliberately among the respondents of the representative households. It was performed to understand villagers' perception of climate change in the context of other challenges being faced by villagers. Respondents were asked to rank the potential socioeconomic and ecological challenges presently faced by their community. It was found that fifty-one percent of the respondent considered that climate change in the region is a severe problem. The remaining 37% of respondents believed that climate change is a severe problem in this area. Forty-nine percent of respondents agreed that Industrialization is a severe problem. 51% agreed that it is a severe threat, which directly and indirectly contributes to climate change in this region. Respondents contemplated climate change, which relates to local and regional changes in weather patterns and conditions, and do not necessarily refer specifically to the broad concept of global and anthropogenic climate change. Even though respondents may not axiomatically understand the complex connections between human activity and change in the region's climate, their responses showed that they were generally aware of the problem. It was also found that the respondents understood the causes and implications of climate change and Industrialization. The inhabitants of the villages were found to be aware about changes in temperature, rainfall, water quality, air quality and visibility both horizontal and vertical that are taken place in the region. The respondents were also knowledgeable about deforestation, industrial and vehicular pollution and their cause and consequences.

Changes in precipitation and temperature

The convoluted topography of the Himalayan region has driven an abundance of micro-climates; to such a degree, this region will experience climate change (Pandey, 2016). Under substantial large-scale data collection often lacks the detail necessary to facilitate local response to changes (Chaudhary and Bawa, 2011). The present study was specifically focused on the local perceptions of changes in climatic conditions. Ninety-seven percent of respondents report a recent shift in rainfall patterns in duration, frequency, and timing. Rainfall has decreased in this region in the last few years. There was less rainfall in the monsoon season, and most farmers lost their maize crops due to insufficient irrigation. Ninety-eight percent of respondents were believed to increase average local temperatures and extreme temperatures during the most recent years. The rise in temperature in Himachal Pradesh for the 1970s varied from 1.7 °C to 2.2 °C and was found to be increased in all seasons (IMD, 2020). Respondents were informed that occurrences of extreme temperature are more frequent. Temperature change has affected not

just the summers but also winters and temperature changes experienced year-round. Respondents reported that winters are shorter and less severe than previously. In the past decades, winter conditions began in October and continued until mid-March, while in recent years, winter conditions have been relegated to a shorter period of November to mid-February. The summer days were reported to be increasing due to the temperature rise, as informed by the local communities.

Due to the increase in hot days, most families dependent on agriculture noticed a shift in the cultivation period. Nowadays, monsoon rains are slightly displaced in an irregular pattern in the period beyond mid-August. Rainfall intensity (the amount of rain falling at one time) has reportedly increased in recent years, but storm frequency and duration have decreased (R. Pandey et al., 2017). Respondents agreed that changes in precipitation patterns, forest degradation, and industrial effluents discharge have resulted in less groundwater recharge, reducing water levels and quality in local springs. According to 82% of respondents, we found a change in the visibility after the setup of the industries in the region. Besides industrial air pollutants were also reported as major causes for the difference in visibility.

Changes in water quality and noise quality

We found that ninety-four percent of respondents believed in the deterioration of water quantity in this region. Respondents also informed that rising temperature due to industrial activities is the primary cause of drying up the water sources and local water bodies. Respondents believed that increasing temperature might be the reason for highly unstable and less rainfall resulting in low groundwater recharge.

