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Extreme snowfall event analysis and its impacts on agriculture and horticultural crops in western Himalaya, India

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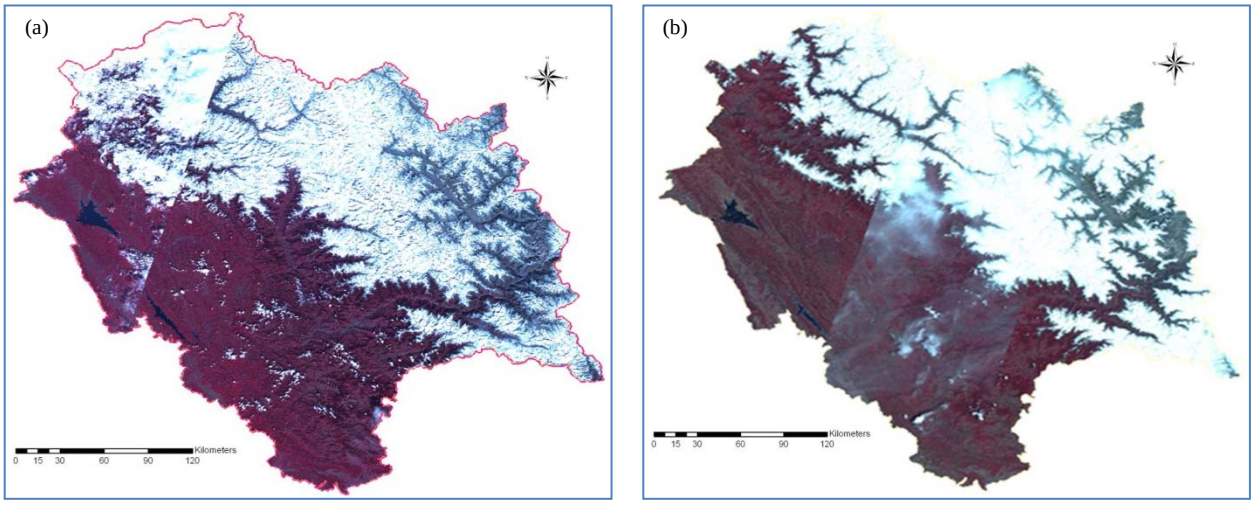
सार – ग्लेशियर और बर्फ जलचक्र के महत्वपूर्ण लक्षण हैं और ये जिन क्षेत्रों में होते हैं वहां की मात्रा, परिवर्तनशीलता और पानी की गुणवत्ता को प्रभावित करते है। हिमाचल प्रदेश और भारत के अन्य उत्तरी राज्यों में सिंचाई के लिए उपयोग किए जाने वाले पानी के आधे से अधिक की आपूर्ति हिम से होती है और पनबिजली और सिंचाई जलाशयों के लिए महत्वपूर्ण योगदान देते है। तथ्य यह है कि बर्फ सर्दियों में पानी के भंडारण के रूप में कार्य करती है और बसंत में मिट्टी की नमी का पुनर्भरण करती है जिसका पहाड़ी क्षेत्रों में कृषि उत्पादकता में विशेष महत्व है। कुल हिमपात और पानी की उपलब्धता तथा फसल उत्पादन का हिमपात पर प्रभाव का आकलन करने के लिए दूर संवेदी तकनीकों और जमीनी वास्तविक आँकड़ों का उपयोग करके हिमाचल प्रदेश में 2004-05 के दौरान हिमाचल प्रदेश में हिमपात के आकलन का अध्ययन किया गया। हिमपात से पहले (अक्तूबर 2004) और बाद में (मई 2005) चित्रों के दो सेटों का उपयोग करके दो अवधियों का दूर संवेदी तकनीकों द्वारा हिमपात का आकलन किया गया। इससे हिमपात से पहले की अवधि की तुलना में हिम आच्छादन में 28.7 प्रतिशत की वृद्धि का पता चला है। 22 क्षेत्रों के वास्तविक आँकड़ों से भी पिछले दो दशकों की तुलना में 2004-05 के दौरान हिमपात की मात्रा में 50 प्रतिशत अधिक की वृद्धि का पता चला है। रबी 2004 के दौरान विभिन्न फसलों के क्षेत्र में 8.57 प्रतिशत की वृद्धि हुई जबकि उसके बाद की खरीफ ऋतु में फसल के क्षेत्र में 1.85 प्रतिशत कमी दर्ज की गई। रबी ऋतु 2004 और खरीफ 2005 के दौरान भी उत्पादकता में वृद्धि हुई। वर्ष 2003-2004 की तुलना में 2004-05 के दौरान कुल खाद्यान्न की उत्पादकता में 19.0 प्रतिशत से अधिक वृद्धि देखी गई। वर्ष 2002-03 तथा 2003-2004 की तुलना में 2004-05 में सेब और अन्य फलों में क्रमश: 12.1 और 59.8 प्रतिशत अधिक उत्पादकता दर्ज की गई। कम अवधि की सब्जियों की फसल में हिमपात का प्रभाव अधिक रहा। गत तीन वर्ष की तुलना में 2004-05 के दौरान बाजार में कुल सब्जियों में 48.33 प्रतिशत की वृद्धि हुई। इससे पता चलता है कि हिमाचल प्रदेश में पहाड़ों और अनुप्रवाहों में कृषि तथा फसल उत्पादकता में भारी हिमपात का सकारात्मक और महत्वपूर्ण प्रभाव रहा।

