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*Research Article*

# A pragmatic approach for analysis of long-term climate trends for apple growing regions of Himachal Pradesh, India

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**Abstract**
The study assessed the long-term climate as well as the area and production trends for four representative decades (1985-2020) in three apple growing districts of Himachal Pradesh, India with the objective of understanding the impact of climate change on apple crop. A long term database was prepared for minimum temperature ($T_{min}$), maximum temperature ($T_{max}$) and rainfall, besides area and production for four decades for three districts of Himachal Pradesh, India. Trend analysis indicated that the temperature in apple growing regions of generally showed an increasing trend, 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 0.82º C, 1.09 º C and 0.03 ºC, 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. Increased warming in the mountain regions is elevating temperatures resulting in the reduction of chilling hours, pre-requisite for apple fruiting. However, in the higher elevation of Shimla, Kullu and Kinnaur districts, in spite of the increase in temperature, the areas are still suitable for apple farming. The study indicated that the area and production of all three districts of study are increasing because growers are slowly shifting to low chilling varieties (Varieties having chilling hours requirement less than 1000 hours). Also, the present ecosystem at lower elevations will not support high chilling requirement varieties and apple growers will have to shift to either low chilling varieties or alternate crops.

**Keywords:** Apple, Climate trends, Himachal Pradesh, Rainfall, Temperature

## INTRODUCTION

Himachal Pradesh is predominantly a horticulture state of India. Horticultural crops play a unique role in boosting the economy by improving the incomes of rural people. Apple being a predominant fruit crop in Himachal Pradesh has emerged as a leading cash crop amongst various fruit crops (Sarkar and Padaria., 2018). It can be grown at an altitude ranging from 1500- 2700 m amsl in the Himalayan range, which experiences 1000-1500 hours of chilling. The cultivation of apples in Himachal Pradesh, India started in the 19th Century and first delicious variety of apple was planted at Bundrole in Kullu district (Wani and Songara, 2018). Many fruit crops are grown in the Himalayan region, including stone fruits (Peach, Plum, Cheery and Apricot) and pome fruits (Apple and Pear) in good amounts (Ahmad *et al*., 2021), whereas apple is preferred over all the horticultural crop grown in Himachal Pradesh (Jamwal *et al.,* 2021).

The state has been known as an “Apple State of India” for being the first to introduce “Delicious” apples and for producing quality fruits. Global warming and climate change has become a matter of international concern in the present day. The impact of global warming on glaciers, human health, sea level rise, global precipitation system, general climate etc., is hotly debated. Due to increasing temperature, apple has frequently failed to meet the chilling requirements in the lower areas of Himachal Pradesh. Its cultivation is shifting towards higher reaches of the mountains (Sharma, 2013).

The IPCC (Intergovernmental Panel on Climate Change), has reported 0.5 to 1.2 °C rise in temperature by 2020, 0.88 to 3.16°C by 2050 and 1.56 to 5.44 °C by 2080 for the Indian region depending on future development scenario. Variations in rainfall increase the

frequency of extreme events like heat waves, cold waves, frost days, droughts and floods are some of the causes projected due to climate change. Thus, climate change is causing global climatic disruption with an immense impact on agriculture. The rise in temperatures over years has adversely affected apple cultivation in both these regions, i.e. Kullu and Shimla (Sen *et al.,* 2015). Reduced snowfall has aggravated the problems in many areas. For example, twenty years ago, snowfall was a regular phenomenon in Kullu town but in the last 25 years, only 2 – 3 instances of snowfall have been recorded. (Singh *et al.,* 2016)

In Himachal Pradesh, the area under apple has increased from 400 ha in 1950–51 to 3,025 ha in 1960–61 (Mohan, 2017), 99,564 ha in 2009–10 and 114144 in 2019-20 (Directorate of Horticulture,Shimla,https://hds.hp.gov.in/GeneralpageWithTemplate.aspx?key=FACTKEY0001). The production of apples in this state has steadily increased by bringing more areas into apple farming, with variable consequences on production. However, apple being highly sensitive to adversities of climate, a decline has been seen in the productivity of the apple (Wani, 2019). Therefore, the present study aims to understand the adverse impact of climate change on apple farming vis-a-vis the climate trends and their impact on area and production.