The present study has shown that chemical fertilizers in agriculture are also a significant issue causing environmental deterioration. Chemical fertilizers initially increase yields but have diminishing returns over time in agriculture practices. Respondents reported that the application of chemicals has resulted in a decrease in soil moisture, which is compounded by changes in precipitation patterns. Due to the open discharge of effluent in the local water bodies, there is contamination in the groundwater in some villages of this region (IIT Kanpur). Respondents concede that air quality is continuously deteriorating from past years after the setup of the industries, which pollutes the air through different types of pollutants such as fossil fuel emissions. These emissions include carbon dioxide, methane, and nitrous oxide, and the combustion creates these toxic pollutants. While all of these are naturally occurring substances, high levels of emissions are of concern. Industrial processes are also emitted manmade emissions such as fluorine-containing gasses such as hydrofluorocarbons. The observed impact of industrial pollution in this area is acid rain. It occurs when factory emissions combine with moisture present in the air to form acidic precipitation. Eighty-eight percent of the respondents believed that they were facing the problem of an increase in noise level. Due to industrial manufacturing and vehicular activities, there was an increase in the noise level. It is a product of Industrialization, urbanization, and modern civilization. The industrial source includes the noise from various industries and big machines working at a very high speed. In the assessment of the local communities' perception of vulnerability to climate change and Industrialization, respondents were asked to rate the 11 potential impacts of climate change and Industrialization on their community.

Respondents were also asked to rate each option on the given scale from very low possibility to high possibility, including prospects "do not expect to change" and "don't know." There were seven potential consequences: viz. local temperature, negative impacts of discharge effluents, decreased air quality, reduction of agricultural productivity, change in local rainfall, and increased respiratory diseases (Fig. 3). The respondent has chosen a meager percentage for the potential impacts of climate change and Industrialization on the open dumping of solid waste. The effects of climate change and Industrialization on local water quality in

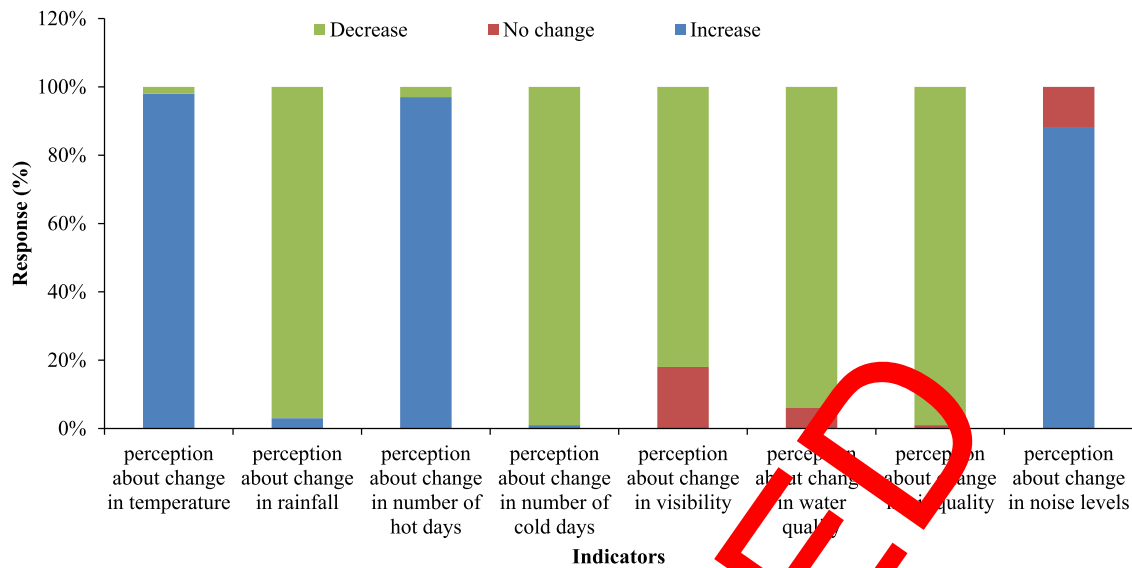


Fig. 3. Perception. of changes in the temperature, rainfall, water quality, air quality and noise levels reported by local respondents due to Climatic or Industrial exposures.

freshwater bodies (river etc.), results in impacts on agriculture crop irrigation due to the open discharge in local water bodies, which also results in contamination of the local water bodies.