ABSTRACT. Glaciers and snow are the important features of hydrological cycle and affect volume, variability and water quality in areas where these occur. Snow supplies more than half of water used for irrigation in Himachal Pradesh and other northern states of India and is an important contributor to hydropower and irrigation reservoirs. The fact that snow acts as water storage over the winter and provides soil moisture recharge in the spring is of particular importance to agriculture productivity in mountainous regions. The study on snowfall estimation during 2004-05 in Himachal Pradesh was carried out using remote sensing techniques and ground truth data to estimate total snowfall and assess the impact of snow fall on water availability and crop productivity. The snowfall estimates using remote sensing techniques for two periods by using two sets of imageries before snow fall (October, 2004) and after snowfall (May 2005). This indicated an increase of 28.7 per cent in snow cover compared to pre snowfall period. The ground data from 22 sites also indicated an increase of more than 50 per cent higher amount of snowfall during 2004-05 compared to last two decades. The area under different crops during *rabi* 2004 was found to be increased by 8.57 per cent, whereas, subsequent *kharif* season registered 1.85 per cent reduction in cropped area. The increase also reflected in higher productivity during *rabi* season 2004 and *kharif* 2005. The productivity of total food grains increased by more than 19.0 per cent during 2004-05 compared to 2003-04. The apple and other fruits registered 12.1 and 59.8 per cent higher productivity, respectively in 2004-05 compared to 2002-03 and 2003-04. The impact of extreme snow fall was more pronounced in short duration vegetables crops. The total vegetables arrivals in the market increased by 48.33 per cent during 2004-05 compared to last three year arrivals. This indicated that there was a positive and significant effect of heavy snowfall on agricultural as well as horticultural crop productivity in the mountains and downstream of Himachal Pradesh.

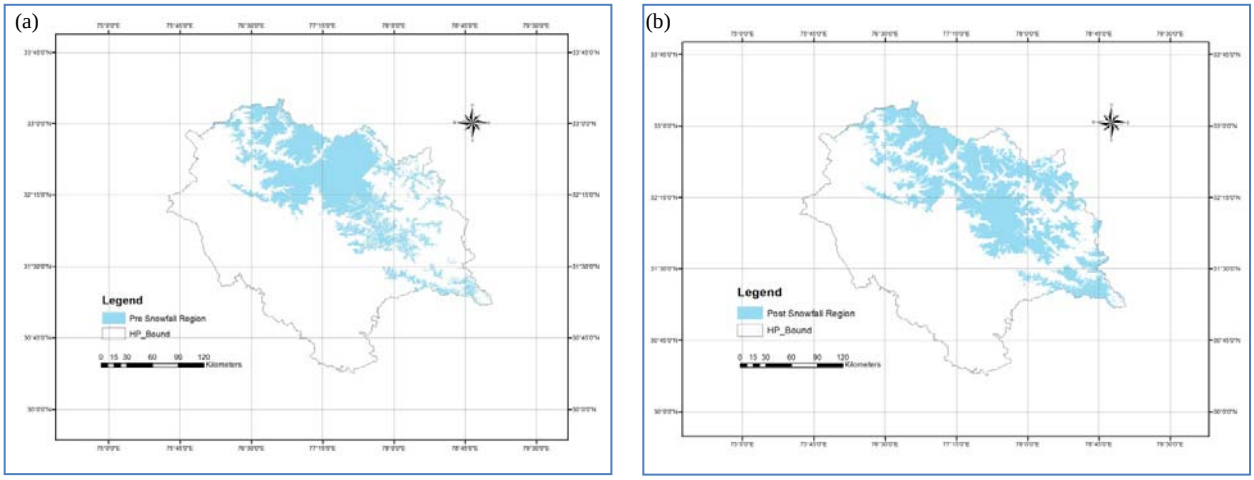
Key words – Heavy snowfall, Estimation, Impacts agriculture and horticulture crops, Western Himalaya.

