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Climate Change Induced spatio- temporal Changes in Area, Production and Productivity of Apple in Four Major Apple Growing Districts of Himachal Pradesh, India

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ABSTRACT: The study was carried out in four mountain districts of the state of Himachal Pradesh, India with the objective of delineating spatio-temporal changes in area, production and productivity of apple. ArcGIS platform was used in a windows environment to delineate spatial changes in area, production and productivity over four decades i.e. 1984-2020 using data from the authorized State Departments. It was observed that there is an increase in area under apple and has spread to non-traditional apple growing areas. The production of apple has in general increased as a consequence of increase in area. Apple productivity has fallen in many areas over decades, but this fall in productivity has been compensated by efficient management and following best agro-techniques. The lower areas in the four mountain districts have experienced loss of apple plantations but has been compensated by an increase in areas at higher elevations. The impact of warming has still not crossed the available amplitude of chilling requirement at higher elevations, but the trend of warming may cross this soon. Apple cultivation in the these districts of Himachal Pradesh faces challenges from climatic changes and developmental activities. Farmers from these districts have already faced a major loss of livelihood due to seasonal changes. Therefore a study suggested that the introduction of low chilling varieties should be expedited.

Keywords: Climate Change, Productivity, Apple.

I. INTRODUCTION

The climate change triggered by global warming is impacting various crops in Himachal Pradesh. Monsoonal climate of Himachal Pradesh is typified by a summer and winter season [3]. A warm winter impacts some crops productivity and apple is one of them. It happens basically due to reduced chilling hours in a warmer climate [8]. Apple is the main fruit crop of Himachal Pradesh, and is the basic livelihood option in apple growing districts [10]. The western Himalayan region has experienced significant warming in the past five to six decades [7]. According to past examples from districts like Shimla and Kullu apple orchards have been wiped out due to reduced winter chill which has subsequently affected the local economy [14]. Farmers in this region report changes in the snowfall patterns, which is either causing them either to switch to the new crops or shift to the higher altitudes [4]. The rise in minimum temperature, reduced snowfall in lower elevations less chilling hours and several other factors have contributed to the sweeping out of various apple plantation in the lower elevations, resulting in areas converting to vegetable production. Apart from this, there has been a rampant shift from subsistence to commercial crops, which is eroding genetic diversity [6].

Apple is majorly grown in four districts of Himachal Pradesh i.e. Kullu, Shimla, Chamba and Kinnaur. These districts fall in the cold mountain areas of Himachal Pradesh [2]. The lower areas are affected by increased in minimum temperature, however, the areas at higher elevations are still within the growing amplitude of apple. There is a great effort being made on developing low chilling varieties with limited success, while apple farmers prefer growing traditional varieties. Apple growing regions have generally showed an increasing trend in the temperature, whereas, decreasing trend was observed in the precipitation. The minimum temperature in apple growing regions of Kullu, Shimla and Kinnaur districts has shown an increase of 0.82ºC,

1.09ºC and 0.03ºC, respectively and the precipitation (rainfall) in the Kullu, Shimla and Kinnaur districts has shown a decrease by 5.3 mm, 3.3 mm and 0.9 mm, respectively [1]. The change in area and production of apple in Himachal Pradesh (Table 1) is always debated with more areas coming under apple, but productivity (Table 2) being compromised [15]. The scenario remains hazy with no real time spatial data available which can be temporally related.

Table 1: Production of crop in Himachal Pradesh (Directorate of Horticulture: Shimla, Himachal Pradesh).