Sensitivity: environmental, economic and social concern

In the assessment of villager's perspectives on climate change, respondents were asked to identify major socioeconomic and ecological concerns which are faced by the community on the basis of three primary circumstances, i.e., environmental, economic, and social. Also, to rate the eight options, including climate change, water quality, noise pollution, drainage facility, air quality, population pressure, living space, and industrial waste. (Fig. 4). In the social concerns, living space and population pressure were the most prevalent concerns faced by the

community. In environmental matters, industrial waste, air pollution, and noise pollution were the most common problems. In economic relations, industrial waste, air pollution, and water quality were significant concerns affecting the region's economy.

Fifty-five percent of respondents agreed that environmental concerns are severe, 30% thought environmental anxiety is very intense, and the rest considered it has a moderate concern. In consonance with 63% of the respondent, economic problems were severe, and 24% concluded to very severe, and according to the 13%, financial concerns were moderate. Fifty-eight percent of respondents believed that social concerns are severe, 35% concurred that social concerns are very severe, and the rest of them feel it is moderate (Fig. 5).

Fig. 6.

The study assessed the respondent's perception and concern

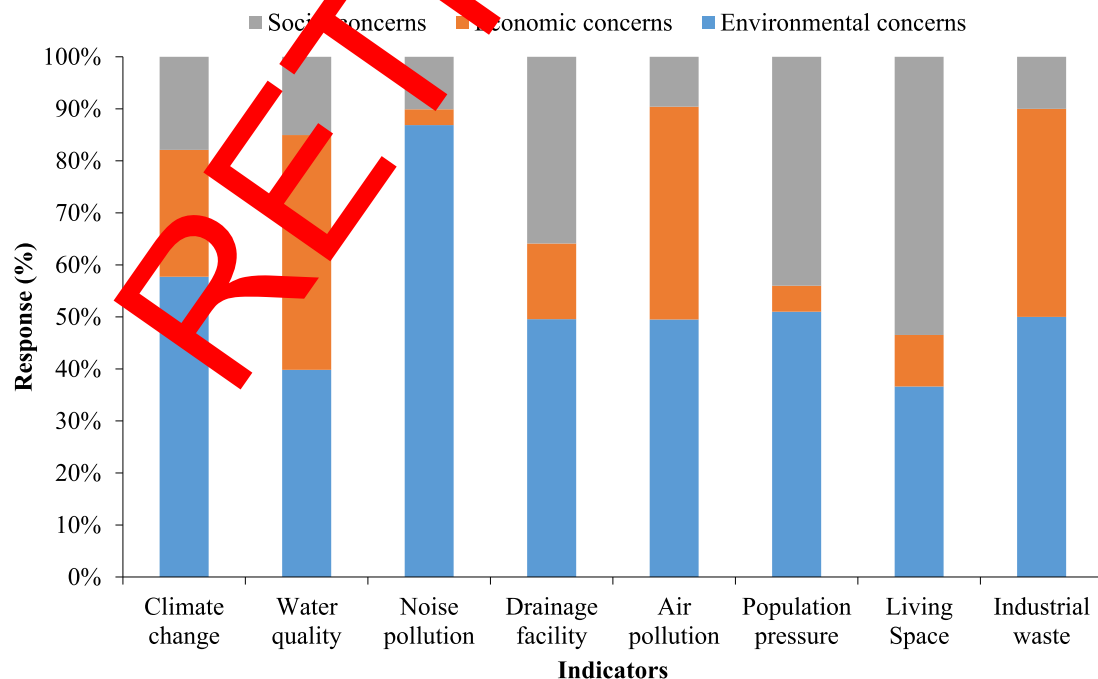


Fig. 4. Degree of impacts of climate change on various sectors reported by the community. The graph shows the percent of respondents for each choice of the different challenge.

