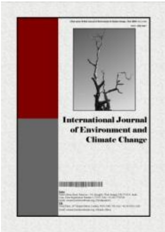

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Vulnerability Assessment for Sub Temperate Fruit Crops under Changing Climatic Conditions in North Western Himalayan Region

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Authors' contributions

This work was carried out in collaboration between both authors. Author Aditya designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SKB managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Climate change and its variability are posing the major challenges influencing the performance of agriculture including annual and perennial horticulture crops. Reduction in production of fruits is likely to be caused by short growing period, which will have negative impact on growth and development particularly due to terminal heat stress and decreased water availability. Hence, crop-based adaptation strategies are needed keeping in view the nature of crop, its sensitivity level and the agro-ecological region. The present investigation was conducted for major sub temperate fruit crops such as apricot, peach and plum in Himachal Pradesh. The investigation was carried out at different altitudinal gradients in fruit growing pockets of Solan district the state. The study was conducted to work out the relationship of weather parameters with phenological stages of major fruit crops and assessment of their vulnerability to climate change under selected altitudinal gradients. The average maximum and minimum temperature showed an increase since last thirty years at all major fruit growing areas, whereas, annual rainfall revealed an erratic trend. The fruit growing areas at 1000-1200 m amsl of Solan district obtained highest score (0.56) and were most

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vulnerable for stone fruit crops production while those at 1400-1600 m above mean sea level (amsl) were least vulnerable amongst the selected altitudes. To cope with climatic changes farmers have adopted various adaptation and mitigation strategies such as improved water conservation techniques, varietal shifts and crop diversification with other fruits like kiwi, pomegranate and vegetables in the region.

Keywords: Climate; temperature; vulnerability; adaptation; diversification.

1. INTRODUCTION

India due to diverse soil and climate regimes has several agro-ecological regions which provide ample opportunity to grow a variety of horticultural crops contributing significantly to total agricultural produce in the country. Horticulture consisting of fruits, vegetables, root and tuber crops, flowers and other ornamentals, medicinal and aromatic plants, spices, condiments, plantation crops and mushrooms has emerged as a core sector in agriculture. In the country, contribution of horticulture sector is about 30 percent to total agricultural GDP. Variability in weather conditions complicates the opportunity for growing various crops as it inflicts increased discrepancy in quality and production of horticultural crops. Some of the climate and soil constraints like water deficit and fertility of the soil can be improved by irrigation and fertilizer applications respectively. However, other factors such as inadequate growing degree days, insufficient winter chilling and frost occurrence can make particular crops marginal or uneconomic in certain regions. Effects of climate change are most seriously felt in Himalayan regions because it belongs to the most vulnerable ecosystems and lives of the people are closely intertwined with the natural resource base, as 90 percent of the population is dependent on agriculture and animal husbandry. The major horticultural crops of Himachal Pradesh include temperate fruits such as apple; stone fruits (peach, plum and apricot) and sub-tropical fruits like mango which are grown in varying altitudes. These crops have specific temperature requirements for their development, optimum yield and quality and are sensitive to changing climate. High temperature and moisture stress increases sunburn and cracking in apple, apricots and cherries. The combined effects of climate variability and other global change drivers impose discernible impacts on species and ecosystems worldwide, however its manifestations and impacts vary locally, so do the adaptation capacities, preferences and strategies. Therefore, effective planning for climate change adaptation requires an assessment of local vulnerabilities to climate for existing indigenous coping mechanism. Vulnerability to climate change refers to the degree to which geophysical, biological and socio-economic systems are susceptible to and unable to cope with adverse impact of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity and adaptive capacity [1]. Accordingly, the vulnerability of major fruit crops to climate change and its mitigation and adaptation strategies need to be worked out considering specific geographical and climatic factors. Climate change not only poses adverse effects but in some mountainous regions, it may also bring regional and local benefits. Higher temperatures could allow farmers to grow crops at upper altitudes and producing abundant yield provided that water and soil conditions are adequate [2], in order to provide nutritional security and sustainable farm income, it is imperative to delineate areas and crops vulnerable to climate change and protect these valuable crops for sustainability against the changing scenario.