Himachal									
Production									
1984-84-1992-93			1993-94-2001-02			2002-03-2010-2011			2011-12-2019-20
1984-85	170629		1993-94	294734		2002-03	348263		2011-12	275036
1985-86	174618		1994-95	122782		2003-04	459492		2012-13	412395
1986-87	359321		1995-96	276681		2004-05	527601		2013-14	738723
1887-88	259277		1996-97	288538		2005-06	540356		2014-15	625199
1988-89	165156		1997-98	234253		2006-07	268402		2015-16	777126
1989-90	394868		1998-99	393653		2007-08	592576		2016-17	468134
1990-91	342071		1999-00	49129		2008-09	510161		2017-18	446574
1991-92	301730		2000-01	376736		2009-10	280105		2018-19	368603
1992-93	279051		2001-02	180528		2010-11	892112		2019-20	715253
				246337.1			491007.6			536338.1

The policy planners as well as research scientists still have no easily comprehendible data in a spatial and temporal form for easy understanding and plan accordingly. Opting for varieties, species, and genotypes that are resilient to climatic changes can improve resilience against humidity, drought, pests, and diseases. Local farmers' participation in identification and implementation of adaptation measures to offset climate change can enhance climate resilience in mountain regions [11]. Although data are available at various platforms which is quite spread and difficult to draw meaningful conclusions. The present study was planned to bring out easily understandable spatial data over time to figure out the change in area and production in the apple growing districts with increase/decrease in productivity, which is a key factor in policy planning.

Table 2: Productivity of Apple crop in Himachal Pradesh (Directorate of Horticulture: Shimla, Himachal Pradesh).

Himachal							
Productivity							
1984-84-1992-93		1993-94-2001-02		2002-03-2010-2011		2011-12-2019-20	
1984-85	3.42	1993-94	4.07	2002-03	4.27	2011-12	2.65
1985-86	3.42	1994-95	1.63	2003-04	5.46	2012-13	3.87
1986-87	6.86	**1995-96**	3.53	2004-05	6.12	2013-14	6.86
1887-88	4.72	**1996-97**	3.63	2005-06	6.10	2014-15	5.71
1988-89	2.87	**1997-98**	2.82	2006-07	2.92	2015-16	7.02
1989-90	6.58	**1998-99**	4.60	2007-08	6.26	2016-17	4.18
1990-91	5.44	**1999-2000**	0.55	2008-09	5.24	2017-18	3.96
1991-92	4.52	**2000-2001**	4.17	2009-10	2.81	2018-19	3.26
1992-93	4.02	**2001-02**	1.94	2010-11	8.79	2019-20	6.27
			2.99		5.33		4.87

II. MATERIALS AND METHOD

The study was carried out in the four districts viz. Kullu, Shimla, Chamba and Kinnaur of Himachal Pradesh (Fig. 1). The data on apple area (Table 3) and production of these districts was collected from the Directorate of Horticulture, Shimla, Himachal Pradesh and was thoroughly checked for any missing gaps. A secondary check of the database was made to ensure and fill the gaps by adding the small unit's data. The Himachal Pradesh state map was generated with districts units using ArcGIS platform in windows environment.

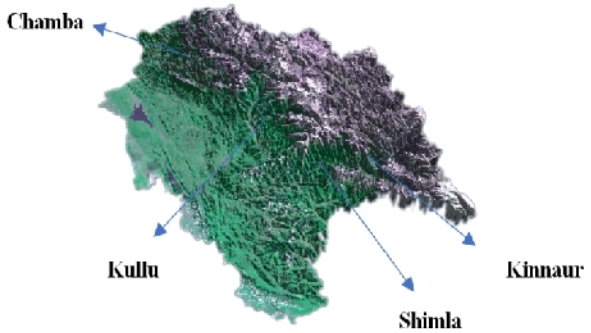

Fig. 1. Study area.

Table 3: Area of apple crop in Himachal Pradesh. (Directorate of Horticulture: Shimla).