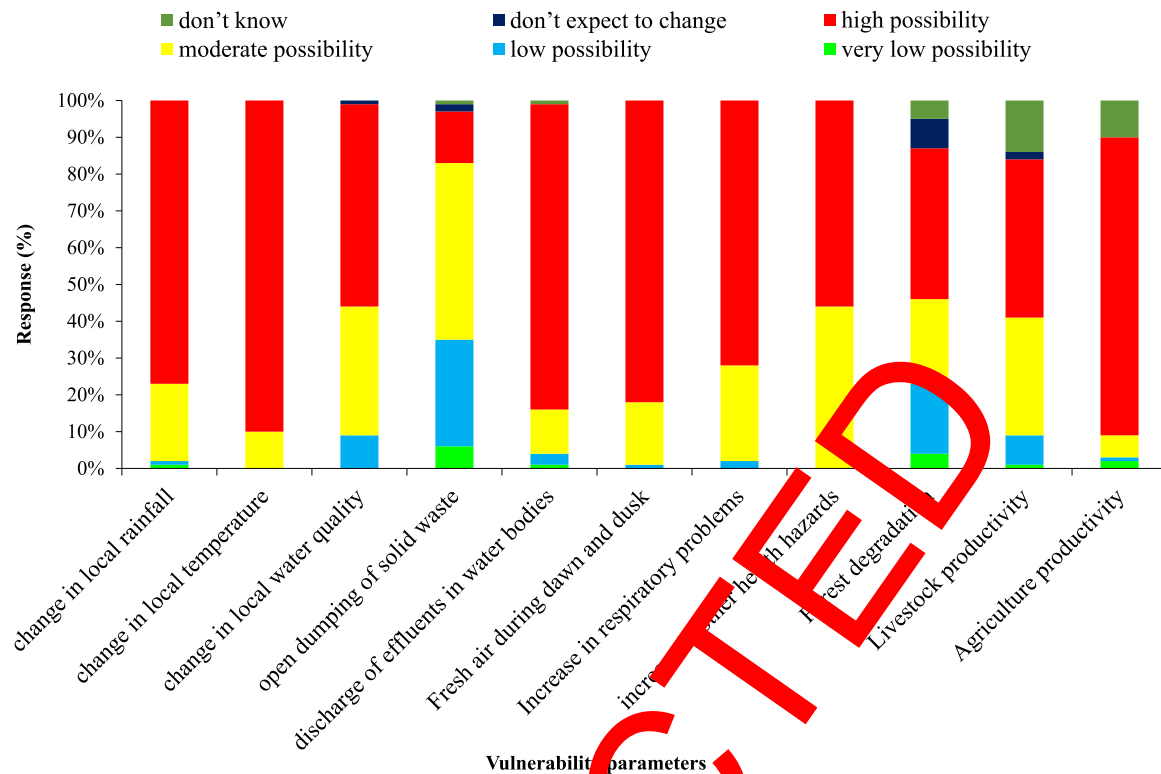


Fig. 5. Relative Socio-Economic and Environment concerns faced by the local communities.

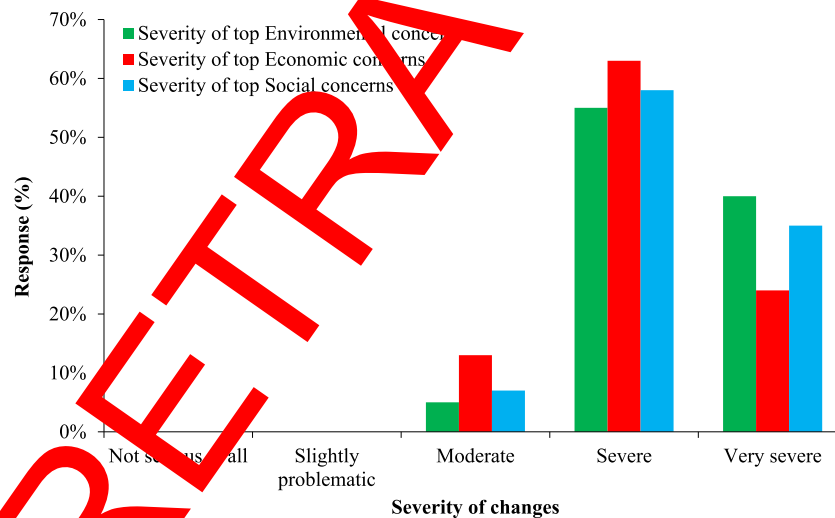


Fig. 6. Local community's severity of the top environmental, economic and social concerns. Bars show the percent of respondents who consider the option to be at very severe to moderately likely.