1. Introduction

The impact of global climatic change on agriculture has recently become a subject of increasing importance. The water availability and agricultural productivity are greatly influenced by changes in the spatial and temporal variability of precipitation and alterations in regional hydrological cycles. Snowfall is one of the important forms of precipitation influencing the water availability and crop productivity in the mountainous regions. The snowfall events have been greatly influenced by climatic changes. These are thought to oscillate in reductions in the intensity of snowfall and changes in the timing of snowfall. Himachal Pradesh is the key and central part of Indian Himalaya Region (IHR) and 30-40 per cent areas of IHR is under seasonal snowfall cover form a unique water reservoir and providing water for drinking, irrigation and hydropower (Anonymous, 2010a). The recent study of Bhardwaj and Sharma (2013) reported drastic reduction in snowfall since the base line period of 1973-1985 in wet temperate hills of North-Western Himalayas. The rise in temperature associated with climate change leads to a general reduction in the proportion of precipitation falling as snow, and a consequent reduction in many areas in the duration of snow cover, although the absolute amount of snowfall may increase if precipitation increases during the winter season. This has implications for the timing of stream flow in such regions, with a shift from spring snow melt to winter runoff. The timing of the snowfall had undergone a change. The onset of early snow in December and January had occurred more infrequently over time and the period of snowfall now extended through the months of February and March. The amount of snow is understood to strongly influence soil moisture, especially in the case of early snow. It is more long lasting and resistant to melting than



Figs. 1(a&b). Pre and post snowfall digitization (a) Satellite image of pre snowfall estimation (October 2004) (b) Satellite image of post snowfall estimation (May 2005)



Figs. 2(a&b). Pre and post snow covered areas in Himachal Pradesh (a) Pre snowfall (October 2004) (b) Post snowfall (May 2005)

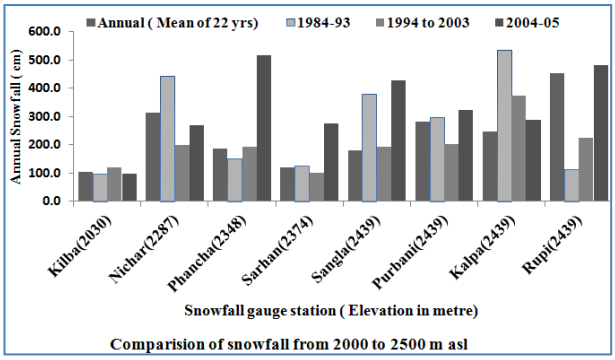


Fig. 3. Mean and decadal snowfall comparison with 2004-05 from 2000-2500 m asl

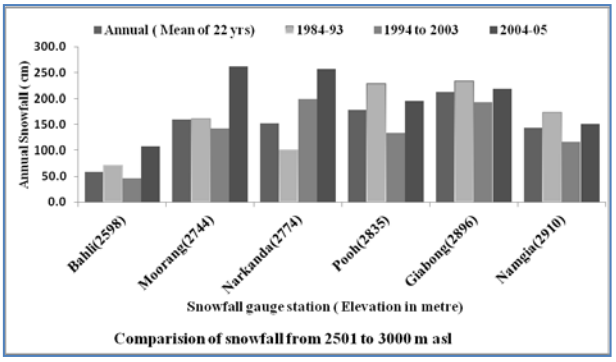


Fig. 4. Mean and decadal snowfall comparison with 2004-05 from 2501-3000 m asl

is the late snow and is suggested to replenish soil moisture and prevent the buildup of humidity in late March and early April. Climatic changes alter the pattern of blossoming, bearing and, therefore, fruit yields. The lack of early cold in December and January is understood to adversely affect the chilling requirements of some of the fruits in the temperate regions. Due to the erratic weather conditions some of the parts of the state dominated by apple are now falling low in terms of being commercially productive (Vedwan, 2006). The winter precipitations occur as snow at an elevation of 1800 m asl and average 3 meter snow is experienced between December to March. In Himachal Pradesh, the sources of its major rivers and the bulk of its freshwater resources are locked up in ice and snow. Himachal Pradesh is divided into four major river basins viz., Sutlej, Beas, Ravi and Chenab having glaciers areas ranging between 235 in Ravi to 1702 in Chenab sq km. The four sub basin namely Tsarp Chu, Taklingla, Bhagirathi and Pabbar having the glaciers area ranging between 6 and 163 sq. km. (Anonymous, 2010b).

