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Short Communication

Assessment of apple crop vulnerability to climate change in Himachal Pradesh, India

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Apple being most significant temperate fruit crop which cover 4.3 per cent of total area under fruit in India and contribute 2.8 per cent of total fruit production. Himachal Pradesh is the second most apple producing state after Jammu and Kashmir, contributing about 29.6 per cent of the total production in India (NHB, 2017). However, decrease in productivity of apple crop in the recent years due to change in climatic conditions have become a serious concern of the growers in Himachal Pradesh. Due to lack of sufficient chilling temperatures during winter apple plant will develop physiological anomalies viz. delayed foliation, reduced fruit set and reduced fruit size which affect the yield of apple crop. In the state of Himachal Pradesh evidence of climate change could be clearly depicted by changes like receding snowfall, increased temperature and shifting of temperate fruit belt upward, adversely affecting productivity of apple (Rana *et al*., 2011). Rise in maximum temperature (3.4 °C) and minimum temperature (0.97 °C) during winter season in wet region of Himachal Pradesh has impacted apple cultivation adversely in mid altitudinal range of 1500-2000 m amsl (Bhardwaj *et al.,* 2010). Apple productivity declined up to 1500 m amsl. to the tune of 40-50 per cent due to warmer climate resulting in lack of chilling requirement during winter and warmer summer in lower elevations resulted in shifting of apple production to higher elevation (2700 m amsl) (Chadda *et al*.,2009). Vulnerability to climate change is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity (IPCC, 2007 a,b)**.** In the state impacts of climate change on apple crop and its vulnerability to apple crop have not been scientifically proved so far in the region.

The present study was conducted during the year 2015 and 2016 in order to assess apple crop vulnerability to climate change three altitudinal gradients in three districts of Himachal Pradesh dominated by apple cultivation i.e. 1500-2000 m amsl (Kullu), 2000-2500 m amsl (Shimla) and 2500-3000 m amsl (Kinnaur) were selected purposely. Both primary and secondary data was collected for this study. The primary data was collected through pre tested questionnaire schedule by personal interview of apple growers in the three selected altitudinal gradients of Himachal Pradesh. Farmers' population at-least 30 per cent from each altitudinal gradient in the three districts were selected to know their perceptions regarding climate change and apple productivity. The secondary data on daily maximum and minimum temperature and rainfall was procured from India Meteorological Department regional station at Bhunter (Kullu) (January, 1985- February, 2015), Shimla regional station (January, 1985- February, 2015) and Kalpa (Kinnaur) regional stations (January, 1993- February, 2015). The data on apple production and area under cultivation (1988-2014) for all three districts was collected from State Horticulture Department Shimla, Himachal Pradesh. The data set for the period 1985-1994 was taken as a baseline and compared with the dataset for the period 2005-2014 to study the decadal changes over the time period. The quantitative assessment of vulnerability was done by constructing 'vulnerability index' based on dataset collected on several set of indicators under three major components of vulnerability i.e. exposure, sensitivity and adaptive capacity. Methodology used in UNDP's Human Development Index (HDI) (UNDP, 2006) was used to normalize the indicators. The value of normalized score lies between 0 to1.

If variable have 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^{th} region.

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

(yij) Normalized score for variable having negative (↓) functional relationship with vulnerability.

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

(Xij) value of the indicator j corresponding to i^{th} region

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

Vulnerability indicators

Exposure : Exposure of apple crop to various climate change indicators (Table 1) showed that there was a decrease in total rainfall over the baseline (1985-1994) at an altitude range of 1500-2000 m amsl (Kullu) and 2500-3000 m amsl (Kinnaur) by 59.31 mm and 112.12 mm while an increase of 48.78 mm in total rainfall has been recorded at an altitudinal gradient of 2000-2500 m amsl (Shimla) during the period of 2005-2014. The maximum temperature showed an increase of 0.61æ%C, 1.44æ%C and 0.43æ%C at an altitudinal gradient of 1500-2000 m amsl, 2000-2500 m amsl and 2500-3000 m amsl, respectively. Similarly, minimum temperature has also increased over baseline during decade of 2005-2014 and it was increased by 0.60æ%C at 1500-2000 m amsl and 1.07æ%C at 2000-2500 m amsl while it was decreased by 0.56æ%C at 2500-3000 m amsl. The rainfall showing hypothesized negative functional relationship with crop vulnerability, while temperature (maximum, minimum) showing hypothesized positive functional relationship, indicated that with the increase in rainfall vulnerability decreased and increase in temperature resulted increase in vulnerability and vice-versa.