regarding the protective and productive functions i.e., disease incidence, food availability, waste disposal, clean water availability, and forest services. As evaluated by the surveyed villages' respondents, 100% of responses felt that the increase in disease incidences is shown in Fig. 9. As in almost every village, many people suffer from skin infection, throat infection, respiratory problems, skin cancer, liver diseases, and heart-related diseases. Almost partly, respondents reported a decrease in food availability in the region due to the population pressure in the area, and due to the variation in the climate, agricultural practices are not giving sound output. The availability of clean water in the area has decreased in the last decades due to the industrial activities, open discharge of effluents, open dumping of solid waste, and many

groundwater resources affected by these activities. The waste disposal system is decreased and involved in the region due to the high waste generation from the industries and households increase the load on the disposal system. According to the respondents, forest services are decreased and declined due to excessive exploitation of forest resources. Changes in the weather system have impacts on this aspect of the ecosystem as well.

Adaptation capacity and coping strategies

The primary objective of this study was to know and understand how vulnerable are the communities of this region currently due to

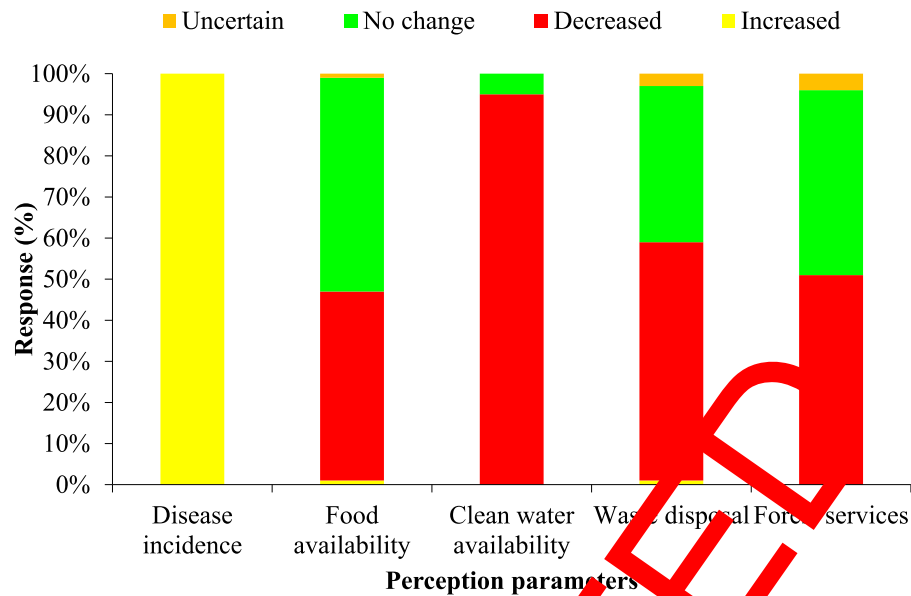


Fig. 7. Perception about Protective and Productive function.

Industrialization and climate change. In this context, respondents were first asked whether if they are getting any kind of assistance or support like medical assistance, and material supports, information and technical assistance, etc. (help from friends, NGOs, Government) for adaptation practices and then were asked whether or not their household has developed any sort of strategies or plans to deal with impacts from the Industrialization and climate change. Given the high disengagement of the study area and the low level of education, the analysis of adaptation strategies is intriguing to put in place by the residents (Pandey et al., 2017).

Sixty-six percent of respondents obtained assistance through their friends and neighbors (Fig. 7), 18% obtained a grant through the government, and 01% from local NGOs or welfare societies, rest of the respondents didn't receive any kind of assistance for adaptation practices and overall 12% households were members of any social organization.

