Analysis of vulnerability indices in agro-climatic zones of low hills of Himachal Pradesh

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ABSTRACT

Vulnerability is understood as a function of three important components viz exposure, sensitivity and adaptive capacity which in turn are influenced by a range of biophysical and socio-economic factors. So to assess the vulnerability of low hills of Himachal Pradesh, the present study was conducted in Hamirpur district of Himachal Pradesh as it had shown the impacts of climate change in the last three decades. For the selection of 120 respondents, the multistage random sampling technique was employed in three selected blocks (Bamson, Nadaun, and Bijhari) of the district. The results of the analysis of vulnerability index revealed that Hamirpur district was the most vulnerable and Lahaul and Spiti was the least vulnerable district during 2007. The exposure component played an important role in ranking the Hamirpur district in the first position by contributing to 55.30 per cent followed by sensitivity (35.69%) and adaptive capacity (9.01%). However the Una district was found the most vulnerable district to climate change during 2017. The sensitivity and exposure indicators were found the highest contributors towards its vulnerability which accounted for 28.59 and 59.58 per cent. Amongst the blocks, Hamirpur block was found as the most vulnerable and Nadaun was the least vulnerable block during 2007. The sensitivity played an important role in ranking Hamirpur block at the first position by contributing to the tune of 43.30 per cent followed by exposure (27.26%) and adaptive capacity (29.44%). However Bijhari was found as the most vulnerable block and Bamson was the least during 2017. The results have led to the conclusion that there was a great need to enhance the adaptive capacity of the people of Hamirpur district on a sustainable basis by creating better facilities for water harvesting structures and other infrastructures to reduce the stress on natural resources.

Keywords: Vulnerability index; exposure; sensitivity; adaptive capacity

INTRODUCTION

Himachal Pradesh is known as one of the most ecologically fragile destinations in the Himalayan region having an immense wealth of natural resources and biodiversity. It exhibits a considerable amount of variation in the physico-climatic conditions like distribution of rainfall, snowfall and temperature due to various aspects and varying altitudes. These environmental changes are impacting various natural resources (Loria 2016) and these impacts are higher especially on the farming communities which perform agriculture in ecologically susceptible zones and depend largely on their surrounding environment (Anon 2004). Changing climate also makes farmers more vulnerable towards natural calamities like droughts, floods, landslides, heat waves, avalanches and windstorms etc and this vulnerability of human societies and natural systems to climatic extremes is explained by the damage, hardship and the death caused by these natural calamities. It is also obtained that variations in temperature and rainfall act as stressors in causing vulnerability in various cereal crops (Venkateswarlu 2009, Balasubramanian and Kumar 2014, Samra and Singh 2002). This year to year variability in climate contributes to the rural poverty where the exposure is high and adaptive capacity is low (Hiremath and Shiyani 2013). A study of Intergovernmental Panel on Climate

Change (IPCC) has revealed that vulnerability of a region is linked with climate change and this vulnerability mostly depends to a great extent on its wealth and the poverty of the people limits the adaptive capacity (Anon 2014).

Blaikie et al (1994) defined this vulnerability as the characteristics of a person or a group in terms of their capacity to anticipate, cope with, resist and recover from the impacts of natural hazards. Conversely the frequency and magnitude of extremely low temperatures such as cold spells are projected to decrease in the future with both positive as well as negative impacts on climate. The impacts of future changes in climate are expected to fall disproportionately on the livelihood of the farmers as small and medium farmers are more vulnerable to climate change and it is also found that the farmers with poor income sources are more vulnerable to climate change as their adaptive capacity is lower (Asha Latha et al 2012, Tripathi 2014). While it is increasingly accepted that the districts of poor infrastructure and demographic development are considered as the regions of maximum vulnerability (Patnaik and Narayanan 2009) and this vulnerability of the farmers cannot be solely understood through the quantification of biophysical impacts but a very few studies in climate change also indicate that the social aspects of vulnerability to climate change with an in-depth examination of the underlying socio-economic and institutional factors help to determine how the farmers respond to and cope up with these climatic vulnerabilities.