## MATERIALS AND METHODS

The present study was carried out in Kullu, Kinnaur and Shimla districts of Himachal Pradesh, India (Fig. 1) representing mid-hill sub-humid agro-climatic zone of Himachal Pradesh, India (1985-2020). The secondary meteorological data for climatic parameters (temperature and rainfall) was collected from the records of met stations of the regional research stations of various districts and institutions (Agriculture University, Palampur, Himachal Pradesh). The database was created after carefully examining and verifying the data within the study area. Apple area and production data for the corresponding period was collected from the Department of Horticulture, Shimla. The statistical trends (xls. program) was worked out using the standard procedure for maximum temperature, minimum temperature, and rainfall and apple productivity. These trends were then interpreted and analyzed to obtain the rate and amount of change in each parameter to examine the accuracy of perceptions of the farmers. Various meteorological parameters were interpreted and correlated with observations made in the past and exceptions if any. For analysis, statistical tool embedded in xls. program was used.

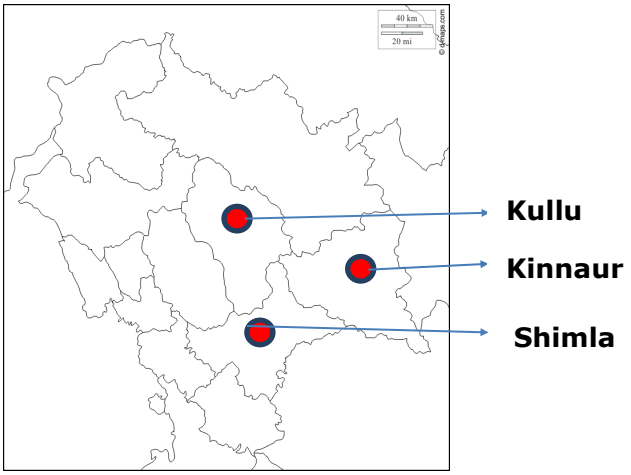
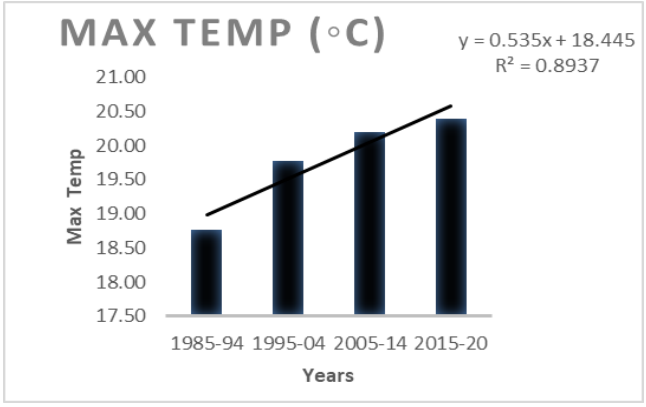
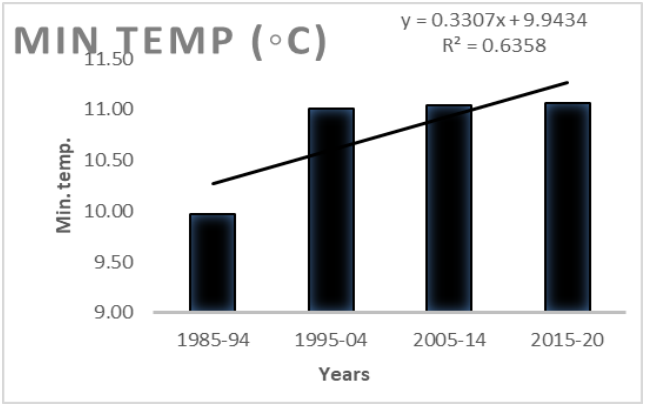