Sensitivity : Sensitivity indicators in the present investigations (Table 1) revealed that the soil fertility scores followed a trend as 2500-3000 m amsl >1500-2000 m amsl > 2000-2500 m amsl at different altitudinal gradient. Higher soil fertility score indicated higher fertility due to most of the available nutrients (N, P, K and Carbon) in the soil. The soil fertility having hypothesized negative relationship with crop vulnerability meaning higher soil fertility (score) resulted lower vulnerability and vice-versa. There was an increase in area under apple crop over the baseline at all the three altitudinal gradients which followed a trend as 2500-3000 m amsl (Kinnaur) > 2000-2500 m amsl (Shimla) > 1500-2000 m amsl (Kullu). The area under apple crop has a hypothesized negative functional relationship with vulnerability which indicated that increased area under apple crop reduced vulnerability to climate change and vice-versa. Fertilizers and manure doses followed trend as 2000-2500 m amsl (Shimla) > 1500-2000 m amsl (Kullu) > 2500-3000 m amsl (Kinnaur). However, fertilizer and manure doses have a hypothesized positive functional relationship with vulnerability which indicated that higher the fertilizers and manure doses higher the vulnerability of crop and vice-versa.

There was an increase in pesticides use at all the three altitudinal gradients which followed a trend as 1500-2000 m amsl (Kullu) > 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur. Pesticides have a hypothesized positive functional relationship with crop vulnerability, which indicated that vulnerability increased with increased use of pesticides in the crop and vice-versa. On the basis of farmer's perceptions, it has been observed that there was an increase in insect-pest and diseases infestation at all the three altitudinal gradients which followed as 1500-2000 m amsl (Kullu) > 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur). The results are agreement with the findings of Gautam *et al*. (2013) who reported that high spring temperature resulted in faster reproduction rate, increased pest population. Insect-pest and diseases infestation showed a hypothesized positive functional relationship with crop vulnerability which indicated that vulnerability of crop increased with increased insect-pests and diseases infestation in the crop and vice-versa.

Flower-visiting insects provide an important ecosystem function to global crop production through their pollination services. In the present study it has been found that there was a decrease in pollinators' population at all the three altitudinal gradients which followed as 1500-2000 m amsl (Kullu) > 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur). The decrease in pollinators' population may be due to excessive use of pesticides, habitat fragmentation, invasive species and agriculture intensification. The present results are conformity with the findings of Rai *et al*. (2015) who reported that changing climate scenario has caused reduction in the population of the pollinating insects. Pollinators have hypothesized negative functional relationship with vulnerability indicated that vulnerability increased with decreased pollinators population and vice-versa.

The time taken for the completion of bud and flowering stages followed a decreasing trend at different altitudinal gradients as 2500-3000 m amsl > 2000-2500 m amsl >1500-2000 m amsl. The maximum numbers of days were taken to complete bud and flowering stages at 2500-3000 m amsl (Kinnaur) while minimum at 1500-2000 m amsl (Kullu) which may be attributed due to variations in the average temperature at all the three altitudinal gradient. The time taken for bud and flowering stages showed a hypothesized negative functional relationship with vulnerability which

Table 1: Vulnerability indicators for apple crop at different altitudinal gradients of major apple growing regions in Himachal Pradesh

Components	Indicators	Functional relationship with vulnerability	Altitudinal gradient in m amsl		
			1500-2000 (Kullu)	2000-2500 (Shimla)	2500-3000 (Kinnaur)
Exposure	(E1) Change in total rainfall from form baseline (mm)	↓	-59.31	48.78	-112.12
	(E2) Change in maximum temperature from baseline (°C)	↑	0.61	1.44	0.43
	(E3) Change in minimum temperature from baseline (°C)	↑	0.60	1.07	-0.56
Sensitivity	(S1) Soil fertility status scores	↓	11.00	10.00	12.00
	(S2) Per cent change in area under the crop	↓	12.70	47.28	50.72
	(S3) fertilizer and manure doses (kg ha^{-1})	↑	16950	17212	16744
	(S4) Pesticides use (% increase)	↑	161.83	159.32	146.34
	(S5) Insect/pest and diseases (% increase)	↑	246.10	225.41	168.09
	(S6) Pollinators status (% decrease)	↓	90.38	88.89	82.69
	(S7) Flowering stages (days from green tip to fruit set)	↓	33	37	41
	(S8a) Pollinizer (% increase)	↓	116.11	155.56	163.16
	(S8 b) Appropriate Pollinizers proportions (% responses)	↓	58.00	65.00	43.00
Adaptive capacity	(A1) Change in varieties (% increase)	↓	114.67	140.75	143.23
	(A2) Average orchard size (ha)	↓	0.89	1.40	1.06
	(A3) Literacy rate (%)	↓	80.06	84.54	80.14
	(A4) Area under low chill varieties (%)	↑	14.62	0.00	0.00
	(A5) Crop density (% decrease)	↓	16.11	16.16	15.60
	(A6) Yield (tons ha^{-1})	↓	4.16	7.81	3.93
	(A7) Shifted to alternate crops (% responses)	↓	28.78	6.67	0.00
	(A8) Income from apple crop (Lakhs)	↓	1480804	1736811	1696942