2. MATERIALS AND METHODS

The present investigation was conducted by selecting major sub temperate fruit crops viz., apricot, peach and plum growing at different agro-climatic regions of Himachal Pradesh lying between 30º22'40" to 33º12'20"N and 75º45'55" to 79º04'20"E. For sub temperate fruit crops, altitudinal gradient I (1000-1200 m amsl), II (1200-1400 m amsl) and III (1400-1600 m amsl) in Solan district representing fruit growing pockets were selected for recording dataset on particular vulnerability indicators.

Both primary as well as secondary data was used for constructing vulnerability index. The primary data for present study was collected through pre-tested questionnaire schedule by personal interview of sampled fruit growers (thirty households from each region comprising small, marginal and large farmers) in the selected altitudinal gradients of Himachal Pradesh. The pre-structured questionnaire on different aspects to extract the detailed information on climate change, its impact on the productivity of fruits, farmer's economy, fruit quality, shifting trends and strategic measures to combat the change was developed. Multistage random sampling technique was employed to collect information on various aspects pertaining to climate change, its impact on fruit production and socio-economic status of farmers. The data on daily maximum and minimum temperature and rainfall was procured from India Meteorological Department and UHF, Nauni for the duration of thirty one years (1985-2016). The data on stone fruits production and area under cultivation (1985-2015) for selected district was collected from State Horticulture Department, Shimla, Himachal Pradesh.

2.1 Climate Variability Analysis

Variations in maximum, minimum, average temperature and rainfall were analyzed for last three decades. The period 1985-1995 was taken as baseline at altitudinal gradient and compared with decade 1996-2005 (decade-1) and 2006-2015 (decade-2) for variations (increase/decrease) over baseline.

2.2 Indicators Selected for Vulnerability Assessment

The quantitative assessment of vulnerability of fruit crops to climate change in the selected potential areas was done by constructing 'vulnerability index' based on several set of indicators mentioned in Table 1.

2.3 Soil Fertility Status

Soil samples were collected from the selected fruit orchard at three altitudinal gradients from the surface layer i.e. 0-15 cm and were analyzed for various physico-chemical properties such as pH, EC, organic carbon (%), available nitrogen (kg/ha), available phosphorus (kg/ha), available potassium (kg/ha) and micronutrients (Zn, Cu, Fe and Mn) by using standard methods. Based upon soil fertility classes for different nutrients the various hypothesized scores used for calculating soil fertility status were: 3 for any nutrient in high range, 2 for medium range and 1 for low range. Finally soil fertility status was calculated by adding the scores given for all the nutrients in each selected altitudinal gradient.

2.4 Normalization of Indicators

The dataset generated for vulnerability indicators were worked out for vulnerability assessment and consist of several steps. The indicators were in different unit and scales, thus the methodology used in UNDP's Human Development Index (HDI) [3] was used to normalize them. Before normalizing, the functional relationship between the indicators and vulnerability were identified. Two types of functional relationships were there; vulnerability increase with increase (positive (↑) functional relationship) or decrease with decrease (negative (↓) functional relationship) in the value of the indicator. Higher the value of indicator more was the vulnerability. The value of normalized score lies between 0 and 1.

If variable has a positive (↑) functional relationship with vulnerability, then normalized score was computed using formula*:*

$$xij = \frac{Xij - \underset{i}{Min}\,(Xij)}{\underset{i}{Max}\,(Xij) - \underset{i}{(Min}\,(Xij)}$$

Where:

- *(xij)* Normalized score for variable having positive (↑) functional relationship with vulnerability.
- *(Xij)* Value of the indicator j corresponding to i region

If variable has a negative (↓) functional relationship with vulnerability, then normalized score was computed using formula:

$$yij = \frac{\underset{i}{Max}\,(Xij) - Xij}{\underset{i}{Max}\,(Xij) - \underset{i}{(Min}\,(Xij)}$$

Where:

- *(yij)* Normalized score for variable having negative (↓) functional relationship with vulnerability.
- (*Xij)* Value of the indicator j corresponding to i region.