**Fig. 1.** *Study area showing three apple growing districts of Himachal Pradesh*



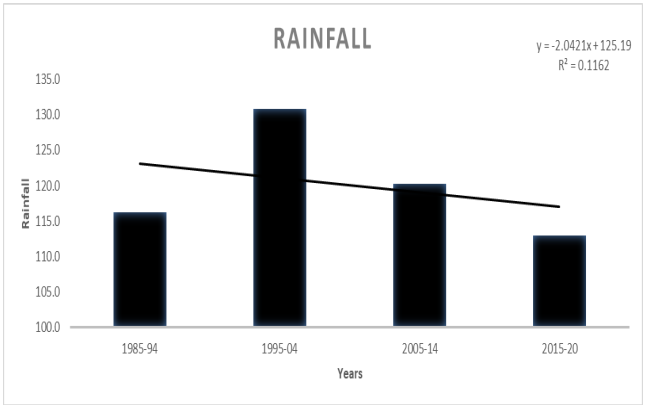




**Fig. 2.** *Maximum, minimum temperature and rainfall data (1985-2021) of Shimla district (Source: Agriculture University, Palampur, Himachal Pradesh)*

## RESULTS AND DISCUSSION

Low temperature is indicative of the chilling hours experienced during winters. During the winters, the plants are dormant. However, they require more than 1000 hours for chilling (Temperature < 7º C). In the duration from 1985-2020 in all the three districts, an increase in the maximum and minimum temperature has been observed with a corresponding decrease in the rainfall in the study area. The district wise results are discussed below.

### Shimla district – Study area I

In Shimla district, Maximum and minimum temperature has increased by 1.64 ºC and 1.09 ºC, respectively, from 1985 to 2020, rainfall in the same area has decreased to 3.3 mm in the same period (Fig 2). The area under the apple crop has increased and correspondingly, production has also increased. This indicated that there is hardly any impact of increased temperature or decreased rainfall, but the productivity has decreased in the trends for the period 1994-02 and 2012-2020. However, the productivity increased in the period 1984-1993 and 2003-2011 (Fig. 3). The decadal averages of various parameters are many times affected by the steep increase and decrease of some years' observations in a particular decade. In each decade, there were some extreme event years (e.g., 2005, 2010,2011) when there was a steep increase or decrease in meteorological parameters, which influenced