2. Data and methodology

The snow estimation was initially conducted for the state of Himachal with reference satellite imageries taken for the year 1999-2000. The study was extended to estimate the heavy snowfall received in the year 2004, the pre snowfall period was estimated using October 2004 satellite imagery sets (IRS LISS 3). The October month imageries were selected because of the maximum availability of cloud free days. The satellite imageries for the month of May 2005 were used for the post snowfall estimation. The month of May 2005 was the earliest period after heavy snowfall where the cloud free imageries were available.

2.1. *Snowfall estimation using satellite imagery sets*

Satellite imagery sets of IRS P6 LISS-3 MX were used for the entire state and snow cover estimation was made. The LISS-III (Linear Imaging Self Scanning Sensor) sensor is an optical sensor working in four spectral bands (green, red, near infrared and short wave infrared). It covers a 141 km-wide swath with a resolution of 23 meters in all spectral bands.

Band	*Spectral Band*
Band 1	0.52 - 0.59 µm
Band 2	0.62 - 0.68 µm
Band 3	0.77 - 0.86 µm

False colour composite (FCC) of the satellite imagery sets were generated using band combinations R-G-B (3-2-1). The two sets of scenes (Pre-snowfall: October 2004 and Post-snowfall: May 2005) were utilized for the purpose and a mosaic was made for the two dates after necessary corrections and image processing techniques.

2.2. *Digitization of snow and glaciers on IRS-LISS3 Imagery*

A systematic screen digitization of both the satellite imagery sets was undertaken in Windows based ILWIS version 3.2 software. Figs. 1(a&b) show the pre and post snowfall satellite image carefully avoiding the cloud cover encountered in some parts. From the Fig. 1(b) it is clearly visible that the post snowfall digitized area has bigger polygons than the pre snowfall digitized area. This shows a preliminary evidence of a heavy snowfall during the period shown in the two satellite images. It can further be observed from the Figs. 1(a&b) that only the north-eastern and the north-western part of the state have snowfall. The mean glacier thickness data are not directly available. It is estimated from the methodology developed for the Tianshan Mountains (Chaohai Liu and Liangfu, 1986) and adopted for inventory of Glaciers and Glacial lake Outburst Floods (GLOFs) affected by global warming in

TABLE 1

Summary of snowfall 2004-2005

Parameter	October, 2004 (pre-snowfall)	May 2005 (post-snowfall)	Per cent increase
Snow covered area (km^2)	12040.95	15499.96	28.72
Ice reserve (km^3)	880.32	950.50	7.97

the mountains of Himalayan region (Bhagat *et al*., 2004). Measurements of glacial ice thickness in the Tianshan Mountains, China, show that the glacial thickness increases with the increase of its area (LIGG/WECS/NEA 1988). The relationship between ice thickness (H) and glacial area (F) was obtained there as :

$$H = -11.32 + 53.21\ F^{0.3}$$

The Fig. 2 shows the snow covered areas in Himachal Pradesh. Almost all the major river basins have snow cover clearly showing that the major river of each basin has a substantial contribution derived from snow. This is indicative of the fact that low snowfall years may result in poor discharge of these rivers.

2.3. *Estimation of snowfall through ground observations*

For the measurement of snowfall data in the state, the selected twenty one sites have been categorized in three elevation zones *viz.*, 2000-2500, 2500 - 3000, above 3000. The area above 4000 m sea level in general, is mostly covered with snow and ice throughout the year (Bhagat *et al.*, 2007). The impact of heavy snow fall during 2004 was compared with past data to estimate the total water availability of water due to high snow fall and its impact primarily on agriculture. Mean and decadal values of snowfall were worked out using data from meteorological stations located in the Sutlej basin. Data of snowfall of two decades (1984-94) and (1994-2004) were compared with snowfall data of 2004-05. It was observed that 14 sites showed increase in snowfall during 2004-05 as compared to average of a decade data between 1984-1993. Similarly data of second decade compared with 2004-05 showed higher snowfall at eighteen sites.