Table 1. List of vulnerability indicators used for construction of vulnerability index

Component	Indicator
Exposure	Percent change in rainfall from base year (E1)
	Change in maximum temperature ºC (E2)
	Change in minimum temperature ºC (E3)
Sensitivity	Soil fertility status (S1)
	Percent area under the crop (S2)
	Fertilizer dose and manure (kg/ha) (S3)
	Pesticides use status (S4)
	Insect/pests and diseases (S5)
	Pollinators status (S6)
	Different growth stages (flowering and fruit setting) (S7)
Adaptive Capacity	Change in varietal status (A1)
	Average orchard size (ha) (A2)
	Literacy rate (A3)
	Cropping intensity (A4)
	Yield per ha (A5)
	Alternate crops (A6)
	Net income from crop (A7)

2.5 Construction of Vulnerability Index (VI)

$$\text{Vulnerability Index } (VI) \quad = \frac{\sum_j xij + \sum_j yij}{K}$$

Where

- *(xij)* Normalized score for variable having positive (↑) functional relationship with vulnerability
- *(yij)* Normalized score for variable having negative (↓) functional relationship with vulnerability
- *(K)* Number of indicators selected

Finally the vulnerability indices were used to rank the different regions in term of vulnerability.

3. RESULTS AND DISCUSSION

Quantitative assessment of vulnerability was done by constructing a vulnerability index. There were three components of vulnerability i.e. exposure, sensitivity and adaptive capacity for which the data has been collected from different altitudinal gradients under study and have been discussed below:

3.1 Exposure Indicators

Exposure can be interpreted as the direct stressor and the nature and extent of changes to a region's climate variables (e.g., temperature and precipitation). It is evident from Table 2 that there was a decrease in total rainfall over the baseline at all selected gradients. A decrease of 153.5, 149.5 and 181.6 mm was recorded over the baseline at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. The maximum temperature showed an increase of 0.7, 0.8 and 1.2ºC at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. A divergent trend of decrease in minimum temperature of 1.2, 1.3 and 1.1ºC over the baseline was observed at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. The observations for climatic analysis are in corroboration with the findings of Garg [4] who observed an increasing trend (0.085^{o}C/year) for maximum temperature and decreasing trend (0.005ºC/year) for minimum temperature in Solan district of Himachal Pradesh.

3.2 Sensitivity Indicators

The higher fertility score (11) was obtained by soil at altitudinal gradient III and lower score (10) was observed at altitudinal gradient I and altitudinal gradient II. The higher soil fertility scores indicated higher fertility due to most of the available nutrients (available Nitrogen, available Phosphorus, available Potassium and Organic Carbon) in the soil. The soil fertility had a negative relationship with crop vulnerability meaning higher soil fertility (score) resulted in lower vulnerability and vice-versa. Changes in average temperature and precipitation patterns influence soil organic matter which in turn affects important soil properties such as aggregate formation and stability, water holding capacity, cation exchange capacity and soil nutrient content. The similar findings have also been accounted by Brevik [5].

Farmers' perceptions for the change in area under stone fruit crops (S2) indicated that there was an increase by 25.26, 10.26 and 4.88 per cent compared to the baseline at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. The decrease in area under crop followed a trend as altitudinal gradient I> altitudinal gradient II> altitudinal gradient III. The area under crop had a negative functional relationship with vulnerability indicating that increased area under apple crop reduced vulnerability to climate change and vice-versa. The farmers' perception regarding usage of fertilizers and manure doses (S3) were to the tune of 16289.5, 16262.5 16987.5 and Kg/ha at altitudinal gradient I, II, and III, respectively. Fertilizers and manure doses followed a decreasing trend as altitudinal gradient I> altitudinal gradient II> altitudinal gradient III. However, fertilizer and manure doses have a positive functional relationship with vulnerability which indicated that higher the fertilizers and manure doses higher the vulnerability of crop.

