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Research Paper

Assessing the vulnerability of farm economies against climate change in Himachal Pradesh

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ABSTRACT

Vulnerability analysis is a crucial step in developing adaptation strategies against the climate change. The communities residing in Himachal Pradesh are more vulnerable to suffer harm due to their inherent socio-economic and geographical characteristics. The present study evaluates the district-level vulnerability of the state by analysing the secondary data on sixteen indicators; which is segregated into its three components (exposure, sensitivity and adaptive capacity) over a period of 34 years (1985-2018). The results reveal that Mandi (0.334) is most vulnerable to climate change, while Lahaul-Spiti (0.074) district is the least one. Out of twelve districts, only three viz., Bilaspur, Lahaul-Spiti and Kinnaur have experienced a declining trend, while, a rising trend has been experienced in the vulnerability of Hamirpur, Kangra, Mandi, Sirmour, Solan and Una districts. Sirmour (31.10) has the highest instability in the vulnerability, whereas lowest instability is observed in Hamirpur district (7.79). The three components of vulnerability index viz., exposure, sensitivity and adaptive capacity have been observed to be highest in Mandi (0.269), Hamirpur (0.146) and Kullu (0.055) and are lowest in Lahaul-Spiti (0.041), Sirmour (0.067) and Kullu (0.040), respectively.

Keywords: Vulnerability index, exposure, sensitivity, adaptive capacity.

Climate change has evolved into a global issue that is no longer limited to a single country or industry. Agriculture is extremely vulnerable to climate change. Higher temperatures eventually reduce yields of many desirable crops while boosting the spread of weeds and pests. Although some crop yields may increase, the overall impact of climate change on agriculture is likely to be negative, putting global food security at risk. Mountain ecosystems are among the most vulnerable to climate change around the world. As a part of the Western Himalayan mountain ecosystem, Himachal Pradesh is particularly vulnerable to climate change, and all its attendant adverse effects. It is located at the foothills of the Western Himalayas, with 89 per cent of its population living in rural areas (Census, 2011). Agriculture roughly employs 70 per cent of the working population and accounts for nearly 22 per cent of the total state domestic product (State Performance Report, 2020-21). Small and marginal farmers own 88.86 per cent of the total land holdings, while 80 per cent of the total cultivated area is rainfed (Economic Survey, H.P., 2020-21). As a result, many farms are partly dependent on rainfall, which has become completely unpredictable in recent years (IHCAP, 2016). The reducing precipitation levels have a potential adverse impact on the river flow as well as on agricultural/ horticultural production (Bhan and Singh, 2011). Further, the state is highly vulnerable to climate-related disasters such as landslides, cloudbursts, etc.; all of which are extremely destructive and make adaptation to long-term climate change effects even more difficult (IHCAP, 2017).

Owing to such conditions and high sensitivity of the region; there is a need to quantify the extent of environmental vulnerability prevailing in the state. The research findings will help the farm planners and policymakers in formulating locally-tailored practices and policies that aims at enhancing resiliency to the weather variations in improving the resource management according to the varying climatic conditions (Singh, *et al.* (2019). Therefore, present study encompasses the district-wise analysis by taking into account a total of 16 indicators under three major components of vulnerability, whose trend has been analysed to determine the underlying causal factors in different districts of the state. Comprehensive assessment of vulnerability with respect to the farm economy is done for the entire state by mapping the districts into low, mid and high vulnerable groups and estimating the trend and instability in the vulnerability index and its components for all the districts over the years.

MATERIALS AND METHODS

The secondary data pertaining to selected indicators has been collected for a period of 34 years (1985-2018) from various government publications. However, the data on weather parameters

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has been procured from the National Data Centre, IMD, Pune. The quantitative assessment is done by constructing 'vulnerability index' based on its three major components:

Exposure: It encompasses historical changes in climatic variables as well as the occurrence of extreme climatic events (IPCC, 2001).

Sensitivity: It refers to the degree to which a system or species is affected, either adversely or beneficially by climate variability or change.

Adaptive capacity: It is defined as the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences.