Himachal							
Area							
1984-84-1992-93		1993-94-2001-02		2002-03-2010-2011		2011-12-2019-20	
1984-85	49840	1993-94	72397	2002-03	81630	2011-12	103644
1985-86	51103	1994-95	75466	2003-04	84112	2012-13	106440
1986-87	52399	1995-96	78292	2004-05	86202	2013-14	107686
1887-88	54912	1996-97	79538	2005-06	88560	2014-15	109553
1988-89	57447	1997-98	83050	2006-07	91804	2015-16	110679
1989-90	59988	1998-99	85631	2007-08	94726	2016-17	111896
1990-91	62828	1999-2000	88673	2008-09	97438	2017-18	112634
1991-92	66767	2000-2001	90348	2009-10	99564	2018-19	113154
1992-93	69439	2001-2002	92820	2010-11	101485	2019-20	114144
			82912.78		91724.6		109981.1

The maps were generated for the area under apple, production of district and the productivity. The change between the districts was captured for the four decades. A digital elevation range map with district boundaries was prepared to delineate the appropriate elevation intervals of the entire state (Fig. 2). These elevation ranges clearly refer to the kind of vegetation available including the agricultural and horticultural crops.

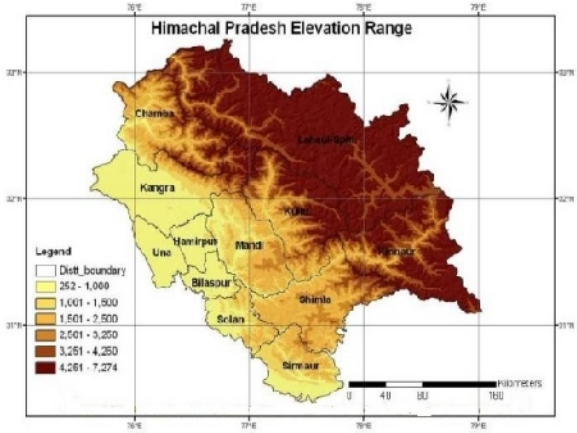

Fig. 2. Digital elevation model of Himachal Pradesh (source: CGRT, CSK HPAU, Palampur, H.P.).

III. RESULTS AND DISCUSSION

A. Apple area changes over four decades.

In general area under apple is increasing in the state of Himachal Pradesh (Table 4), thanks to the increase in the use of low chilling varieties as well as new areas being used for apple production.

In addition to increase in area in lower elevations, there is a shift of apple cultivation to higher altitudes [9]. The (Fig. 4) shows that the area of apple production has progressively increased under each district and in each decade. Some minor dips were noted in 2002 -2011, with a steep jump in the next decade *i.e.* 2012-2020. During 2002-2011, some area in this district was put under off season vegetables, which seems back converted to apple plantations. This observation was noted in the interviews conducted with various apple growers, who tried to converted part of their areas to other agricultural crops, but back converted to apple. All these four districts are basically mountain districts and has supported apple for many decades and has a wide amplitude for apple growing apple in terms of temperature requirement in terms of Chilling hours, but if the warming continues like this, the only alternative will be to expedite the introduction of low chilling varieties. However in these districts apple crop is still profitable venture [13].

B. Apple production changes over four decades

The apple production in the four districts of Himachal Pradesh (Table 5) has increased over the four decades, which corresponds to the increase in area under apple production under these districts (Fig. 5). There is a quantum jump in the production of apple in 2012-20 as compared to 1984-93. This has happened primarily because of farmers awareness because of trainings by Horticultural Department as well as Universities/Institutes in Himachal Pradesh, besides taking adaptation measures to increased temperature, improved irrigation infrastructure as well as improved techniques of apple growing over the years coupled with adding low chilling varieties in lower areas of these districts.

Table 4: Apple area (ha) change represented in maps.