Farmers' perception on pesticides use (S4) in stone fruit crops indicated that use of pesticides has increased over the baseline by 213.7, 149.3 and 151.4 per cent at altitudinal gradient I, II and III, respectively. An increasing trend of pesticides usage was observed as altitudinal gradient I> altitudinal gradient II> altitudinal gradient III. This can be attributed to the fact that strengthening and improvement of quality control infrastructure such as increase in pesticides and fertilizers use lead to an enhanced adaptive capacity against climate change. The similar findings regarding alleviation of adaptive capacity to minimize production related risks have also been described by Garg [4].

Farmers professed an increase in insect-pest and diseases infestation (S5) over the baseline by 161.8, 159.3 and 146.3 per cent at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. On the basis of farmers' perceptions, it was observed that altitudinal gradient I experienced highest increase in insect-pest and diseases infestation followed by altitudinal gradients II and III. The prominent increase in insect-pest infestation at lower elevation can be ascribed to high temperatures coupled with augmented humidity which facilitated ideal conditions for the growth of a number of disease pathogens. Gautam, et al. [6] also reported that elevated spring and winter temperatures resulted in faster reproduction rate, higher survival of larvae, hence increased pest population causing greater infestation in the crop.

Majority of the farmers perceived a substantial decrease in pollinators' activity (S6) at all the selected altitudinal gradients. About 93.5 per cent of farmers at altitudinal gradient III followed by 92.9 per cent at altitudinal gradient II and 91.7 per cent at altitudinal gradient I opined that there was a decrease in natural pollinators' population due to soaring temperature. The decrease in pollinators' population can be attributed to indiscriminate use of pesticides, competitor species, phenophase shifts and agriculture intensification. The similar findings have also been reported by Ricketts, et al. [7] who attributed increasing climate variability for reduction in the population of the pollinating insects.

The observation of number of days taken for bud and flowering stages (pink bud to fruit set) (S7) revealed that highest duration (25 days) for phenophases was observed at altitudinal gradient III followed by a decrease in duration at altitudinal gradient II (24 days) and altitudinal gradient I (23 days). The less duration for completion of phenophases of stone fruits at lower elevation can be attuned to the increasing temperatures during dormancy which led to a more rapid fulfilment of heat requirements. Jindal, et al. [8] in their study on apple fruit crops also specified that lower winter temperature and ample precipitation especially in the form of snow are very crucial for induction of dormancy, bud break and ensuring flowering.

3.3 Adaptive Capacity Indicators

Adaptive capacity symbolizes the potential to employ adaptation measures that help prevent impending impacts of climate change.

The indicator for change in varieties of stone fruit crops (A1) based on farmers' perceptions connoted an increase in number of stone fruit crop varieties by 80.0, 66.7 and 33.3 per cent compared to the baseline, at altitudinal gradient I, II, and III respectively. The increase in number of varieties followed a decreasing trend as altitudinal gradient I> altitudinal gradient II> altitudinal gradient III.

The land possessed is the single most important asset which is used to adopt land based livelihoods and it alone determines the social and economic status of family. The average orchard size (A2) observed at altitudinal gradient I was lowest (0.78 ha), followed by altitudinal gradient II (0.71 ha), altitudinal gradient III (1.02 ha), respectively. The average orchard size had a negative functional relationship with vulnerability; higher land holding therefore indicated high capacity to adapt to the changing climatic scenarios. The results are in conformity with the findings of Garg [4] who analysed land holdings distribution and concluded that size of land holding largely affect the income, consumption, saving and investment of the household.

The highest (83.5%) literacy rate (A3) was recorded at altitudinal gradient II, followed by altitudinal gradient III (79.9%) and lowest (78.4%) at altitudinal gradient I. Education status of family members plays a catalytic role in the scientific management of farms, adoption of recommended technologies and efficient marketing of farm produce. The findings are in accord with the results of Chand [9] who highlighted the higher literacy rate at Shimla district for improved livelihood strategies supporting enhanced capabilities for higher chances of sustenance in a longer period of time.