Vulnerability assessment: The vulnerability index is calculated with the approach used in Human Development Index (HDI) of United Nations Development Programme (UNDP, 2006). For the indicators having positive functional relationship with their respective index, normalized score is computed using the formula:

$$Y_{ij} = \frac{\text{Actual Value} - \text{Minimum Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

On the other hand, if negative functional relationship exists, then following formula has been used for normalization.

$$Y_{ij} = \frac{\text{Maximum Value} - \text{Actual Value}}{\text{Maximum Value} - \text{Minimum Value}}$$

After normalization, weights are assigned to indicators in order to create a composite index from the multivariate data by using the Iyengar and Sudarshan (1982) method. Finally, vulnerability indices are computed by adding the exposure and sensitivity indices, which together describe the potential impact (PI) that climate change, can have on a system and then deducting the adaptive capacity index.

Vulnerability Index = Potential Impact – Adaptive Capacity

The vulnerability index so computed lies between 0 and 1, with 1 indicating maximum vulnerability and 0 indicating no vulnerability at all. The composite vulnerability indices of all the districts have been computed by taking the average of 34 years. For a comparative characterization, districts of Himachal Pradesh have been classified into four classes according to the vulnerability scale:

Upto 0.25 - Low vulnerable, More than 0.25 to 0.5 - Moderately vulnerable, More than 0.5 to 0.75 - High vulnerable, and More than 0.75 to 1 - Very high vulnerable.

Further, trend and variability of the vulnerability indices and its components (exposure, sensitivity and adaptive capacity) for different districts over the study period have been analysed using linear trend analysis and Cuddy Della Valle instability index (CDVI).

RESULTS AND DISCUSSION

Vulnerability is a comprehensive multidimensional concept affected by large number of related indicators. The trend of growth has been analysed for all the selected indicators and its results have been used to support the major findings of the vulnerability analysis. Table 1 indicates the district-wise composite index of vulnerability and its components along with their trend values over the study period.

Exposure component

Evaluating the exposure allows to identify the regions that have been most exposed to climate variability. The composite exposure index for various districts has been computed using the following indicators viz., average maximum temperature, average minimum temperature and average annual rainfall. Based on the score, highest exposure is found in Mandi (0.269) and the lowest is observed in district Lahaul-Spiti (0.041), indicating around five times

Table 1: Composite index and trend analysis of vulnerability along with its components in Himachal Pradesh over the study period (1985-2018)

District	Exposure		Sensitivity		Adaptive Capacity		Vulnerability	
	CI	Trend	CI	Trend	CI	Trend	CI	Trend
Bilaspur	0.231	-0.0025*	0.137	0.0003*	0.049	-3.1E-05**	0.319	-0.0022*
Chamba	0.058	0.0006	0.111	-0.0001	0.041	3.0E-05**	0.129	0.0005
Hamirpur	0.233	0.0021*	0.146	0.0001***	0.052	-9.43E-05*	0.328	0.0021*
Kangra	0.203	0.0036*	0.106	-0.0002*	0.055	-5.33E-05*	0.255	0.0035*
Kinnaur	0.059	-0.0022*	0.077	-0.0001	0.045	0.0002*	0.091	-0.0024*
Kullu	0.147	0.0001	0.114	0.0007*	0.040	1E-04*	0.221	0.0006
Lahaul-Spiti	0.041	-0.0003	0.078	-0.0003**	0.045	0.0001*	0.074	-0.0007*
Mandi	0.269	0.0018*	0.118	0.0002*	0.053	-0.0001*	0.334	0.0022*
Shimla	0.112	-0.0006	0.104	0.0002*	0.051	6E-05***	0.166	-0.0005
Sirmour	0.075	0.0020*	0.067	0.0002	0.053	0.0002*	0.089	0.0020*
Solan	0.188	0.0020*	0.093	0.0006*	0.054	4.1E-06	0.227	0.0026*
Una	0.178	0.0026*	0.127	-0.0009*	0.054	0.0001	0.251	0.0016*

Note: CI- Composite index, * indicate significant at 1 per cent level of probability, respectively.