There is a great need to assess this vulnerability which generally measures the seriousness of potential threats based on known hazards and the level of vulnerability of the society and its individuals. It can also be used to convey early warning information into preventive action (Anon 1999) and is a key tool for informing adaptation planning, decision making and enabling resource managers to take such decisions (Loria et al 2015). Hence present study was attempted to analyze the pattern of vulnerability of climate change and its impacts on local climatic variables viz climate-associated extreme events like rainfall, temperature, droughts, landslides, snowfall, seasonal changes etc of the people living in low hills of Himachal Pradesh and vulnerability indices were built for both Himachal Pradesh and the Hamirpur district and ranks were obtained in terms of their performances on the index.

METHODOLOGY

Description of the study area

Hamirpur district lies in the humid sub-tropical region (Fig 1) and has four seasons in a year. The total geographical area of the district is 1,118 km^2 which constitutes 2.01 per cent of the total area of the state. The net sown area in the district is 352.95 km^2 out of which 325.72 km^2 is sown more than once. The total cropped area is 678.67 km^2 and the net irrigated area is 195.4 km^2 which is 5.54 per cent of total net sown area of the district. The people of Hamirpur mostly depend on agriculture for their livelihood and the major cereal crops are wheat, maize, paddy and barley in which wheat is grown the most.

Field survey, respondents' selection, data collection and analysis

The multistage random sampling technique was used to select 120 respondents. In the first stage, 3 blocks were selected randomly out of the 6 blocks of the district. Three blocks selected were Bamson, Nadaun and Bijhari. In the second stage of sampling, 5 villages from each block were selected randomly and in the third stage a list of households from the selected villages was prepared and by using proportional allocation method 120 respondents were chosen randomly. To achieve the objectives of the present study, both mathematical and statistical techniques were employed for the analysis of both primary as well as secondary data which were collected during the investigations.

Vulnerability index (VI)

The process of construction of vulnerability index has used the indicator approach which is the most common method adopted for quantifying the vulnerability and is used to develop a better understanding of the socio-economic and biophysical factors contributing towards vulnerabilities (Hebb and Mortsch 2007). Keeping in view the advantages of the indicator approach, the present study has used this approach to construct the vulnerability index for selected blocks of Hamirpur district of Himachal Pradesh and the method of Iyengar and Sudarshan (1982) was used for the development of composite indices of vulnerability to climate change (Table 1).