2.4. *Impact assessment of extreme snowfall event on area, production & productivity of food grains, vegetable and fruits in the state during 2004-05*

Agriculture/ horticulture are the main occupation of the people of Himachal Pradesh as it provides direct employment to about 70 per cent of total workers of the State (Anonymous, 2015). About 14 per cent of the total

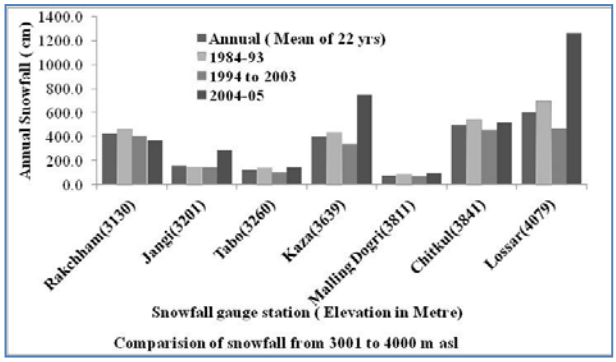


Fig. 5. Mean and decadal snowfall comparison with 2004-05 from 3001-4000 m asl

gross state domestic product (GSDP) comes from agriculture and its allied sectors in the State. To know the impact of higher snowfall on crop yield during 2004-05, an out of state commodity export and variation in yields, the data/information available from different published and unpublished (from out of state export outlets) sources were mainly used. The simple statistical techniques like tabular analysis, percentages etc., were used for analyzing the data.

3. Results and discussion

3.1. *Snowfall estimation*

The data in Table 1 analyzed from satellite imageries indicated 28.72% more area covered with seasonal snowfall during 2004-05. Bhardwaj (2014) reported that aerial extent of glaciers in H.P. is about 2175 sq. km besides about 1775.19 sq. km area under permanent snowfields which are major source of perennial river water in H.P. and total replenishable ground water resources in H.P. are 0.036 million ha-m per year. Another study conducted by Singh *et al.* (2009) on snow cover extent and snow line in the entire Beas and Pārbati basins using multi temporal Advance Wide Field Sensor (AWiFS) of IRS-6 for the period October to June 2004-05, 2005-06 and 2006-07 revealed that during December to June in 2004-05, both monthly average snow area and total discharge flow from the streams of the region were higher as compared the period 2005-06 and 2006-07.

On an average snowfall values showed an increasing rate per year of 8.6 mm during 1984 to 1993, 7.3 mm 1994 to 2003 and 14.9 mm during 2004-05 respectively, with increase in elevation from 2000 m to more than 4000 m. The data reflected that there is a general increase in snowfall amount with increase in altitude in snow bound area of Himachal Pradesh. Higher altitude areas experience higher amount of snowfall compared to lower attitude areas. The increasing trends with elevation were

TABLE 2

Decadal snow fall observed on different sites in varying elevations of H.P.

Elevation (meter amsl)	1984-85 to 1993-94	1994-95 to 2003-04	2004-05
2000-2500	y = 15.076*x* + 200.64	y = 20.768*x* + 107.96	y = 27.77*x* + 211.25
2500-3000	y = 24.357*x* + 75.523	y = 12.429*x* + 95.2	y = 0.7571*x* + 195.8
Above 3000	y = 51.184*x* + 154.74	y = 27.971*x* + 169.1	y = 109.82*x* + 52.2

TABLE 3

Comparison between average monthly snowfalls (1984-85, 1994-2003 to 2004-05)

Years	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1984- 1993 (First Decade)	0.2	1.4	9.4	40.8	57.2	63.0	67.4	20.7	7.9
1994- 2003 (Second Decade)	0.1	2.0	8.0	21.5	47.5	63.4	51.6	15.5	0.5
2004-2005	0.0	13.7	1.5	16.3	124.8	122.3	41.7	16.5	11.8

TABLE 4

Productivity (Per ha.) of principal crops in Himachal Pradesh ('000' tonnes)