indicated that vulnerability increased with decrease in number of days taken for bud and flowering stages in apple crop and vice-versa. There was an increase in number of pollinizers varieties in apple orchard at all the three altitudinal gradients which followed as 2500-3000 m amsl (Kinnaur) > 2000-2500 m amsl (Shimla) 1500-2000 m amsl (Kullu). In the present findings it has also been observed that there was an increase in the number of orchardist using appropriate proportion (25-33 %) of pollinizers in their respective orchards at all the three altitudinal gradients which followed as 2000-2500 m amsl > 1500-2000 m amsl > 2500-3000 m amsl. The pollinizers have shown hypothesized negative functional relationship with vulnerability which indicated that vulnerability increased with decreased pollinizers and vice-versa.

Adaptive capacity : The adaptive capacity indicators selected for the apple crop vulnerability assessment (Table 1) showed that there was an increase in number of varieties over the baseline (1990s) during the year 2014 at all the altitudinal gradients and followed a trend as 2500-3000 m amsl (Kinnaur) >2000-2500 m amsl (Shimla) >1500-2000 m amsl (Kullu). The apple crop varieties showed a hypothesized negative functional relationship with vulnerability which indicated that with increased apple crop varieties vulnerability to climate change decreased and vice-versa.

Average orchard size varied at all the three altitudinal gradients and followed a decreasing trend as 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur) > 1500-2000 m amsl (Kullu). However, the average orchard size showed a hypothesized negative functional relationship with vulnerability which indicated that higher the orchard size lesser the vulnerability of crop and vice-versa. Literacy rate of a population is the primary indicator of awareness. Hence to know the awareness of farmers about management practice, climate change as well as adaptation measures literacy rate of the farmers has been studied. The study revealed that literacy rate followed a decreasing trend at different altitudinal gradients as 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur) > 1500-2000 m amsl (Kullu). Average literacy rate was 79.40 per cent, 80.00 per cent and 83.60 per cent in Kullu, Kinnaur and Shimla district, respectively.

Literacy rate showed a hypothesized negative functional relationship with vulnerability which indicated that vulnerability decreased with increased literacy rate and vice-versa. It was observed that farmers at lower altitude 1500-2000 m amsl have shifted toward low chill varieties this could be attributed to the fact that the region was receiving less chill unit hours due to increased temperature as this region was marginal for apple cultivation due increase in average temperature compared to other altitudinal gradients. The present results are in line with the findings of Sen *et al.* (2015) who reported that 100 per cent people professed increase in low chill cultivars in Kullu valley of Himachal Pradesh. Prasad (2013) also reported that in the face of climate change shift in varietal choices have become necessary in case of important horticulture crops. Area under low chill varieties of apple crop showed a hypothesized positive functional relationship with crop vulnerability which indicated that vulnerability of crop increased with increased area under low chill varieties of apple crop and vice-versa.

On the basis of farmers' perceptions, it was observed that farmers have shifted for high density plantation of most of the spur cultivars as the plants are smaller. There was an increase in plant density at all the three gradients which followed as 2500-3000 m amsl (Kinnaur) > 1500-2000 m amsl (Kullu) > 2000-2500 m amsl (Shimla). Apple crop plant density showed a hypothesized negative functional relationship with vulnerability which indicated that vulnerability decreased with increased crop plant density and vice-versa. Good yield is the indicator of favorable climatic conditions as well as better management practices followed by the farmers. Hence it was also an indicator of vulnerability assessment for the apple crop. Overall the yield of apple crop varied at different altitudinal gradients which followed a decreasing trend as 2000-2500 m amsl (Shimla) > 1500-2000 m amsl (Kullu) > 2500-3000 m amsl (Kinnaur). The average yield showed a hypothesized negative functional relationship with vulnerability which indicated that vulnerability increased with decreased average yield in apple crop and vice-versa.