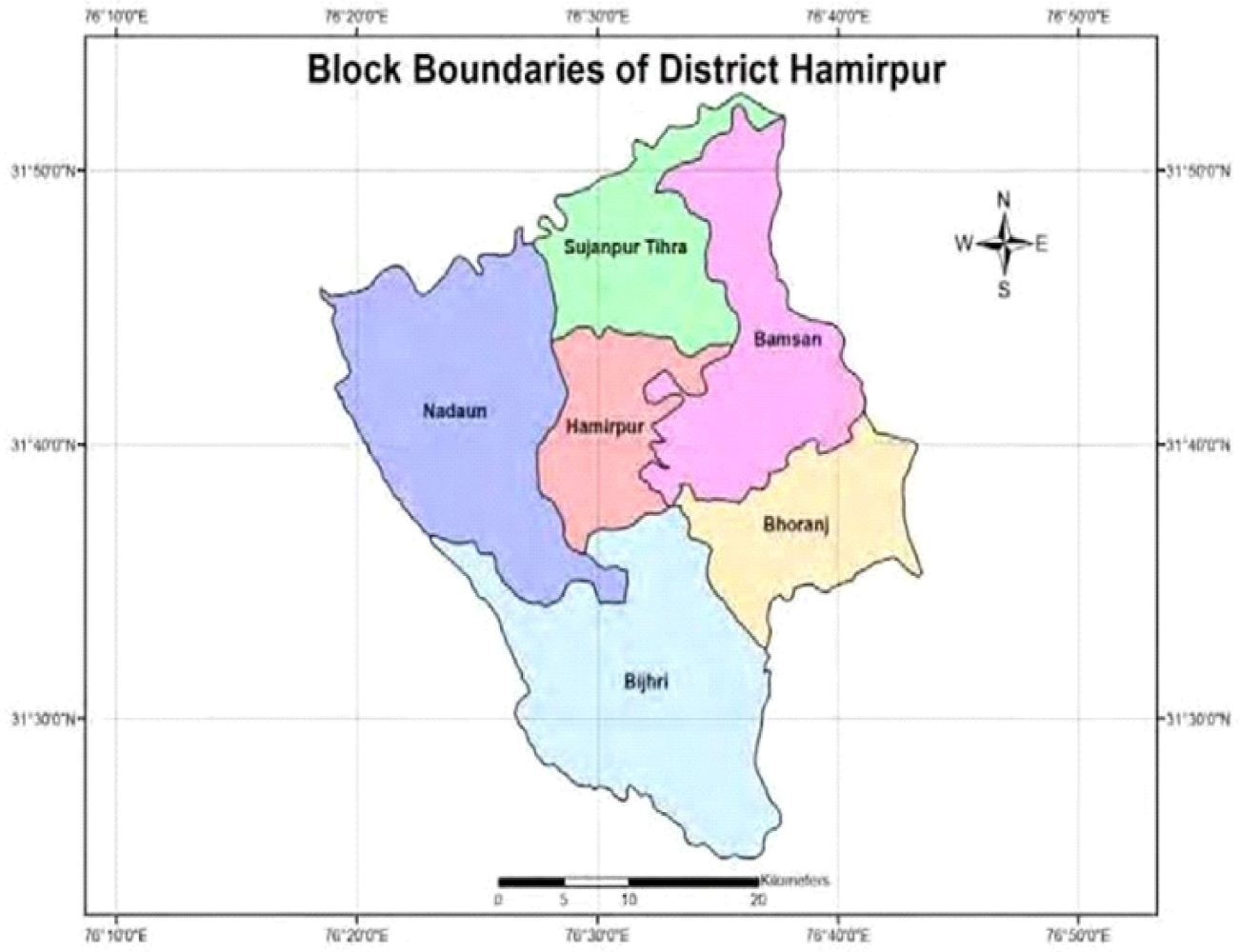

Fig 1. Map of Hamirpur district, Himachal Pradesh

RESULTS and DISCUSSION

Vulnerability indices of Himachal Pradesh

The vulnerability of Himachal Pradesh towards climate change has been assessed by using the above mentioned method and the results pertaining to component-wise contributions to overall vulnerability as well as component-wise vulnerability indices of various districts to climate change for the year 2007 and 2017 are presented in Tables 2 to 7?. It was observed that the ranks and relative magnitudes of the vulnerability indices fluctuated during the period 2007 and 2017. In general the variables pertaining to sensitivity and adaptive capacity were found the major contributors in the overall vulnerability to climate change in these two periods. In the year 2007, Hamirpur was found as the most and Lahaul & Spiti was the least vulnerable district. The values of vulnerability indices varied from 0.10847 (Lahaul & Spiti) to 0.32221 (Hamirpur) during the period 2007 (Table 3). The exposure component of vulnerability played an important role in ranking Hamirpur district at the first position by contributing to 55.30 per cent followed by sensitivity (35.69%) and adaptive capacity (9.01%) as shown in Table 2.