Crops	2001-02	2002-03	2003-04	2004-05	Per cent change over 2003-04
			Kharif		
Paddy	137.42	85.65	120.62	100.00	(-) 17.10
Maize	768.20	479.21	729.57	783.00	(+) 7.32
Ragi	4.69	4.05	4.28	3.00	(-) 29.91
Millets	6.30	6.85	7.42	4.00	(-) 46.09
			Rabi		
Wheat	637.07	495.56	496.93	682.00	(+) 37.24
Barley	34.68	30.61	28.14	42.00	(+) 49.25
Gram	1.11	1.01	1.21	4.50	(+) 271.90
Other pulses	9.45	7.92	9.80	17.50	(+) 78.57
Total Food grains	1598.92	1110.86	1397.97	1636.00	(+) 17.03

TABLE 5

Area, production and productivity of total food grains in Himachal Pradesh

Particulars	2001-02	2002-03	2003-04	2004-05	Per cent change over 2003-04
Area (000, ha)	817.20	806.30	812.4	797.00	(-) 1.90
Production (000, m tonnes)	1598.92	1110.90	1398.00	1636.00	(+) 17.02
Productivity (tonne/ha)	1.96	1.38	1.72	2.05	(+) 19.19

TABLE 6

Season-wise area, production and productivity of total vegetable crops in Himachal Pradesh

Year	Area (,000 ha)		Production (,000 M tons)		Productivity (tonne/ha)	
	Rabi	*Kharif*	*Rabi*	*Kharif*	*Rabi*	*Kharif*
2002-03	19.480	15.74	278.77	343.15	14.31	21.81
2003-04	26.465	17.81	366.58	364.77	13.85	20.48
2004-05	28.733	17.48	412.79	419.65	14.37	24.00
Per cent change over 2003-04	8.57	-1.85	12.61	15.04	3.75	17.24

observed in 1984-93 1994 to 2003 and in 2004-05. The amount of increase was higher at higher elevation (Figs. 3-5). The average snow fall at twenty-one sites was observed to be 268.0 mm in 1984-93, 210.0 mm in1993-03 and 348.6 mm in 2004-05, respectively. The year 2004-05 received 80 mm and 138 mm average snowfall over all observational sites compared to 1984-93 and 1994 to 2003, respectively as decadal average values was observed (Table 2). Similar results from Baspa basin of Himachal Pradesh also revealed that lowest snowline altitude in Baspa observed as 2425 m in February, 2004-05 compared to 2846.25m in March, 2006 indicated more snowfall occurrence during 2004-05 (Kaur *et al.*, 2009)

3.2. *Comparison between average monthly snowfalls (1984-93, 1994-2003 to 2004-05)*

Result showed that in first decade average monthly snowfall values in all the twenty one sites over the twenty-two years was increasing from the month of September to month of March and similar type of trend was observed in second decade up to the month of February. The increase reached a maximum in the year of 2004-05 till the month of February (Table 3).

3.3. *Impact of extreme snowfall event on area, production and productivity of food grains, vegetable and fruits in the state during 2004-05*

The production of principal crops including the total food grains during the years 2002-03 to 2004-05 is given in Table 4. A close look at the table revealed that production of *rabi* cereals and pulses like wheat, barley, gram and other pulses was higher during 2004-05 in comparison to their production in the year 2003-04. The maximum increase (more than 271 per cent) was noticed in gram production. The per cent increase in production of wheat, barley and other pulses was to the tune of about 37 to 79 per cent. An increase of about 17 per cent was recorded in the production of total food grains during the year 2004-05. In the *kharif* season (2005), the maize crop also registered an increase of more than 7 per cent in its production, while the production of paddy, ragi and other millets reduced by about 17 to 46 per cent during as compared to their production in the year 2003-04.

Although the area under total food grains crops during the year 2004-05 increased by about 2.37 per cent as compared to area under food grains in the year 2003-04, however, the productivity of total food grains which was 1.72 tonne/ha during 2003-04 increased to 2.05 tonne/ha in 2004-05which reflected in 19 per cent increased food grains (Table 5).