Shift for the cultivation of alternate crops (crop other than apple) is an alarming indicator of vulnerability for apple crop. Hence farmers' perceptions on shift to alternate crop were studied at all the selected altitudinal gradients. In the present study, it was observed that most of the farmers were shifted for the cultivation of crop other than apple like pears, vegetables, pomegranate, kiwi at an altitudinal gradient of 1500-2000 m amsl (Kullu) followed by altitudinal gradient 2000-2500 (Shimla) where they shifted for the cultivation of cherry, peaches , Almond, vegetables and legume crops. The results are conformity with the findings of Sen *et al.* (2015) 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 (2013) 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 crop. Shift to alternate crop showed a hypothesized positive functional relationship with vulnerability which indicated that vulnerability of apple crop increased with increased alternate crop and vice-versa. Income from crop is another important adaptive capacity indicator of vulnerability as better income through apple cultivation means less vulnerability. The gross income from apple crop at different altitudinal gradient followed as 2000-2500 m amsl (Shimla) > 2500-3000 m amsl (Kinnaur) > 1500-2000 m amsl (Kullu). The gross income from apple crop showed a hypothesized negative functional relationship with vulnerability which indicated that vulnerability increased with decreased gross income from apple crop and vice-versa.

Normalized scores for vulnerability indicators

The normalized scores for various vulnerability indicators has also been described under three main components of vulnerability i.e. normalized scores for exposure, sensitivity and adaptive capacity indicators for the data collected from three different altitudinal gradients Table 2.

Table 2: Normalized scores for selected indicators for apple crop and vulnerability index at different altitudinal gradients of major apple growing regions in Himachal Pradesh

Components	Indicators	Altitudinal gradient in m amsl		
		1500-2000 (Kullu)	2000-2500 (Shimla)	2500-3000 (Kinnaur)
Exposure	(E1) Change in total rainfall from form baseline	0.67	0.00	1.00
	(E2) Change in maximum temperature from baseline	0.19	1.00	0.00
	(E3) Change in minimum temperature from baseline	0.72	1.00	0.00
Exposure sum		1.58	2.00	1.00
Sensitivity	(S1) Soil fertility status	0.50	1.00	0.00
	(S2) Change in area under the crop	1.00	0.09	0.00
	(S3) fertilizer and manure doses	0.44	1.00	0.00
	(S4) Pesticides use	1.00	0.84	0.00
	(S5) Insect/pest and diseases	1.00	0.82	0.00
	(S6) Pollinators status	1.00	0.81	0.00
	(S7) Flowering stages	1.00	0.50	0.00
	(S8a) Pollinizer	1.00	0.16	0.00
	(S8b) appropriate proportion of pollinizers	0.32	0.00	1.00
Sensitivity sum		6.94	5.22	1.00
Adaptive capacity	(A1) Change in Varieties	1.00	0.09	0.00
	(A2) Average Orchard Size	1.00	0.00	0.67
	(A3) Literacy Rate	1.00	0.00	0.98
	(A4) Area under Low chill Varieties	1.00	0.00	0.00
	(A5) Crop Density	0.09	0.00	1.00
	(A6) Yield	0.94	0.00	1.00
	(A7) Shifting for Alternate crops	1.00	0.23	0.00
	(A8) Income From Apple crop	1.00	0.00	0.16
Adaptive capacity sum		7.03	0.32	3.81
Vulnerability	Exposure + Sensitivity + Adaptive capacity	15.55	7.54	5.81
	Vulnerability Index	0.77	0.37	0.29
	Ranks	I[st]	II[nd]	III[rd]

Normalized scores for various climate change indicators were discussed in (Table 2). The higher normalized score for an indicator in a region indicated higher is the vulnerability of the region and vice-versa. Overall the altitude gradient of 2000-2500 m amsl obtained highest (2.00) exposure scores, followed by 1500-2000 m amsl (1.58) and 2500-3000 m amsl (1.00). Thus altitude gradient of 2000-2500 m amsl (Shimla) was highly exposed to climate change, while altitude gradient 2500-3000 m amsl (Kinnaur) have lowest exposure to climate change.

Normalized score for eight sensitivity indicators of apple crop Table 2 revealed that altitude gradient 1500-2000 m amsl obtained highest (6.94) sensitivity score, followed by altitude gradient of 2000-2500 m amsl (5.22) and altitude gradient of 2500-3000 m amsl (1.00). Thus, altitude gradient of 1500-2000 m amsl (Kullu) was highly sensitive to climate change, whereas altitude gradient of 2500-3000 m amsl (Kinnaur) was lowest sensitive to climate change among the three altitudinal gradients.