Sr. No.	Districts	1984-1993	1994-2002	2003-2011	2012-2020
1.	Shimla	23797.3	32715.89	30777.8	39170
2.	Kullu	13558.7	18357	22042.4	26114.4
3.	Kinnaur	3784	5712	8550.9	10787
4.	Chamba	3486	7785.9	10808.8	12632.7

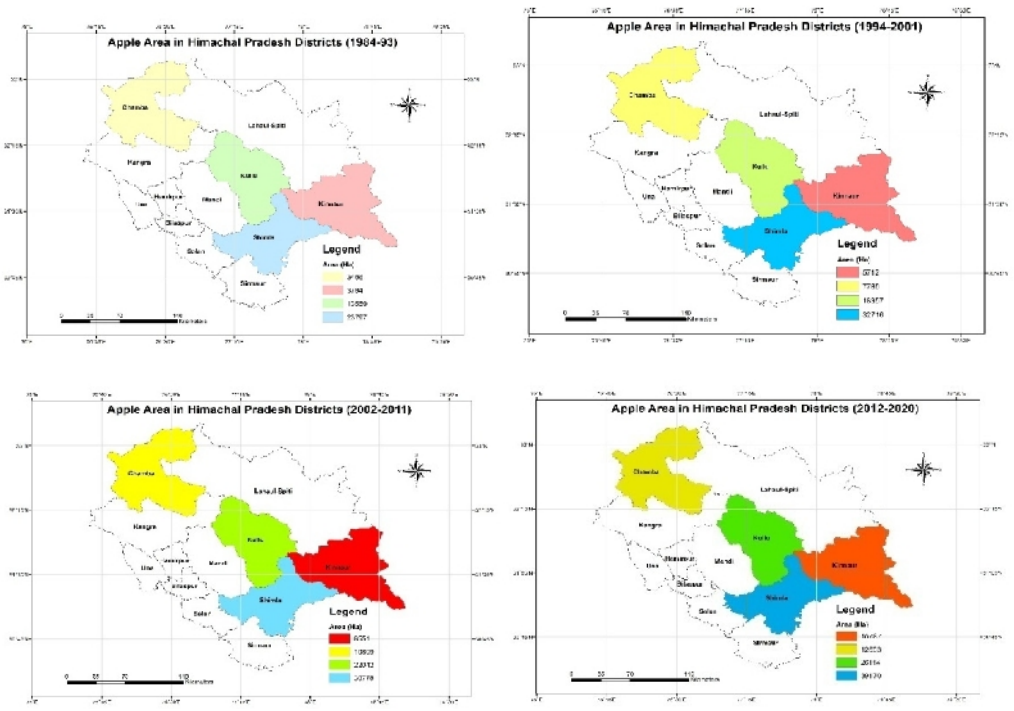

Fig. 4. Apple areas change in four apple growing districts of Himachal Pradesh for four decades.

There is lot of contribution of improved agro-techniques adopted by the apple growers in the state. The support from the government has been tremendous to tide over the difficulties faced by the apple growers, because this crop is the major livelihood option in these districts and contribute to the state economy. This has also helped in the eco-system stability to a greater extent in Himachal Pradesh [12].