TABLE 7

Area, production and productivity of apple in Himachal Pradesh

Year	Area (,000 ha)	Production (,000) tonnes)	Productivity (tonnes/ha)
2001-02	92.82	180.53	1.95
2002-03	81.63	348.26	4.27
2003-04	84.11	459.49	5.46
2004-05	86.20	527.60	6.12
Per cent change over 2003-04	2.49	14.82	12.09

TABLE 8

Area, production and productivity of fruits other than apple in Himachal Pradesh

Year	Area (,000 ha)	Production (,000) tonnes)	Productivity (tones/ha)
2001-02	130.21	82.92	0.64
2002-03	94.58	111.36	1.18
2003-04	98.33	100.48	1.02
2004-05	100.70	164.41	1.63
Per cent change over 2003-04	2.41	63.62	59.80

Table 6 shows the season wise area, production and productivity of total vegetables in the state during 2004-05. The table revealed that area under total vegetables in *rabi* and *kharif* season was 26.47 and 17.81 thousand hectare in 2003-04, which increased to 28.73 and 17.48 thousand hectare respectively, in 2004-05 and subsequent *kharif*. The production of total vegetables also registered a growth of 12.61 per cent in *rabi* and 15.04 per cent in *kharif* season over a period of one year. A similar trend was also noticed in the productivity of total vegetables. It increased from 13.85 m tonnes/ha in *rabi* and 20.48 m tons/ha in *kharif* season (2003-04) to 14.37 and 24 tons/ha (2004-05) in *rabi* and subsequent *kharif* season, respectively. This showed that during a period of one year (Year of heavy snowfall) yields increased by 3.75 and 17.24 per cent in *rabi* and *kharif* seasons, respectively. This clearly showed the positive impact of heavy snowfall of 2004-05 on the area, production and productivity of total vegetables in state during 2004-05. The crops in H.P. are grown in between 5 to 30 per cent slope and double cropping without irrigations possible in parts of state where there is adequate level of non monsoonal rainfall. The winter cropping is vulnerable to rainfall irregularities (Anonymous, 2010c). The study clearly proved that snowfall has definite impact on agriculture, horticulture and vegetables crops of the Himachal Pradesh. The mountain agriculture in past three decades from 1981 has witnessed a shift from traditional crops to off seasonal vegetables crops (Anonymous, 2009). The long term

TABLE 9

Arrivals of apple, fruits other than apple and total vegetable in different markets of the state (2004-05)(Qtls.)

Market	Apple			Fruits other than Apple			Total Vegetables		
	2003-04	2004-05	% change over 2003-04	2003-04	2004-05	% change over 2003-04	2003-04	2004-05	% change over 2003-04
Kangra	-	11,273,	-	70,380	53,949	-23.35	1,76,638	2,64,205	+49.57
Hamirpur	-	5,097	-	24,458	29,579	+20.94	1,18,811	1,04,371	-12.15
Kullu	70,752	96,110	+35.84	2,522	22,452	+790.25	12,435	3,41,031	+2642.51
Bilashpur	-	465	-	5,994	3,977	-33.65	15,709	14,763	-6.02
Solan	3,22,102	4,43,760	+37.77	8,250	28,147	+241.18	24,449	2,90,525	+20.33
Sirmaur	-	1,571	-	10,867	10,575	-2.69	23,873	51,183	+114.40
Una	14,012	6,161	-56.03	14,325	15,277	+6.65	29,798	88,828	+198.10
Shimla	84,002	1,57,630	+87.65	11,269	28,842	+155.94	3,88,327	3,97,766	+2.43
Chamba	-	15	-	-	1,268	-	2,365	19,299	+546.89
Mandi	-	12,622	-	58,165	47,464	(-)18.40	1,10,160	92,635	-15.91
Total	4,90,868	7,34,704	+49.67	2,06,230	2,41,530	+17.12	11,19,565	16,60,606	+48.33

rainfall trends analysis done by Jaswal *et al*. (2015) based 37 rainfall stations spread over 1000 msl to more than 2000 msl in Himachal Pradesh. The resulted indicated that summer rainfall (March to May) during 2005 was about 15-20 per cent higher with 7 rainy days compared to summer, 2004 with five rainy days only. The higher rainfall might have contributed towards the higher yield of *kharif* season, 2005 by contributing towards the timely sowing of crops during June month.