During the year 2017, Hamirpur district fell to the second position and Una district attained the position of the most vulnerable district to climate change (Table 6). The sensitivity and exposure indicators were found the highest contributors towards the highest vulnerability of Una district which accounted for 28.59 and 59.58 per cent respectively as shown in Table 5. Since the exposure component was found to have the greatest bearing towards the overall vulnerability to climate change, there is a need to shift focus towards

Table 1. Components of vulnerability index used under indicator approach

Determinant of vulnerability	Component indicator	Description of the indicator	Unit	Hypothesized relation
Exposure	Change in climate variables (from selected base year)	Change in maximum and minimum temperature	Coefficient of trend	+
		Change in rainfall	Coefficient of trend	+
Senstivity	Crop diversification index	Area under major crops	%	-
	Rural population density	Total rural population/km^2	%	+
	Percentage of marginal and small farmers	Percentage	%	+
	Irrigated land	Percentage of irrigated land	%	-
	Irrigation intensity	Gross area under irrigation with reference to net area under irrigation	%	-
Adaptive capacity	Literacy rate	The proportion of persons aged 15 years or older who can read and write	%	-
	Farmholding size	Average farm size	ha	-
	Share of agriculture in state GDP	Percentage	%	+
	Food crop production per unit area	Amount of food grain produced per hectare	q/ha	-
	Non-food crop production per unit area	Amount of non-food grain produced per hectare	q/ha	+
	Percentage of workers employed in agriculture	Number of farmers engaged in agriculture	Number	+
	Marginal workers	Number of marginal workers	Number	+
	Non-workers	Number of non-workers	Number	+
	Total main workers	Number of total main workers	Number	+

Table 2. Component-wise contribution (%) to overall vulnerability to climate change (2007)

District	Exposure	Sensitivity	Adaptive capacity	Overall
Bilaspur	51.53	38.91	9.55	100.00
Chamba	53.18	31.48	15.34	100.00
Hamirpur	55.30	35.69	9.01	100.00
Kangra	64.92	14.49	20.59	100.00
Kinnaur	9.61	74.08	16.31	100.00
Kullu	40.50	45.57	13.93	100.00
Lahaul & Spiti	12.19	66.22	21.59	100.00
Mandi	58.70	23.38	17.92	100.00
Shimla	29.65	49.90	20.45	100.00
Sirmaur	61.88	26.66	11.46	100.00
Solan	61.98	28.11	9.91	100.00
Una	60.20	30.98	8.82	100.00

the investments in adaptation capacity particularly in the development of drought-resistant varieties as well as using the existing improved crop varieties that can cope up with a wide range of climatic conditions (Garg 2015). Also conservation technologies for improving soil productivity such as tillage operations, natural and organic farming etc may be adopted.

Vulnerability indices of different blocks of Hamirpur district

Assessment of climatic vulnerabilities of agriculture to climate change in Hamirpur district is based on secondary data collected from various government departments of Himachal Pradesh and the results pertaining to component-wise contributions to

Table 3. Component-wise and overall vulnerability indices (VI) to climate change (2007)

District	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Bilaspur	0.18638	8	0.14074	2	0.03455	8	0.29257	3
Chamba	0.19726	6	0.11678	8	0.05688	3	0.25715	6
Hamirpur	0.21735	4	0.14027	3	0.03542	7	0.32221	1
Kangra	0.27066	1	0.06043	12	0.08584	1	0.24525	7
Kinnaur	0.01716	12	0.13224	5	0.02911	12	0.12029	11
Kullu	0.13503	9	0.15194	1	0.04646	5	0.24052	8
Lahaul & Spiti	0.02327	11	0.12643	6	0.04123	6	0.10847	12
Mandi	0.24945	2	0.09937	9	0.07616	2	0.27266	5
Shimla	0.08192	10	0.13786	4	0.05648	4	0.16330	10
Sirmaur	0.18755	7	0.08082	11	0.03472	9	0.23364	9
Solan	0.21385	5	0.09701	10	0.03418	10	0.27668	4
Una	0.23005	3	0.11839	7	0.03372	11	0.31473	2