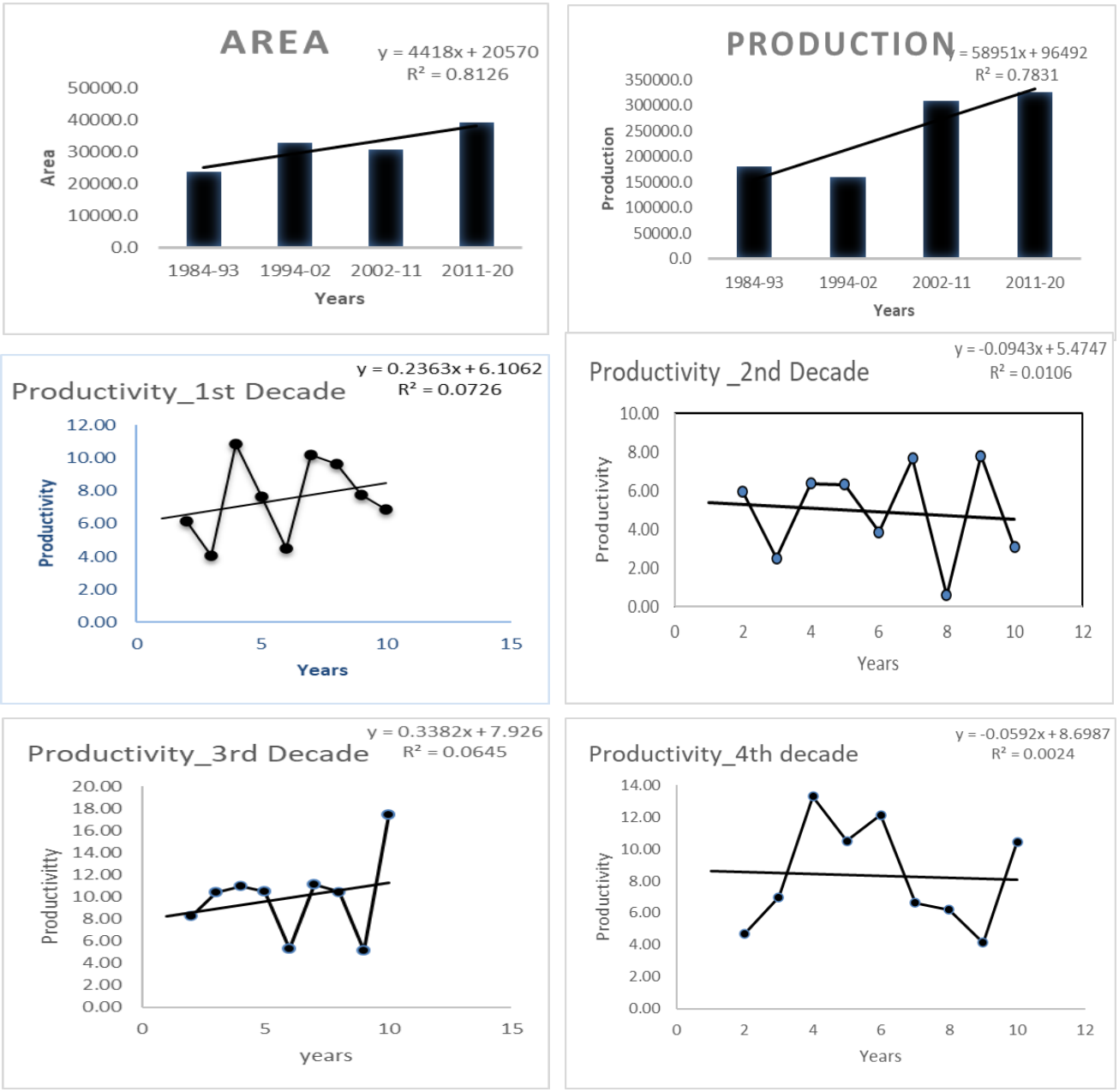



**Fig. 3.** *Area, production and productivity of Shimla district (Source: Directorate of Horticulture, 2021)*

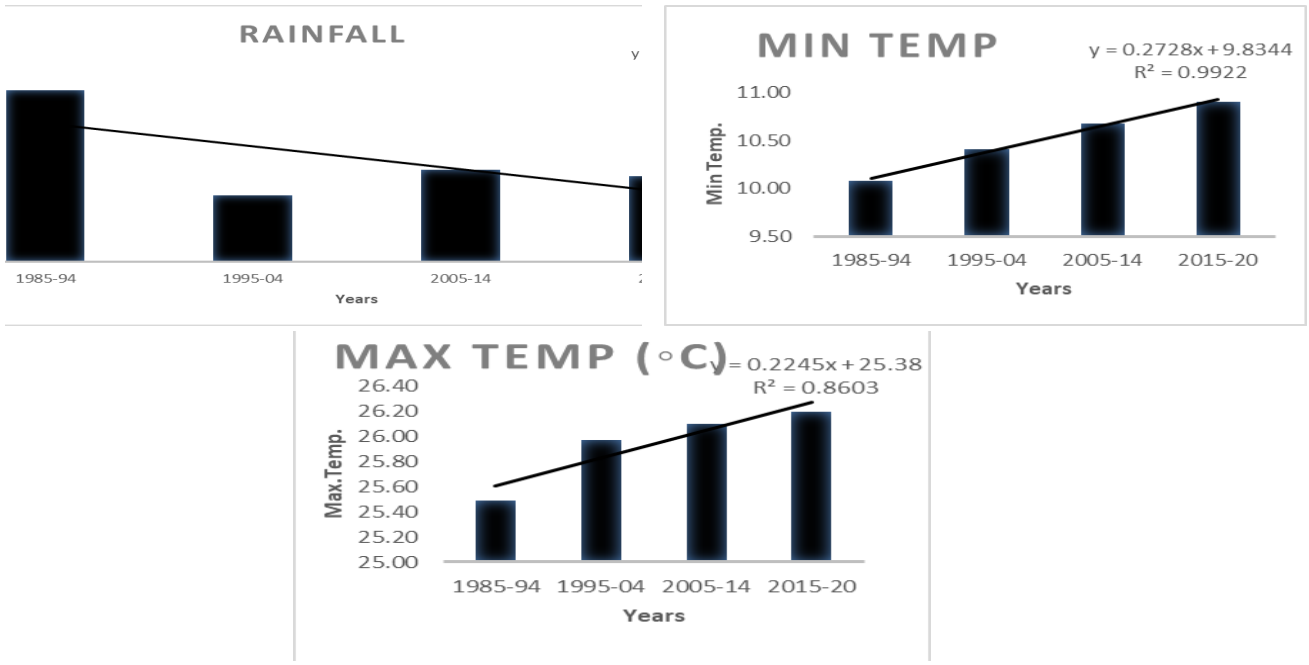



**Fig. 4.** *Maximum temperature, minimum temperature and rainfall data (1985-2020) of Kullu district (Source: Agriculture University, Palampur, Himachal Pradesh)*