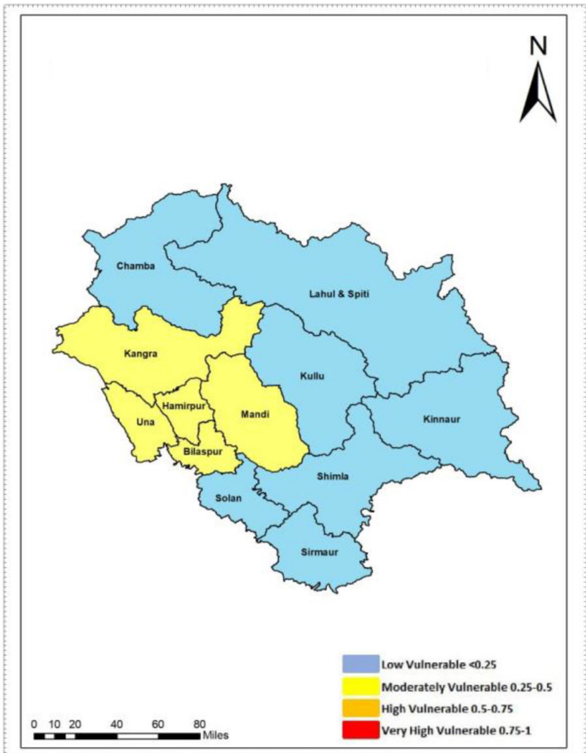

Fig. 1: Mapping of districts in terms of composite vulnerability index (1985 to 2018)

higher exposure in Mandi district. A significant rising trend has been noticed in the exposure of Mandi district; mainly due to the highest average minimum temperature and average maximum temperature found in the district, which is further increasing significantly over the years. Whereas, in district Lahaul-Spiti, average maximum temperature is relatively low and also, the district is having lowest rainfall, which has further observed a declining trend over the years. This has contributed towards the lowest exposure to climate change in the district.

Among other districts, exposure is found to decline only in Bilaspur and Kinnaur districts. This is due to the reason that no significant trend has been observed in average maximum temperature and average rainfall of Bilaspur district. Similarly, in Kinnaur district, average rainfall is declining, while no trend has been observed in average maximum temperature. However, a rising trend in the exposure has been observed in Hamirpur, Kangra, Mandi, Sirmour, Solan and Una districts because the climatic variables are increasing at higher rates in these districts. The exposure to climate change is found to be highly instable in Chamba (62.98) district, while lowest instability is observed in Solan (9.71) district.

Sensitivity component

Assessing the sensitivity of a region offers more fundamental and practical treatment of vulnerability, as results are helpful in identifying the drivers of vulnerability. The composite sensitivity index has been computed by taking into account a total of five indicators including crop diversification index, rural population density, marginal and small farmers, irrigated land and cropping intensity. Table 1 reveals that Hamirpur district (0.146) is the most sensitive to climate change followed by Bilaspur (0.137) and Una (0.127) districts. Highest sensitivity to climate change in Hamirpur district is mainly due to the decreasing crop diversification and cropping intensity, as well as increasing rural population density and percentage of small and marginal farmers in the district. Moreover, the sensitivity of the district is found to increase significantly over the years. On the other hand, lowest sensitivity to climate change is observed in Sirmour district (0.067), which is due to the fact that cropping intensity, per cent irrigated area and crop diversification has increased in the district over the years.

Among other districts, sensitivity to climate change has increased in Bilaspur, Kullu, Mandi, Shimla and Solan districts over the study period. This is mainly due to the reason that cropping intensity has declined in all these districts, while crop diversification is found to decline in Bilaspur, Mandi and Solan districts; contributing to overall increase of sensitivity in these districts. However, Kangra, Lahaul-Spiti and Una districts have become less sensitive to climate change over the years. Although, sensitivity of the Una district is comparatively higher than other district, but it has observed a declining trend over the study period due to the rising irrigated area and cropping intensity. Sirmour district has witnessed the highest instability in the sensitivity index over the study period, while it is lowest in Kangra district.