Tree spacing and canopy density act as a function for maximizing the percentage of solar radiation intercepted by the orchard to optimize crop yield and minimize the stresses. Change in stone fruits crop density (A4) as an adaptive capacity indicator revealed an increase in crop plant density at all selected altitudinal gradients. An increase of 13.2, 8.4 and 6.9 per cent over the baseline were observed at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III, respectively. A decreasing trend in plant density was observed as altitudinal gradient I> altitudinal gradient II> altitudinal gradient III. The results are in corroboration with the results of Chand [9] who observed that farmers at lower altitudes of Kullu and Shimla district have also opted for high density plantation of most of the spur cultivars as the plants were smaller.

Average yield of crop (A5) was highest (5.66 MT/ha) at altitudinal gradient III followed by altitudinal gradient II (4.89 MT/ha) and lowest (3.12 MT/ha) at altitudinal gradient I (Table 2). Optimal yield is an indicator of favourable climatic conditions as well as better management practices followed by the farmers, hence an indicator of vulnerability of apple crop to climate change. Weather parameters showed significant effect on selected crops which indicates that crop yields are influenced by combinations of weather parameters [10]. Liangzhi, et al. [11] also found that a 1ºC increase in temperature during wheat growing season reduces wheat yields by about 3–10 percent.

Farmers' perceptions on shift to alternate crop (A6) revealed that about 34.89, 29.32 and 31.55 per cent at altitudinal gradients I, II and III, respectively have shifted their preference to alternate crops. Shift to alternate crop showed a positive functional relationship with vulnerability hence considered an alarming indicator of vulnerability for stone fruits. In the present study, it was observed that most of the farmers had shifted towards the cultivation of crops other than apple such as pears, vegetables, pomegranate, kiwi at altitudinal gradient I followed by altitudinal gradient III and altitudinal gradient II where they opted for the cultivation of cherry, peaches, almond, vegetables and legume crops. The results are conformity with the findings of Aditya, et al. [12] who reported that 63 per cent of farmers in the Kullu valley have switched over to alternate crops (pears, kiwis, pomegranate, persimmon, cabbage and other vegetables) along with the apple crop. Similarly, Jangra and Sharma [13] reported that farmers in the lower areas of Kullu and Mandi districts of Himachal Pradesh have shifted to the cultivation of tomato, pea and other viable crops.

Income from crop is another important adaptive capacity indicator of vulnerability as better income through stone fruits crop cultivation means less vulnerability. Therefore income from apple crop has also been studied at all selected altitudinal gradients. Gross income from apple crop (A7) was highest (11.45 lakhs/ha) at altitudinal gradient III followed by 10.98 lakhs/ha at altitudinal gradient II and 9.98 lakhs/ha at altitudinal gradient I. This can be credited to the brunt of climatic changes at lower elevations which has led to alterations in agricultural productivity (mostly a decline in crop production) and ultimately the income. Deschenes and Greenstone [14] also assessed the link between agricultural profits and climate change using year-to-year weather variations and accounted rising temperature and reducing rainfall lessened the farm income, consequently exacerbating vulnerability.

3.4 Normalized Scores for Vulnerability Indicators for Stone Fruit Crops

The normalized scores for various selected vulnerability indicators have been described under three components of vulnerability i.e. normalized scores for exposure, sensitivity and adaptive capacity indicators.

A. Normalized scores for exposure indicators

Normalized scores for three exposure indicators i.e. change in total rainfall from baseline (E1), change in maximum temperature form baseline (E2) and change in minimum temperature from baseline (E3) during the decade 2006-2015 are presented in Table 3. Normalized scores for change in total rainfall (E1) were 0.12, 0.00, at altitudinal gradient I and altitudinal gradient II and 1.00 at altitudinal gradient III over the baseline respectively. Normalized scores for change in maximum temperature (E2) were 0.00, 0.20 and 1.00 at altitudinal gradient I and altitudinal gradient II and altitudinal gradient III respectively. Maximum normalized score (1.00) for change in minimum temperature was obtained by altitudinal gradient II followed by score of 0.50 at altitudinal gradient I and minimum score of 0.00 was obtained at altitudinal gradient III.

The higher normalized score for an indicator in a region indicated higher is the vulnerability of the region and vice-versa. Overall the altitudinal gradient III obtained highest (2.00) exposure scores, followed by altitudinal gradient II (1.20) and altitudinal gradient I (0.62). Thus altitudinal gradient III was highly exposed to climate change, while altitudinal gradient I had lowest exposure to climate change.