Data on normalized scores for eight adaptive capacity indicators selected for the apple vulnerability assessment were presented in Table 2. The study revealed that altitude gradient of 1500-2000 m amsl obtained highest (7.03) adaptive capacity scores, followed by 2500-3000 m amsl (3.11) and 2000-2500 m amsl (0.32). Thus, altitude gradient of 1500-2000 m amsl (Kullu) was highly adaptive to climate change, whereas altitude gradient of 2000-2500 m amsl (Shimla) was least adaptive to climate change among the three altitudinal gradients.

Vulnerability status

Data presented in Table 2 revealed that altitudinal gradient of 1500-2000 m amsl (Kullu) obtained highest total scores (exposure + sensitivity + adaptive capacity) of 15.55, followed by 2000-2500 m amsl (7.54) and 2500-3000 m amsl (5.81). The vulnerability index was highest (0.77) for altitudinal gradient of 1500-2000 m amsl (Kullu), followed by 0.37 for altitudinal gradient of 2000-2500 m amsl (Shimla) and 0.29 for altitudinal gradient of 2500-3000 m amsl (Kinnaur). The present study revealed that altitudinal gradient of 1500-2000 m amsl (Kullu) obtained highest vulnerability index score and was most vulnerable for apple production due to climate change while altitudinal gradient of 2500-3000 m amsl (Kinnaur) obtained lowest vulnerability index score was least vulnerable among the three gradients. The results are in line with the findings of Singh and Patel (2017) they also reported that apple belt is shifting from lower to higher elevation in Himachal Pradesh on account of non-optimal availability of chilling unit requirement and suitable area for apple production decreased from 53 per cent to 39.9 per cent in the state. However, altitudinal gradient 2000-2500 m amsl obtained intermediate index score thus occupied second place after 1500-2000 m amsl (Kullu). Thus, on the basis of vulnerability index scores, the three altitudinal gradients ranked as 1500-2000 m amsl (Kullu) rank-I, 2000-2500 m amsl (Shimla) rank-II, 2500-3000 m amsl (Kinnaur) rank-III. The high vulnerability of altitudinal gradient 1500-2000 m amsl (Kullu) may be attributed to its high sensitivity to climate change.

REFERENCES

Bhardwaj, S. K., Verma, K. S. and Sharma, S. D. (2010). Horticulture production in North-western Himalayan region under changing climatic scenario – a case study. In: "Proceedings of 2nd international conference on environmental management". Hyderabad, pp. 206-213.

Chadda, K. L. and Sharma, N. K. (2009). Climate change impacts on production of horticulture crops. In: "Impact of climate change on fruit crops". (Eds. Dhillon, W. S. and Aulakh, P. S.). pp. 3-9. (Narendra Publishing House, New Delhi, India).

Gautam, H. R., Bhardwaj, M. L., Kumar, R. (2013). Climate change and its impact on plant diseases. *Curr. Sci*., 105:1685-1691.

IPCC. (2007a). Special Report on Emissions Scenarios. Intergovernmental Panel on Climate Change. 28SRES.29. Retrieved 26 June.

IPCC. (2007b). Climate Change: Climate change impacts, adaptation and vulnerability. Intergovernmental Panel on Climate Change, Valentia, Spain, 28p.

Jangra, M. S. and Sharma, J. P. (2013). Climate resilient apple production in Kullu valley of Himachal Pradesh. *Inter. J. F. Sci.,* 3:91-98.

NHB. (2017). Indian Horticulture Database-2017. National Horticulture Board. Ministry of Agriculture. Government of India., 302p. www.nhb.gov.in.

Prasad, H.C. S. (2013). Adaptation and Mitigation Strategies for Climate-Resilient Horticulture. In: "Climate resilient horticulture: adaptation and mitigation strategies". (eds. Prasad, H. C. S., Rao, N. K. S., Shivashankar, K. S.). pp.1-7. (Springer, India).

Rai, R., Joshi, S., Roy, S., Singh, O. and Samir, M. (2015). Implications of changing climate on productivity of temperate fruit crops with special reference to apple. *J. Hort*., 2:135.

Rana, R. S., Bgagat, R. M. and Kalia, V. (2011). Impact of climate change on apple crop in Himachal Pradesh. *J. Agrometeorol*., 13 (2): 97-103.

Sen, V., Rana, R. S., Chauhan, R. C. and Aditya. (2015). Impact of climate variability on apple production and diversity in Kullu valley, Himachal Pradesh. *Ind. J. Hort*., 72 (1):14-20.

Singh, J and Patel, N. R. (2017). Assessment of agro climatic suitability of apple orchards in Himachal Pradesh under changing climate. *J. Agrometeorol.*, 19 (2): 110-113.

UNDP. (2006). Human Development Report. United Nations Development Program, pp. 73-81.

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