Table 4. Classification of the districts under different degrees of vulnerability (2007)

Less vulnerable	Moderately vulnerable	Highly vulnerable
Kinnaur	Bilaspur	Una
	Chamba	
Lahaul & Spiti	Kangra	
	Kullu	
	Mandi	Hamirpur
Shimla	Sirmaur	
	Solan	

Table 5. Component-wise contribution (%) to overall vulnerability to climate change (2017)

District	Exposure	Sensitivity	Adaptive capacity	Overall
Bilaspur	47.38	37.82	14.80	100.00
Chamba	51.01	32.30	16.69	100.00
Hamirpur	51.85	35.71	12.44	100.00
Kangra	64.24	13.84	21.92	100.00
Kinnaur	6.17	73.22	20.61	100.00
Kullu	37.95	44.98	17.07	100.00
Lahaul & Spiti	15.14	67.98	16.89	100.00
Mandi	58.49	21.92	19.59	100.00
Shimla	31.80	45.23	22.97	100.00
Sirmaur	61.86	23.13	15.02	100.00
Solan	58.18	29.56	12.26	100.00
Una	59.78	28.59	11.64	100.00

overall vulnerability as well as component-wise and overall vulnerability indices of various blocks to climate change for the year 2007 and 2017 are presented in Tables 8-13. In general the variables pertaining to sensitivity were major contributors to the overall vulnerability of climate change. The significant variables of sensitivity considered for this study were the rural population density, area under major crops, irrigation intensity and percentage of irrigated land and percentage of small and marginal farmers. During the year 2007, Hamirpur block was found as the most vulnerable block and Nadaun was the least vulnerable one (Table 9). The value of the vulnerability indices varied from 0.00681 (Nadaun) to 0.04624 (Hamirpur). The sensitivity played a significant role in ranking Hamirpur block at the first position by contributing to the tune of 43.30 per cent followed by exposure (27.26%) and adaptive capacity (29.44%) as shown

Table 6. Component-wise and overall vulnerability indices (VI) to climate change (2017)

District	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Bilaspur	0.17801	8	0.14211	2	0.05562	6	0.26451	5
Chamba	0.20168	7	0.12772	6	0.06600	4	0.26340	6
Hamirpur	0.20246	6	0.13940	3	0.04857	8	0.29329	2
Kangra	0.26336	1	0.05673	12	0.08986	1	0.23022	8
Kinnaur	0.01076	12	0.12779	5	0.03597	11	0.10259	12
Kullu	0.13129	9	0.15559	1	0.05904	5	0.22784	9
Lahaul & Spiti	0.02810	11	0.12620	7	0.03135	12	0.12295	11
Mandi	0.25775	2	0.09660	10	0.08632	2	0.26803	4
Shimla	0.09155	10	0.13021	4	0.06613	3	0.15564	10
Sirmaur	0.20563	5	0.07687	11	0.04992	7	0.23258	7
Solan	0.21750	4	0.11049	9	0.04584	10	0.28215	3
Una	0.24432	3	0.11684	8	0.04756	9	0.31360	1

Table 7. Classification of the districts under different degrees of vulnerability (2017)

Less vulnerable	Moderately vulnerable	Highly vulnerable
Kinnaur	Bilaspur	Una
	Chamba	
	Hamirpur	
Lahaul & Spiti	Kangra	
	Kullu	
Shimla	Mandi	
	Sirmaur	
	Solan	

Table 8. Component-wise contribution (%) to overall vulnerability to climate change (block-wise) (2007)

Block	Exposure	Sensitivity	Adaptive capacity	Overall
Hamirpur	27.26	43.30	29.44	100.00
Bhoranj	19.53	45.12	35.34	100.00
Nadaun	23.27	30.43	46.29	100.00
Bijhari	39.62	23.34	37.04	100.00
Tira Sujanpur	44.37	34.72	20.91	100.00