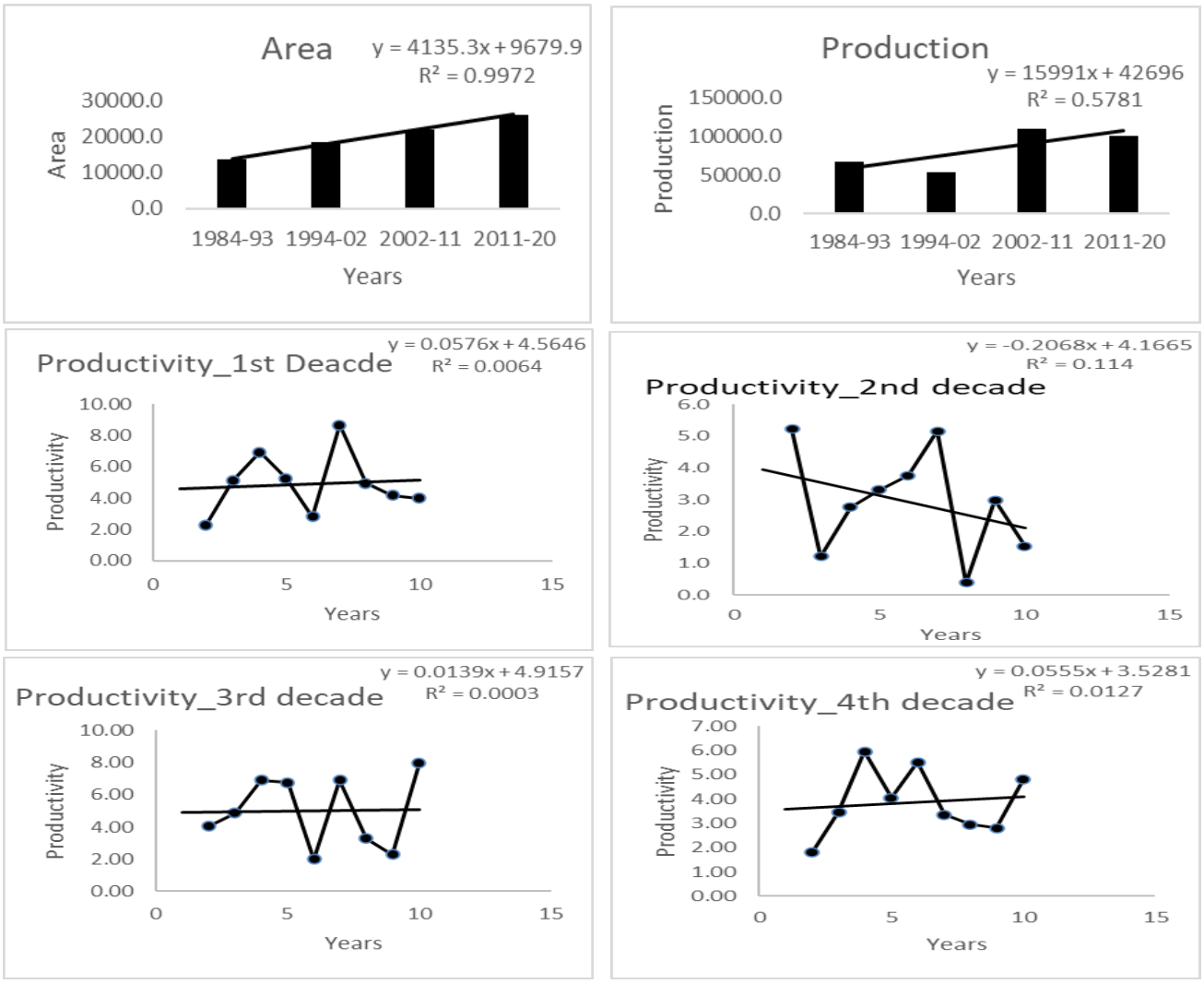



**Fig. 5.** *Area, production and productivity of Kullu district (Source: Directorate of Horticulture, 2021)*

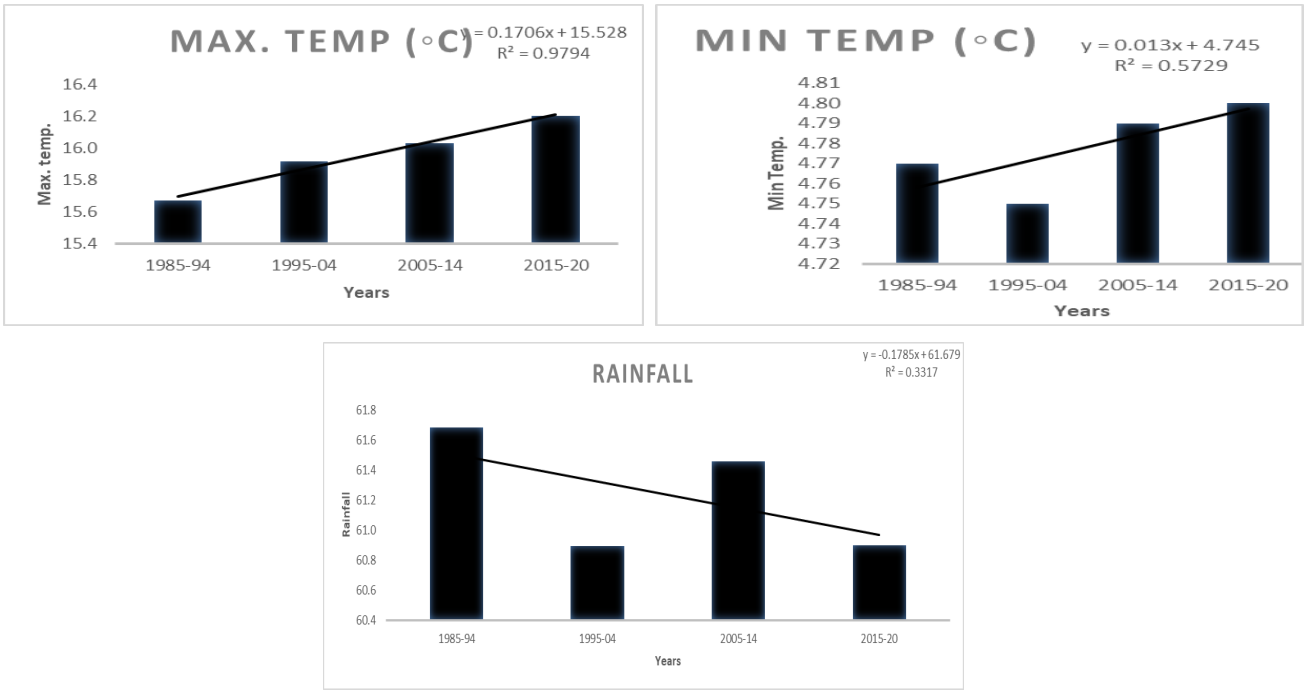



**Fig. 6.** *Maximum, minimum temperature and rainfall data (1985-2021) of Kinnaur district (Source: Agriculture University, Palampur, Himachal Pradesh)*

the decadal averages. Such extreme events in some years have also been found to influence the decadal averages in various studies in fruit crops like plum, pear and apricot (Ahmed *et al.* 2019) and tea (Baruah *et al*., 2012).

**Kullu district – Study area II**

In Kullu district Maximum and minimum temperature is increased by 0.71 ºC and 0.82 ºC from 1985 to 2020, however, rainfall in the same area has decreased to 5.3 mm in the same period (Fig 4). The apple crop in this area has shown an increase in area and production, but the productivity has decreased for the period 1994-02 and 2012-2020, however, an increase observed for 1984-1993 and 2003-2011, almost similar to Shimla district (Fig 5). Since study area I and area II are spaced by about a hundred kilometres, but it is observed from the data analysis results that climate, as well as growing conditions, remain by and large the same. In previous studies also, it has been observed that these two study areas converge in many ways for same climatic impacts on cereals, vegetables and apple (Rana *et al*., 2012, Rana *et al*., 2013). In an earlier study, Bhagat *et al*., 2009) also observed that the weather-related changes impacts on apple crop shift follow definite elevation besides meteorological parameters. In simple terms, it can be interpreted that similar elevations will have similar impacts even if they are separated by hundreds of kilometres in a large agriculture landscape.

**Kinnaur district – Study area III**

In Kinnaur district maximum and minimum temperature is increased by 0.5ºC and 0.03 ºC, respectively, from 1985 to 2020, rainfall in the same area has decreased by 0.9 mm in the same period (Fig 6). The apple crop in this area has shown an increase in area and production and also productivity except for 1994-02 (Fig 7). In this study area, the temperature ranges were highly suitable for apple growing. This implies that the increase in temperature has so far not influenced the chilling requirement and the growing conditions for apple are by and large most favorable. Similar observations have also been made on tea, crops in Northeastern India, where temperature changes are still within the crop growing amplitude and not much damage has been caused (Baruah *et al*., 2014, Baruah *et al.,*2016).

## Conclusion

The temperature in apple growing regions of the mountain state of Himachal Pradesh, India, showed increasing trends, whereas precipitation showed decreasing trends. Variability of weather elements was observed both at different locations and with changes in time in most apple growing regions. Increased warming is elevating the minimum temperature, which is the major concern for apple growers in Himachal Pradesh. The increasing trends of minimum temperature in Shimla, Kullu and Kinnaur districts have suggested that the area is still suitable for apple farming, but it may impact