The area production and productivity of apples in 2004-05 is given in Table 7. The table showed that the area under apple cultivation came down from 92.82 thousand ha in 2001-02 to 84.11 thousand hectares in 2003-04. However, during 2004-05 it increased to 86.20 thousand hectare. During the year 2004-05, about 2.5 per cent more area was put under apple cultivation in comparison to the area under apple cultivation in 2003-04. The production of apple crop also increased from 180.53 million tonnes in 2001-02 to 459.5 million tonnes in 2003-04. But during the year 2004-05, the apple production registered significant increase of more than 14 per cent in comparison to its production in the year 2003-04. The Table 7 further elaborated that the productivity of apple increased from 5.46 tonnes/ha (2003-04) to 6.12 tonnes/ha (2004-05). This clearly showed the impact of heavy snowfall of 2004-05 on the productivity of apple crop in state during the year 2004-05 as it increased by more than 12 per cent over a period of one year. The similar type of trend was also noticed in the area production and productivity of fruits other than apple (Table 8). During the year 2004-05, 2.41 per cent more area was put under fruits other than apple in comparison to area in the year 2003-04. The production of fruits other than apple also increased by more than 63 per cent over during 2004-05 compared to last year**.** The productivity which was 1.02 tonnes/ ha during 2003-04 increased to 1.63 tonnes/ha shows on increase of about 60 per cent.

3.4. *Market arrivals and export of apple, fruits other than apple and total vegetables*

The market arrivals of apple, fruits other than apple and total vegetables in the different market of the state during 2004-05 are presented in Table 9. It can be seen from this table that in the year 2004-05, nearly 50 per cent more arrivals of apple were recorded in the state markets (viewed as a whole) in comparison to apple arrivals in 2003-04. The maximum increase of about 88 per cent was noticed in Shimla market of the state which is the leading apple producing district in the state. About 36 to 38 per cent more arrivals of apple were recorded in the markets of Kullu and Solan. The table further indicated that the market arrivals of fruits other than apple also rose by 6.15 to 790.25 per cent in different markets over a period of one year (2004-05). However, in few markets the arrivals reduced by about 3 to 34 per cent during 2004-05. In the state as a whole the market arrival were 17.12 per cent higher in 2004-05 as compared to the arrivals in 2003-04. In case of total vegetables, the arrivals were significantly higher during 2004-05 compared to their arrival in the year 2003-04. During the year 2004-05 48.33 per cent more arrivals were recorded in the state. This clearly showed the favorable impact of the heavy snowfall during 2004-05 on the water availability and chilling hours and its positive effect on the productivity, production and arrivals of fruits such as apple, fruits other than apple and total vegetable in the state during 2004-05.

TABLE 10

Export of apple from Himachal Pradesh

Year	Boxes (Lakhs)	Quantity (Lakh tonnes)
2001-02	81.11	16.22
2002-03	166.89	33.78
2003-04	218.39	43.68
2004-05	225.90	45.18
% Change over 2003-04	3.44	3.44

The export of apple from the state of Himachal Pradesh to outside the state during the year 2004-05 is presented in Table 10. The table reveals that 225.90 lakhs boxes of apple weighing 45.18 lakh quintals were exported from the state to other parts of the country during the year 2004-05 as against 218.39 boxes weighing 43.68 lakh tones in the year 2003-04 (3.44 per cent more than its export in the year 2003-04). However, there is a general lack of information regarding the export of fruits other than apple and total vegetables for the year 2003-04 and 2004-05 and thus the impact of heavy snowfall of 2004-05 on their export could not be analyzed. The study conducted by Jangra and Sharma (2013) revealed that there is a strong relationship between snowfall and apple production, apple production decreased when there is poor and late snowfall.

4. Conclusions

The snowfall estimate using remote sensing techniques for two periods using imageries before snow fall (October 2004) and after snowfall (May 2005) indicated an increase of 28.72 per cent (3459.0 sq. km area) in snow cover compared to pre snowfall period. The ground truth data from 22 sites also indicated an increase of more than 50 per cent higher amount of snowfall during 2004-05 compared to last two decades. The area under different crops during *rabi* 2004 has been found to be increased by 8.57 per cent whereas subsequently *kharif* season register 1.85 per cent reduction in cropped area. The increase also reflected in higher productivity during *rabi* season 2004 and *kharif* 2005. The productivity of total food grains increased by more than 19.0 per cent during 2004-05 compared to 2003-04.The apple and other fruits registered 12.1 and 59.8 per cent higher productivity respectively in 2004-05 compared to 2003-04.The impact of extreme snow fall was more pronounced in short duration vegetables crops. The total vegetables arrivals in the market increased by 48.33 per cent during 2004-05 compared to last year estimates. The production of apple crop also increased from 180.53 million tonnes in 2001-02 to 459.5 million tonnes in 2003-04. Overall it may be concluded that there is increase in vegetable and fruit production with the increase in snowfall during 2003-04 and these are the potential crops of the state.

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