B. Normalized scores for sensitivity indicators

The perusal of data on normalized score for seven sensitivity indicators of stone fruit crops revealed that the highest normalized score 1.00 for soil fertility status (S1) was obtained at altitudinal gradient I and altitudinal gradient II followed by altitudinal gradient III receiving minimum score (0.00). Normalized scores for change in area under stone fruit crops (S2) were 0.00, 0.74, and 1.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. Fertilizers and manure doses (S3) obtained normalized scores of 0.04, 0.00 and 1.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The altitudinal gradient I obtained highest normalized score of 1.00 for pesticides use (S4) in stone fruit crops whereas normalized score of 0.00 and 0.03 at altitudinal gradient II and altitudinal gradient III were obtained respectively. Normalized scores for insect- pests and diseases infestation (S5) were, 1.00, 0.84 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. Normalized scores for pollinators' status (S6) were 1.00, 0.33 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The normalized scores for flowering stages (green tip to fruit set) (S7) were 0.00, 0.50 and 1.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively.

The altitudinal gradient I obtained highest (4.04) sensitivity score, followed by score of 3.41 at altitudinal gradient II and lowest (3.03) at altitudinal gradient III. Thus, altitudinal gradient I was highly sensitive to climate change, whereas altitudinal gradient III was least sensitive to climate change among the selected altitudinal gradients.

C. Normalized scores for adaptive capacity indicators

Data on normalized scores for seven adaptive capacity indicators selected for the stone fruits vulnerability assessment were presented in Table 3. Normalized scores for change in varieties of stone fruit crops (A1) were 0.00, 0.28, and 1.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. Normalized scores obtained for average orchard size (A2) were 0.77, 1.00 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The normalized scores for literacy rate (A3) were 1.00, 0.00 and 0.71, at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The normalized scores for stone fruit crops density (A4) were 0.00, 0.76 and 1.00, at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. Normalized scores for average yield of crop (A5) were 1.00, 0.30 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The normalized scores for shift to alternate crop (A6) were 1.00, 0.58 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively. The normalized scores for gross income from stone fruit crops (A7) were 1.00, 0.32 and 0.00 at altitudinal gradient I, altitudinal gradient II and altitudinal gradient III respectively.

Table 2. Vulnerability indicators for stone fruit crops at selected altitudinal gradients in Himachal Pradesh

Components	Indicators	Functional relationship with vulnerability	Solan (1000-1600 m amsl)		
			Altitudinal gradient I	Altitudinal gradient II	Altitudinal gradient III
Exposure	(E1) Change in total rainfall from baseline (mm)	↓	-153.5	-149.5	-181.6
	(E2) Change in maximum temperature from baseline (ºC)	↑	0.7	0.8	1.2
	(E3) Change in minimum temperature from baseline (ºC)	↑	1.2	1.3	1.1
Sensitivity					
	(S1) Soil fertility status scores	↓	10	10	11
	(S2) Per cent change in area under the crop	↓	25.26	10.26	4.88
	(S3) Fertilizer and manure doses (Kg/ha)	↑	16289.5	16262.5	16987.5
	(S4) Pesticides use (% Increase)	↑	213.7	149.3	151.4
	(S5) Insect/pest and diseases (% Increase)	↑	161.83	159.32	146.34
	(S6) Pollinators status (% Decrease)	↓	91.7	92.9	93.5
	(S7) Flowering stages (days from pink to fruit set)	↓	23	24	25
Adaptive capacity					
	(A1) Change in Varieties (% increase)	↓	80	66.7	33.3
	(A2) Average Orchard Size (ha)	↓	0.78	0.71	1.02
	(A3) Literacy Rate (%)	↓	78.4	83.5	79.9
	(A4) Crop Density (% Decrease)	↓	13.2	8.4	6.9
	(A5) Yield (tons/ha)	↓	3.12	4.89	5.66
	(A6) Shifted to Alternate crops (% responses)	↑	34.89	29.32	31.55
	(A7) Income From crop (Lakhs)	↓	9.98	10.98	11.45