Adaptive capacity component

Understanding the various ways and characteristics of enhancing the adaptive capacity of a system is extremely important for the development of policies that seek to preserve the communities' livelihoods. It is computed by using 8 indicators including literacy rate, average farm holding, cultivators, agricultural labour, total livestock population, total fertilizer consumption, area under high yielding varieties and area under non- food crops. The analytical results reveal that Kangra district has the highest adaptive capacity; although, it is found to decrease over the study period. This declining trend can be attributed to the declining livestock population, average land holding size and area under other food crops in the district. On the other hand, lowest adaptive capacity has been observed in Kullu district due to its relatively lower literacy rate and lowest average farm holding size, which is further declining over the years. The adaptive capacity of Bilaspur, Hamirpur, Kangra and Mandi districts is declining over the years. However, Chamba, Kinnaur, Kullu, Lahaul-Spiti, Shimla and Sirmour districts have witnessed a rising trend, probably due to the increasing area under other food crops and high yielding varieties, increasing trend of fertilizer consumption and increasing livestock population in these districts. Different indicators contribute significantly in different districts. Shimla district has experienced the highest instability in adaptive capacity as well whereas, it is observed to be lowest in Bilaspur district.

Vulnerability index

Composite vulnerability index computed using exposure, sensitivity and adaptive capacity is presented in Table 1. Wide variations have been witnessed in the vulnerability of different districts, with highest being observed in district Mandi (0.334), which is in conformity to the results obtained by Upgupta, *et al.* (2014). Mandi district is highly exposed to climate change and has comparatively higher sensitivity, while the adaptive capacity is declining over the years; thus, increasing the overall potential impact of climate change in the district. Hamirpur district (0.328) ranks second while Bilaspur (0.319) ranks third in terms of vulnerability to climate change. Hamirpur district has the highest sensitivity and second highest exposure among all the districts. The vulnerability of Bilaspur district is comparatively higher but is declining, which is mainly due to the declining trend of exposure in the district. The vulnerability level to climate change is observed to be lowest in district Lahaul-Spiti (0.074), which is attributed to the lowest exposure index and comparatively lower sensitivity of the district. Climate vulnerability is found to decline in Bilaspur, Lahaul-Spiti and Kinnaur districts, while, a rising trend has been experienced in the districts of Hamirpur, Kangra, Mandi, Sirmour, Solan and Una. Sirmour has the highest instability in the vulnerability index, while lowest instability is found in Hamirpur district.

While classifying the districts into different groups based on the scale of vulnerability index, it is observed that none of the districts belong to high and very high vulnerable category. The analytical results are being demonstrated in Fig. 1, which reveals that districts like Mandi, Hamirpur, Bilaspur, Kangra and Una; that are industrial and more populated falls into the category of moderately vulnerable districts. This is in conformity to the results obtained by Jogesh and Dubash (2014). On the other hand, Chamba, Kinnaur, Lahaul-Spiti, Kullu, Shimla, Solan and Sirmour belong to the group of low vulnerable districts according to their composite vulnerability indices.

CONCLUSION

Overall, vulnerability to climate change is highest in Mandi district and lowest in Lahaul-Spiti district. A significant rising trend has been experienced in the vulnerability of Hamirpur, Kangra, Mandi, Sirmour, Solan and Una districts, while it is found to decline in the districts of Bilaspur, Lahaul-Spiti and Kinnaur. The study concludes that different components contribute differently in determining the vulnerability of farming communities; however, exposure of a district has a predominating impact. Exposure to climate change is increasing in the districts of Kangra, Hamirpur, Mandi, Sirmour, Solan and Una, where the overall vulnerability is rising over the period. Its impact on the vulnerability of a district can be reduced by strengthening the adaptive capacity, while reducing its sensitivity. Different indicators analysed in the study under different components could help the farm planners and policymakers in improving the resource management according to the varying climatic conditions; in order to mitigate the negative effects of climate change. Thus, the study identifies the target regions in need of adaptation and policy support, and will be extremely useful when it comes to prioritizing the adaptive capacity measures required for their better management.

Conflict of Interest Statement: The author (s) declares (s) that there is no conflict of interest.

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