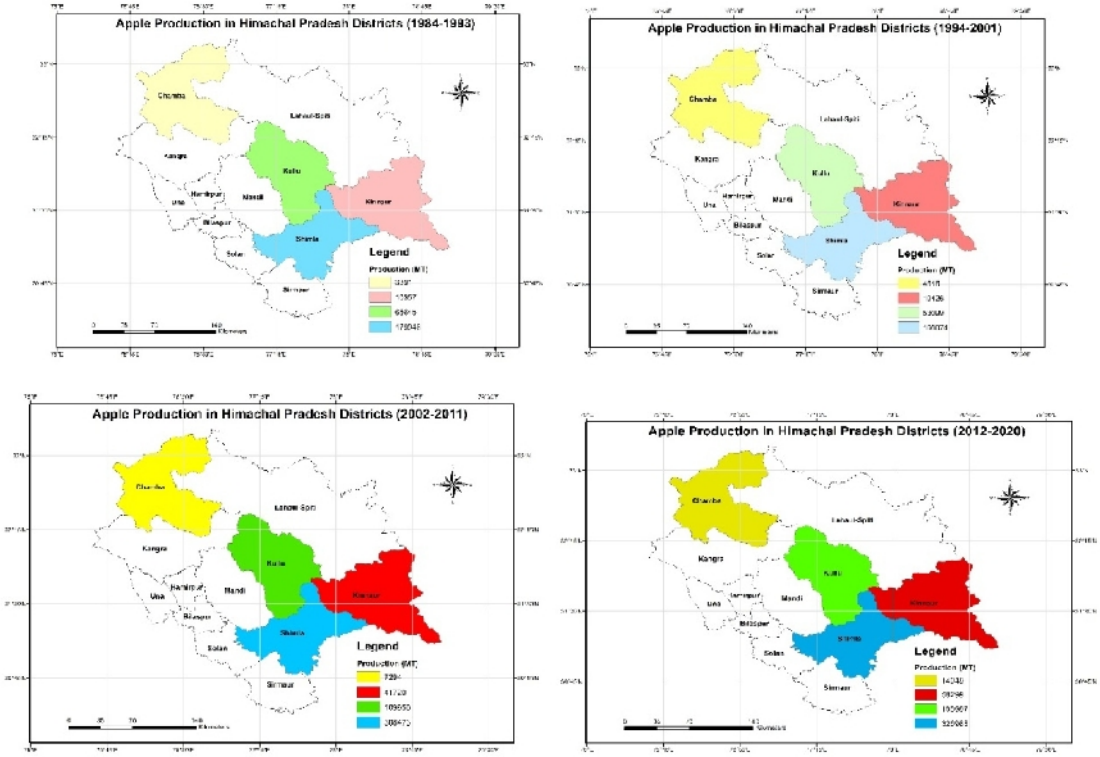

Fig. 5. Apple Production change in four apple growing districts of Himachal Pradesh for four decades.

Table 5: Apple production (MT) change represented in maps.

Sr. No.	Districts	1984-1993	1994-2002	2003-2011	2012-2020
1.	Shimla	179945.9	160074	308472.8	326982.6
2.	Kullu	66645.3	53099.1	109956.3	100997.1
3.	Kinnaur	10357.1	19426.2	41720.4	58298.7
4.	Chamba	3390.8	14949	7294.2	14948.7

C. Apple productivity changes over four decades

The most important feature of the apple production is the apple productivity. This is independent of area and gives a true picture of the impact of adverse factors in production of a particular crop. There being no clear trend, but in general it shows a decreasing trends (Fig. 6) with decadal variations in different districts (Table 6). Productivity is highly influenced by the GxExM factors [5], where G is genotype, E is environment and M is the Management. Apple being a long-term perennial crop, the G factor doesn't influence much, but environmental factors will influence the productivity due to change in meteorological features prevailing in different areas. The major factor will be the M factor, because the management of the plantation and taking adaptive measures, besides following best agro techniques will influence the productivity and contribute to production. Also, this is a localized feature and will vary from orchard to orchard and hence gives trends in a landscape that are most difficult to explain [12].