Respondent was asked whether or not their household carried out or developed a plan or strategy to deal with the potential impacts of Industrialization and climate change. Overall, 51% of the respondents conveyed that they have plans for minimizing the effects of Industrialization with the help of some social organization and panchayat or

through the social organization. Thirty-three percent of respondents reported that the procedure is being carried out for impacts of Industrialization. Individually livelihood strategy, maximum households have changed their livelihood strategies by shifted towards doing business for their livelihood. Options for the changes in the livelihood of the communities were migration, wage labor, business, and some activities. According to ninety-four percent of respondents, there was an increase in the job opportunities due to the setup of the many new industries in the region, which provides new job opportunities to local communities. People from other areas are migrating to this region in search of job opportunities. Forty eight-percent of respondents reported that there is no change in the cultivation period. In contrast, 38% reported a decrease in the cultivation period as almost all households using fertilizers and insecticides to use chemical fertilizer, hybrid seeds, and pesticides in their agriculture practices.

A preceding similar study has delineated that adaptation decisions can be contagious (Archie, 2013). Respondent was asked to adjust the water scarcity; 53% of respondents said they bring water from other places while the rest had underground water resources but in low conditions. The majority of the population did not have any adjustment of

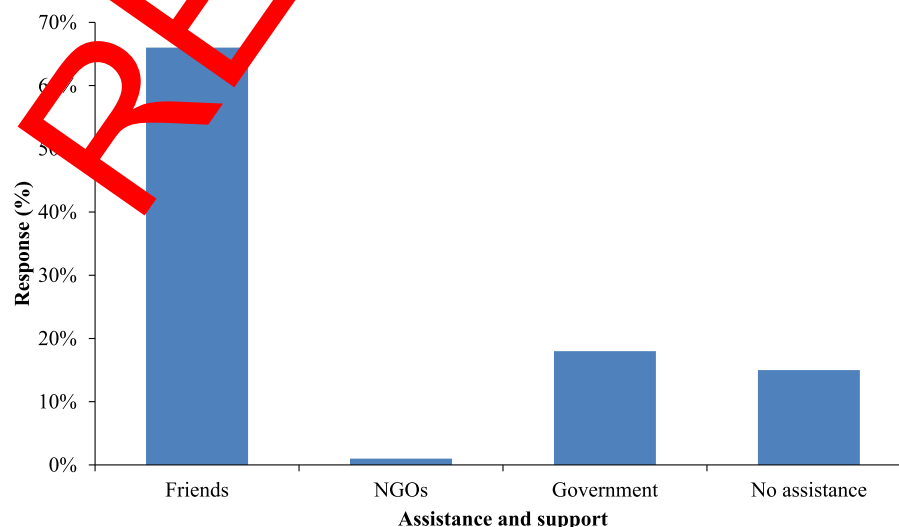


Fig. 8. Assistance and support obtained by households for adaptation practices.