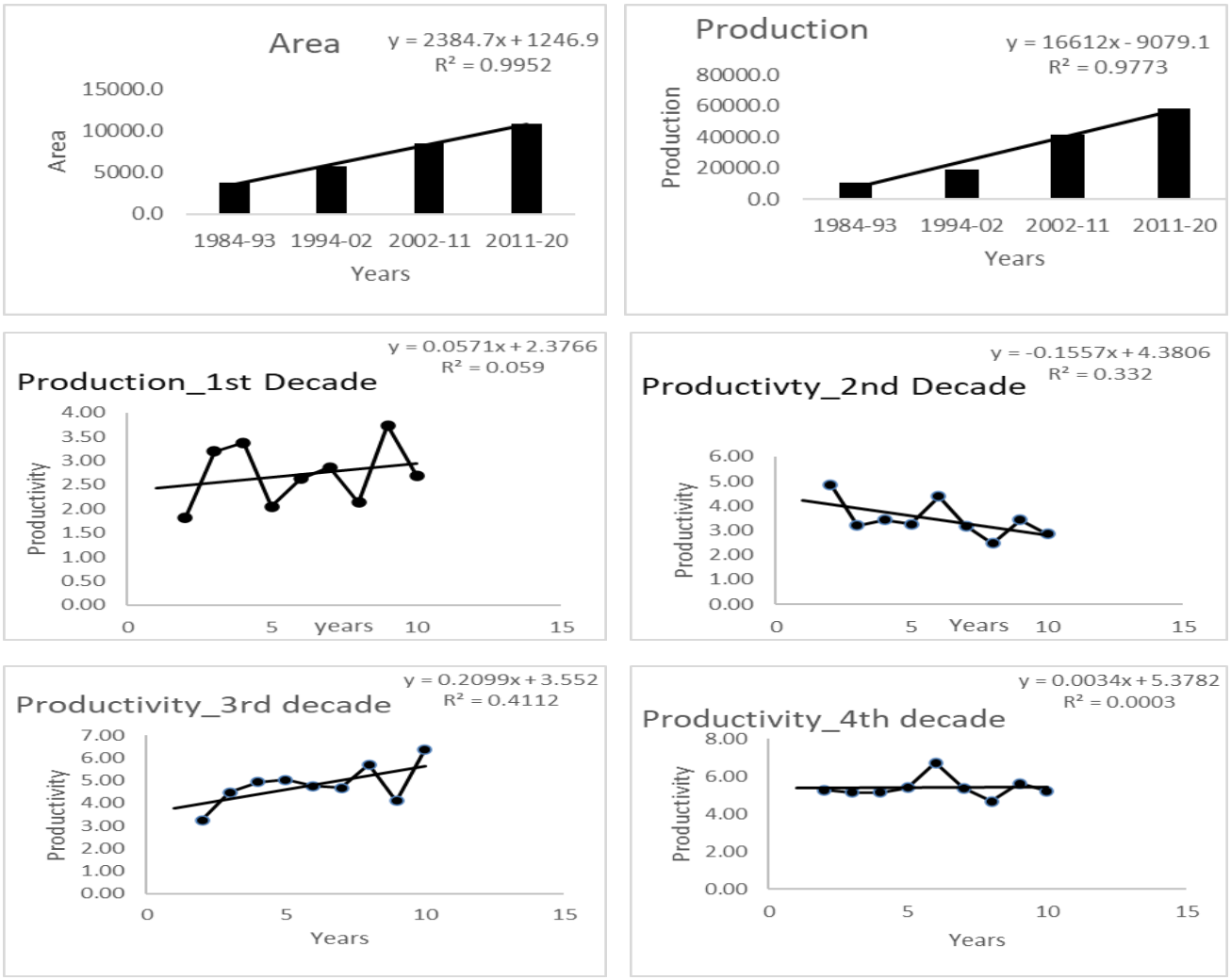



**Fig. 7.** *Area, production and productivity of Kinnaur district (Source: Directorate of Horticulture, 2021)*

the quality of the crop. Area and production of all three districts of study are increasing, because growers are slowly shifting to low chilling varieties.

## Conflict of interest

The authors declare that they have no conflict of interest.

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