

IMPACT OF CLIMATE CHANGE ON PRODUCTIVITY OF WHEAT AND COTTON IN SOUTH WEST PUNJAB

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
AGRICULTURAL METEOROLOGY
(Minor Subject: Agronomy)**

By

**Ramandeep Kaur
(L-2017-A-29-M)**

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LUDHIANA-141 004**

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CERTIFICATE – I

This is to certify that the thesis entitled, **“Impact of climate change on productivity of wheat and cotton in south west Punjab”** submitted for the degree of **M.Sc.** in the subject of **Agricultural Meteorology (Minor subject: Agronomy)** of the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Ramandeep Kaur (L-2017-A-29-M)** under my supervision and no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigations have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled, **“Impact of climate change on productivity of wheat and cotton in south west Punjab”** submitted by **Ms. Ramandeep Kaur (L-2017-A-29-M)** to the Punjab Agricultural University, Ludhiana in partial fulfillment of the requirements for the degree of **M.Sc.**, in the subject of **Agricultural Meteorology** (Minor subject: **Agronomy**) has been approved by the Student’s Advisory Committee along with External Examiner after an oral examination of the same.

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ABSTRACT

The study entitled "Impact of climate change on productivity of wheat and cotton in south west Punjab" was conducted to assess the shift, variation and deviation in climate of Punjab during 37 year (1981-2017) in Bathinda and 17 years (2001-2017) in Faridkot using correlation regression techniques and estimating the possible effects of climate and technology on the productivity of cotton (*Gossypium* spp.) and wheat (*Triticum aestivum* L.) crops. Three different statistical models i.e. Basic Model (Model 1), Modified Model (Model 2) and SPSS Software (Model 3) were used. The results showed that in case of maximum temperature at Bathinda, more variation has been found in fourth decade as compared to others and at Faridkot the variation was observed more during second pentad. More variation in minimum temperature has been found in fourth decade and third pentad at Bathinda and Faridkot, respectively. In case of rainfall at Bathinda, more variation has been found in fourth decade as compared to others. At Faridkot, the variation was more during second pentad. GStat was used for the development of multiple regression equation and correlation was developed for the sensitive crop periods in model I or basic model. The basic model is then modified through inclusion of an assumed composite index while other independent variables are kept constant. SPSS software was used as a model for wheat and cotton for forecast analysis. The use of basic model (model 1) has shown that the maximum temperature during 2nd and 3rd weeks of wheat growing season had negative effect on wheat yield at Bathinda district. At Faridkot, minimum temperature during 2nd week showed negative effect on wheat yield. The three models (i.e. basic model, modified model and SPSS software) predicted wheat and cotton yield and the error per cent of all these models was remained 30 per cent for two districts (Faridkot and Bathinda) of south west Punjab. For American cotton and desi cotton grown in Bathinda and Faridkot districts, SPSS software (model 3) was best fit as R² value was highest for American cotton by 83 % (Bathinda district) and 97% (Faridkot district), whereas, for desi cotton it was 82 % and 96 % for Bathinda and Faridkot district, respectively. For wheat grown in Bathinda, SPSS software was best fit as R² value was 97 % while wheat grown in Faridkot, modified model (model 2) was best fit (95 %).