Table 9. Component-wise and overall vulnerability indices to climate change (block-wise) (2007)

Block	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Hamirpur	0.03066	3	0.04869	1	0.03311	4	0.04624	1
Bhoranj	0.01978	5	0.04570	2	0.03579	3	0.02969	3
Nadaun	0.02137	4	0.02795	3	0.04252	1	0.00681	5
Bijhari	0.04161	1	0.02451	4	0.03891	2	0.02722	4
Tira Sujanpur	0.03068	2	0.02401	5	0.01446	5	0.04024	2

in Table 8. Nadaun block was found less vulnerable as compared to other blocks because the adaptive capacity was found the major contributor in the overall vulnerability (46.29%). Beta distribution was used to classify vulnerability into three different categories viz very less vulnerable, highly vulnerable and very highly vulnerable. Based on beta distribution Nadaun was found lying in the class of very less vulnerable category

and Hamirpur and Tira Sujanpur were found lying in the class of very highly vulnerable category (Table 10).

Before the year 2010, there were only 5 blocks in the Hamirpur district but after the reorganization of the blocks one more block ie Bamson was created. Bijhari had emerged as the most vulnerable block followed by Hamirpur and Nadaun and the least vulnerable block to climate change was Bamson in Hamirpur district (Table 13).

Vulnerability indices of selected blocks in Hamirpur district

Hamirpur was found as a vulnerable district towards climate change as discussed earlier and needs a strong adaptive capacity to deal with its harmful impacts. The vulnerability of the selected blocks in Hamirpur district was analyzed through the primary data collected from the respondents and the results pertaining to component-wise contribution to overall vulnerability as well as component-wise and overall vulnerability indices to climate change are presented in Tables 14-19.

In the year 2007 the Bamson block was not independent and as a Tehsil it remained submerged in the Bhoranj block. So the analysis was continued as Bamson Tehsil merged in Bhoranj block and it was revealed that the variables pertaining to sensitivity component were the major contributors in the overall vulnerability towards climate change. Similarly Table 15 reveals that Bijhari was the most vulnerable block and Bhoranj block (including Bamson Tehsil) was the least vulnerable in selected blocks of Hamirpur district. Under beta distribution it is also revealed that Bijhari block lied under highly vulnerable category and Bhoranj block (including Bamson Tehsil) lied under very less vulnerable category (Table 16).

In the year 2017, Bamson had already emerged as an independent block of Hamirpur district as discussed earlier so further analysis was carried out as three independent selected blocks in which sensitivity was the major contributor of climatic vulnerability (Table 17). Similarly the Bamson block was found under less vulnerable category and Bijhari under highly vulnerable category and it was obtained using beta distribution (Table 19). Thus there is a great need for those adaptive measures which help in dealing with changing climatic conditions. Existing strategies need to be improved through government interventions

Table 10. Classification of different blocks under different degrees of vulnerability (block-wise) (2007)

Very less vulnerable	Highly vulnerable	Very high vulnerable
Nadaun	Bhoranj Bijhari	Hamirpur Tira Sujanpur

Table 11. Component-wise contribution (%) to overall vulnerability to climate change (block-wise) (2017)

Block	Exposure	Sensitivity	Adaptive capacity	Overall
Hamirpur	35.30	35.72	28.99	100.00
Bhoranj	31.42	41.04	27.54	100.00
Nadaun	21.93	46.96	31.11	100.00
Bijhari	40.50	34.37	25.12	100.00
Tira Sujanpur	43.93	17.07	39.00	100.00
Bamson	16.33	36.83	46.84	100.00

Table 12. Component-wise and overall vulnerability indices (VI) to climate change (block-wise) (2017)

Block	Exposure	Ranks	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Hamirpur	0.035	2	0.035	3	0.029	3	0.041	2
Bhoranj	0.025	4	0.033	4	0.022	5	0.036	4
Nadaun	0.024	5	0.050	1	0.033	2	0.041	3
Bijhari	0.043	1	0.036	2	0.026	4	0.052	1
Tira Sujanpur	0.032	3	0.013	6	0.016	6	0.005	5
Bamson	0.013	6	0.029	5	0.037	1	0.005	6

Table 13. Classification of the blocks under different degrees of vulnerability (block-wise) (2017)

Very less vulnerable	Highly vulnerable	Very high vulnerable
Bamson	Tira Sujanpur	Hamirpur Bhoranj Nadaun Bijhari

Table 14. Component-wise contribution (%) to overall vulnerability to climate change in selected blocks (2007)

Block	Exposure	Sensitivity	Adaptive capacity	Overall
Bhoranj (including Bamson Tehsil)	12.98	43.56	43.46	100.00
Nadaun	40.71	16.80	42.49	100.00
Bijhari	39.96	52.21	7.83	100.00

Table 15. Component-wise and overall vulnerability indices to climate change in selected blocks (2007)

Block	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Bhoranj (including Bamson Tehsil)	0.050	3	0.169	1	0.168	2	0.051	3
Nadaun	0.262	1	0.108	3	0.274	1	0.097	2
Bijhari	0.128	2	0.168	2	0.025	3	0.271	1

Table 16. Classification of the blocks under different degrees of vulnerability in selected blocks (2007)

Very less vulnerable	Moderately vulnerable	Highly vulnerable
Bhoranj (including Bamson Tehsil)	Nadaun	Bijhari

Table 17. Component-wise contribution (%) to overall vulnerability to climate change in selected blocks (2017)

Block	Exposure	Sensitivity	Adaptive capacity	Overall
Bamson	27.43	32.41	40.16	100.00
Nadaun	13.76	57.23	29.02	100.00
Bijhari	39.84	39.20	20.96	100.00

Table 18. Component-wise and overall vulnerability indices to climate change in selected blocks (2017)

Block	Exposure	Rank	Sensitivity	Rank	Adaptive capacity	Rank	VI	Rank
Bamson	0.119	2	0.140	3	0.174	1	0.051	3
Nadaun	0.039	3	0.161	2	0.082	3	0.097	2
Bijhari	0.315	1	0.310	1	0.166	2	0.271	1

Table 19. Classification of the blocks under different degrees of vulnerability in selected blocks (2017)

Very less vulnerable	Moderately vulnerable	Highly vulnerable
Bamson	Nadaun	Bijhari

and more support should be provided through policy making.

CONCLUSION

The present study has led to the conclusion that the Hamirpur district is vulnerable and has a weaker adaptive capacity towards climate change. So there is a great need for robust policy making by the government to reduce, mitigate and adapt to the potential impacts of climate change. More improved agricultural technologies should be implemented by the farmers and necessary financial support should also be provided by the government at the grass-root level. Similarly the changes in cropping patterns, crop rotation, planting dates, plant densities and crop sequences can help to deal with delayed rainy seasons, longer dry spells and earlier crop maturity. On the same lines the use of high yielding and climate-proof crops (drought resistant and heat resistant varieties) can cope up with a wide range of climatic conditions.

Technologies for minimising soil disturbances such as reduced tillage, conservation agriculture, soil testing, use of soil health cards etc should be adopted by the farmers. The existing adaptation strategies need to be enhanced and more awareness should be created among the farmers through various awareness programmes/camps. More local researches should also be done at the village level so that people become more aware of the climatic risks. Similarly the adaptive capacity of the people of Hamirpur district should be enhanced on a sustainable basis by creating better facilities for water harvesting structures and other infrastructures to reduce the stress on natural resources.

Thus Hamirpur district strongly needs enhanced development strategies that integrate with climate change-related policies with sustainable development strategies and improvements are also required to be done in existing adaptation strategies so as to effectively deal with climate change.

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