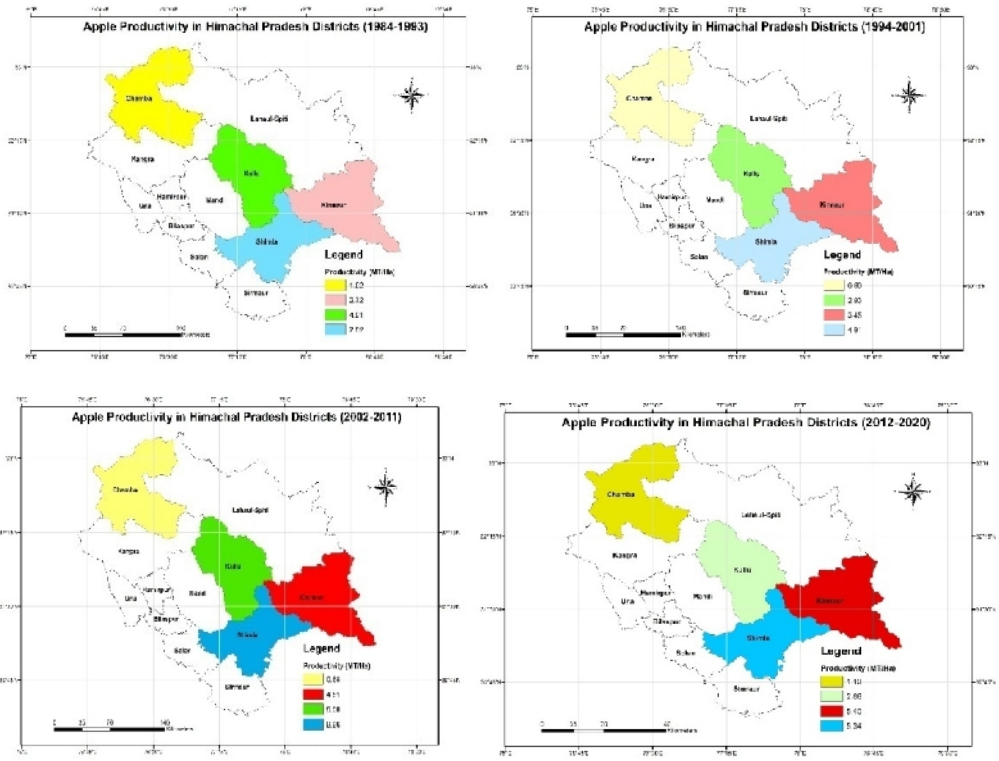

Fig. 6. Apple Productivity change in four apple growing districts of Himachal Pradesh for four *decade*s.

Table 6: Apple productivity (MT./Ha) change represented in maps.

Sr. No.	Districts	1984-1993	1994--2002	2003--2011	2012-2020
1.	Shimla	7.52	4.91	9.96	8.34
2.	Kullu	4.91	2.93	5.00	3.86
3.	Kinnaur	2.7	3.4	4.81	5.40
4.	Chamba	1.02	0.60	0.68	1.19

CONCLUSION

The study has brought out some important conclusions on the impact of climate change on apple area, production and productivity. The findings show that seasonal variations in apple growth are already visible, although some regions show higher variability than others, especially those at lower altitudes.

The productivity has in general fallen but has been levelled of by efficient management and introduction of new cultivars. These four districts have majority of area under apple production falling in higher altitudes where the effect of climate change is a bit slow and the chilling requirement is still completed, however, in lower areas the traditional varieties have been wiped out. New cultivars with low chilling requirement are slowly replacing the high chilling requirement varieties. This, coupled with some efficient management and agro-techniques have compensated for the fall in total production, rather in many areas increase in production. Area has also increased as the plantations have spread out of traditional areas and also moved upwards in altitude. Low-altitude regions where farmers are shifting to alternate crops (Off season vegetables) or shifting apple to higher altitudes can survive with good adaptation mechanisms, early warning systems, and capacity building. Further, lower altitude regions are already facing reduced chilling hours and increased precipitation in the form of rain or hail instead of snow. The study does not indicate a complete eradication of apple cultivation from the low altitude regions but rather shows possibilities for the adaptation using low chilling varieties. Therefore the introduction of low chilling varieties, without compromising the quality should be introduced.

Therefore, this study suggest

(i) furnish the provisions for weather-based risk insurance, not only for crop produce, but also for the apple trees to make farmers resilient to climatic vagaries.

(ii) making efforts to enrich preparedness towards changes in climatic pattern through available meteorological predictions on seasonal variability.

(iii) to bring up the alternate livelihoods or new apple cultivars that require less chilling hours, especially at the lower elevations.

Conflict of Interest: None.

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