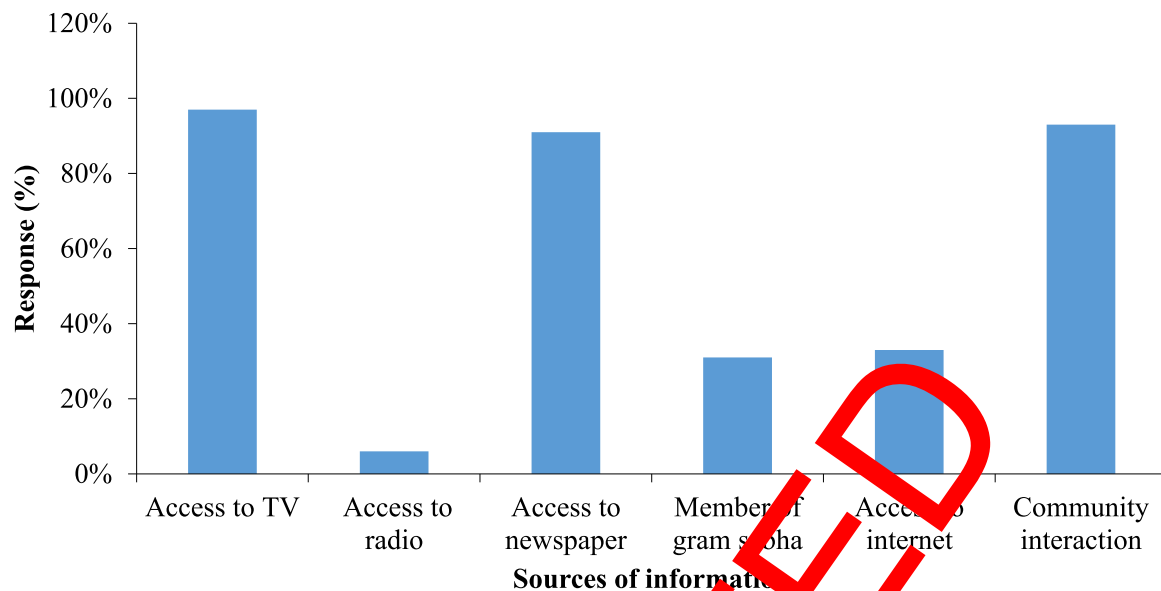


Fig. 9. Sources of information for adaptation practices. The graph shows the percentage of respondents who access information via these sources.

energy requirement, only 5% were using more resources of forests for the energy requirements, and the rest were using alternative energy sources. Past research showed that village elders and audiovisual systems are the most commonly accessed source of information, and more than 90% of villagers rely on them (Pandey et al., 2017). Respondents were asked about their sources of awareness concerning climate change and adaptation planning. The primary source of awareness in the community was television, newspaper, and community interaction (Fig. 8). 33% population were getting awareness through the internet as internet infrastructure is still not improved in the rural areas. Other sources include radio and Gram Sabha. The Gram Sabha work as the general body of the Gram Panchayat. Gram Panchayat is a basic village governing institute which has a democratic structure at the grassroots level in India. It is a political institute, acting as the cabinet of the village. Sources were different for the respondents in different regions; some sources are used more widely than others. Despite information availability and its utility, it is more important for the communities to cope with climate change. Socio-ecological systems in the Indian Himalayan foothill region are some of the worst affected globally, and the negative impacts are likely to intensify over time due to the changing climate (Gupta et al., 2019). Climate variability and changes have the worst effects on socio-environmental systems in the Himalayan region, and the negative impacts are likely to intensify over time. Climate risks are on high exposure, and the urgent need to reduce current and future community vulnerability to these risks is substantially required to make livelihood sustainable (Pandey et al., 2017).

Conclusion

It is concluded that Industrialization in the Shiwalik region was dominating exposure affecting climate and environment, consequently impacting the community's livelihood. The study provides information to understand the impacts of various exposure on vulnerability and risks of communities residing within industrial and urban limits. Assessment based on multiple indicators of vulnerability reflected that communities living in the industrial area faced various problems such as increase air temperature, deteriorating air quality, depletion of water resources, and evolution of various health issues. Besides, the application of chemical fertilizers was also a significant reason for soil pollution, water quality, and resources. Further, communities were suffering from climate-related issues resulting decline in agriculture productivity. An increasing trend of air temperature was found owing to industrial and

other unplanned activities. However, economic status was improved due to more job opportunities due to rapid Industrialization. Communities were also dependent on various forest resources, i.e., goods and services such as wood extraction for fuel and preparing agriculture implements and other household uses. This study demonstrated that unplanned urbanization and severe industrialization consequences on community health and other natural resources increased job opportunities. This study suggested that local communities' perception can be translated into developing adaptation and mitigation measures to cope with Industrialization, climate change, and other exposure to minimize community vulnerability.

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Declaration of Competing Interest

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