Table 3. Normalized scores for selected indicators and vulnerability index for stone fruit crops at selected altitudinal gradients in Himachal Pradesh

Components	Indicators	Solan (1000-1600 m amsl)		
		Altitudinal gradient I	**Altitudinal gradient II**	**Altitudinal gradient III**
Exposure	(E1) Change in total rainfall from baseline	0.12	0.00	1.00
	(E2) Change in maximum temperature from baseline	0.00	0.20	1.00
	(E3) Change in minimum temperature from baseline	0.50	1.00	0.00
Exposure sum		**0.62**	**1.20**	**2.00**
Sensitivity	(S1) Soil fertility status	1.00	1.00	0.00
	(S2) Change in area under the crop	0.00	0.74	1.00
	(S3) Fertilizer and manure doses	0.04	0.00	1.00
	(S4) Pesticides use	1.00	0.00	0.03
	(S5) Insect/pest and diseases	1.00	0.84	0.00
	(S6) Pollinators status	1.00	0.33	0.00
	(S7) Flowering stages	0.00	0.50	1.00
Sensitivity sum		**4.04**	**3.41**	**3.03**
Adaptive capacity	(A1) Change in Varieties	0.00	0.28	1.00
	(A2) Average Orchard Size	0.77	1.00	0.00
	(A3) Literacy Rate	1.00	0.00	0.71
	(A4) Crop Density	0.00	0.76	1.00
	(A5) Yield	1.00	0.30	0.00
	(A6) Shifting for Alternate crops	1.00	0.58	0.00
	(A7) Income From crop	1.00	0.32	0.00
Adaptive capacity sum		**4.77**	**3.25**	**2.71**
Vulnerability	Exposure + Sensitivity + Adaptive capacity	9.44	7.86	7.74
	Vulnerability Index	0.555	0.462	0.455
	Ranks	I^{st}	II^{nd}	III^{rd}

In the present study the altitudinal gradient I obtained highest (4.77) adaptive capacity scores, followed by altitudinal gradient II (3.25) and altitudinal gradient III (2.71). Thus, altitudinal gradient I was highly adaptive to climate change, whereas altitude gradient of altitudinal gradient III was least adaptive to climate change among the selected altitudinal gradients.

3.5 Vulnerability Index for Sub Temperate Fruit Crops

Data contained in Table 3 revealed that altitudinal gradient I obtained highest total scores (exposure + sensitivity + adaptive capacity) of 9.44, followed by altitudinal gradient II (7.86) and least score (7.74) was obtained at altitudinal gradient III. The vulnerability index was highest (0.56) for altitudinal gradient I, followed by 0.47 for altitudinal gradient II and 0.46 for altitudinal gradient III. The present study revealed that altitudinal gradient I of Solan district obtained highest vulnerability index score and was most vulnerable for stone fruits production due to climate change while altitudinal gradient III obtained lowest vulnerability index score and was least vulnerable among the selected gradients. Thus, on the basis of vulnerability index scores, the selected altitudinal gradients ranked altitudinal gradient I rank-I, altitudinal gradient II rank-II and altitudinal gradient III rank-III. The high vulnerability of altitudinal gradient I of Solan district may be attributed to its high sensitivity to climate change. The results are in accord with the findings of Garg [4] who assessed Solan district for climate change vulnerabilities and recorded similar observations of vulnerability in terms of crop diversity index.

4. CONCLUSION

The stone fruits growing at an elevation of 1000-1200 m amsl of Solan district have now become vulnerable for cultivation of these crops. However, the region with elevation of 1400-1600 m amsl facing a meagre rise in temperature has become suitable because of its least vulnerability to changing climate. Interestingly, to cope up with climatic changes farmers have adopted various adaptation and mitigation strategies such as improved water conservation techniques, varietal shifts and crop diversification by introducing kiwi, pomegranate and vegetables in the region. Thus, indicating that performing climate change vulnerability assessment emphasizes the identification, prioritization and implementation of adaptation policies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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