Keywords: Climate change, cotton, statistical models, South West Punjab, wheat

Signature of Major Advisor

Signature of the Student

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ਮੌਜੂਦਾ ਅਧਿਐਨ “ਦੱਖਣ-ਪੱਛਮੀ ਪੰਜਾਬ ਵਿੱਚ ਕਣਕ ਅਤੇ ਨਰਮੇ ਦੀ ਉਤਪਾਦਕਤਾ ਉਪਰ ਮੌਸਮੀ ਤਬਦੀਲੀ ਦਾ ਪ੍ਰਭਾਵ” ਸਿਰਲੇਖ ਅਧੀਨ ਸਹਿ-ਸਬੰਧਨ ਪ੍ਰਤੀਗਮਨ ਵਿਧੀਆਂ ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਬਠਿੰਡਾ ਵਿੱਚ 37 ਸਾਲਾਂ (1981-2017) ਅਤੇ ਫਰੀਦਕੋਟ ਵਿੱਚ 17 ਸਾਲਾਂ (2001-2017) ਦੇ ਅੰਕੜੇ ਲੈ ਕੇ ਪੰਜਾਬ ਦੇ ਮੌਸਮ ਵਿੱਚ ਆਉਣ ਵਾਲੇ ਬਦਲਾਅ, ਵਿਭਿੰਨਤਾ ਅਤੇ ਵਿਚਲਣ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਲਈ ਅਤੇ ਨਰਮੇ (*ਗੋਸੀਪੀਅਮ ਸਪੀਸੀਜ਼*) ਅਤੇ ਕਣਕ (*ਟ੍ਰੀਟੀਕਮ ਐਸਟੀਵਮ* ਐਲ.) ਦੀ ਉਤਪਾਦਕਤਾ ਉਪਰ ਮੌਸਮ ਅਤੇ ਤਕਨੀਕ ਦੇ ਸੰਭਾਵਤ ਪ੍ਰਭਾਵਾਂ ਦਾ ਅਨੁਮਾਨ ਲਗਾਉਣ ਲਈ ਕੀਤਾ ਗਿਆ। ਅੰਕੜਾ ਗਣਿਤ ਦੇ ਤਿੰਨ ਵੱਖ-ਵੱਖਰੇ ਮਾਡਲਾਂ ਭਾਵ ਬੇਸਿਕ ਮਾਡਲ (ਮਾਡਲ 1), ਰੁਪਾਂਤਰਿਤ ਮਾਡਲ (ਮਾਡਲ 2) ਅਤੇ ਐਸ ਪੀ ਐਸ ਐਸ ਸਾਫਟਵੇਅਰ (ਮਾਡਲ 3) ਦੀ ਵਰਤੋਂ ਕੀਤੀ ਗਈ। ਅਧਿਐਨ ਦੇ ਨਤੀਜਿਆਂ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਵੱਧ ਤੋਂ ਵੱਧ ਤਾਪਮਾਨ ਵਿੱਚ ਬਠਿੰਡਾ ਵਿਖੇ ਬਾਕੀ ਦਹਾਕਿਆਂ ਦੇ ਮੁਕਾਬਲੇ ਚੌਥੇ ਦਹਾਕੇ ਦੌਰਾਨ ਅਤੇ ਫਰੀਦਕੋਟ ਵਿੱਚ ਦੂਜੇ ਪੰਜਵਾਂ ਦੌਰਾਨ ਸਭ ਤੋਂ ਵਧੇਰੇ ਵਿਭਿੰਨਤਾ ਦਰਜ ਕੀਤੀ ਗਈ। ਬਠਿੰਡਾ ਅਤੇ ਫਰੀਦਕੋਟ ਵਿੱਚ ਕ੍ਰਮਵਾਰ ਚੌਥੇ ਦਹਾਕੇ ਅਤੇ ਤੀਜੀ ਪੰਜਵਾਂ ਦੌਰਾਨ ਘੱਟ ਤੋਂ ਘੱਟ ਤਾਪਮਾਨ ਵਿੱਚ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਵਿਭਿੰਨਤਾ ਦਰਜ ਕੀਤੀ ਗਈ। ਬਠਿੰਡਾ ਵਿੱਚ ਬਾਕੀ ਦਹਾਕਿਆਂ ਦੇ ਮੁਕਾਬਲੇ ਚੌਥੇ ਦਹਾਕੇ ਦੌਰਾਨ ਵਰਖਾ ਵਿੱਚ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਵਿਭਿੰਨਤਾ ਪਾਈ ਗਈ। ਫਰੀਦਕੋਟ ਵਿੱਚ ਦੂਜੇ ਪੰਜਵਾਂ ਦੌਰਾਨ ਵਰਖਾ ਦੀ ਮਿਕਦਾਰ ਵਿੱਚ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਵਿਭਿੰਨਤਾ ਦਰਜ ਕੀਤੀ ਗਈ। ਬਹੁ ਪ੍ਰਤੀਗਮਨ ਸਮੀਕਰਨ ਵਿਕਸਤ ਕਰਨ ਲਈ ਜੀ ਸਟੈਟ ਦੀ ਵਰਤੋਂ ਕੀਤੀ ਗਈ ਅਤੇ ਮਾਡਲ 1 ਜਾਂ ਬੇਸਿਕ ਮਾਡਲ ਵਿੱਚ ਸੰਵੇਦਨਸ਼ੀਲ ਫਸਲ ਅੰਤਰਾਲਾਂ ਲਈ ਸਹਿਸੰਬੰਧਨ ਵਿਕਸਤ ਕੀਤਾ ਗਿਆ। ਇਸ ਮਗਰੋਂ ਇੱਕ ਕਲਪਿਤ ਕੰਪੋਜ਼ਿਟ ਸੂਚਕਾਂਕ ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਬੇਸਿਕ ਮਾਡਲ ਨੂੰ ਸੋਧਿਆ ਗਿਆ ਜਦੋਂਕਿ ਬਾਕੀ ਅਜ਼ਾਦ ਵੇਰੀਏਬਲਾਂ ਨੂੰ ਸਥਿਰ ਰੱਖਿਆ ਗਿਆ। ਭਵਿੱਖਤ ਅਨੁਮਾਨ ਦੇ ਮੁਲਾਂਕਣ ਲਈ ਕਣਕ ਅਤੇ ਨਰਮੇ ਲਈ ਐਸ ਪੀ ਐਸ ਐਸ ਸਾਫਟਵੇਅਰ ਨੂੰ ਇੱਕ ਮਾਡਲ ਵਜੋਂ ਵਰਤਿਆ ਗਿਆ। ਬੇਸਿਕ ਮਾਡਲ (ਮਾਡਲ 1) ਦੀ ਵਰਤੋਂ ਨੇ ਬਠਿੰਡਾ ਵਿਖੇ ਕਣਕ ਦੇ ਵਾਧੇ ਦੇ ਛੇਵੇਂ ਅਤੇ ਸਤਵੇਂ ਹਫ਼ਤੇ ਦੌਰਾਨ ਵੱਧ ਤੋਂ ਵੱਧ ਤਾਪਮਾਨ ਦਾ ਕਣਕ ਦੇ ਝਾੜ ਉਪਰ ਨਾਕਾਰਾਤਮਕ ਪ੍ਰਭਾਵ ਦਰਸਾਇਆ ਅਤੇ ਫਰੀਦਕੋਟ ਵਿੱਖੇ, ਦੂਜੇ ਹਫ਼ਤੇ ਦੌਰਾਨ ਘੱਟੋ ਘੱਟ ਤਾਪਮਾਨ ਨੇ ਕਣਕ ਦੇ ਝਾੜ ਉਪਰ ਨਾਕਾਰਾਤਮਕ ਪ੍ਰਭਾਵ ਦਰਸਾਇਆ। ਤਿੰਨ ਮਾਡਲਾਂ (ਭਾਵ ਬੇਸਿਕ ਮਾਡਲ, ਰੁਪਾਂਤਰਿਤ ਮਾਡਲ ਅਤੇ ਐਸ ਪੀ ਐਸ ਐਸ ਸਾਫਟਵੇਅਰ) ਨੇ ਕਣਕ ਅਤੇ ਨਰਮੇ ਦੇ ਝਾੜ ਦਾ ਅਨੁਮਾਨ ਲਗਾਇਆ ਅਤੇ ਦੋਨਾਂ ਜ਼ਿਲ੍ਹਿਆਂ (ਫਰੀਦਕੋਟ ਅਤੇ ਬਠਿੰਡਾ) ਲਈ ਇਹਨਾਂ ਤਿੰਨਾਂ ਮਾਡਲਾਂ ਦੀ ਗਲਤੀ ਦੀ ਪ੍ਰਤੀਸ਼ਤਤਾ 30 ਪ੍ਰਤੀਸ਼ਤ ਰਹੀ। ਬਠਿੰਡਾ ਅਤੇ ਫਰੀਦਕੋਟ ਵਿੱਚ ਕਾਸ਼ਤ ਕੀਤੇ ਜਾਂਦੇ ਅਮਰੀਕਨ ਨਰਮੇ ਅਤੇ ਦੇਸੀ ਨਰਮੇ ਲਈ, ਐਸ ਪੀ ਐਸ ਐਸ ਸਾਫਟਵੇਅਰ (ਮਾਡਲ 3) ਸਭ ਤੋਂ ਵਧੀਆ ਸੀ ਕਿਉਂਕਿ ਅਮਰੀਕਨ ਨਰਮੇ ਲਈ R^2 ਦੀ ਮਿਕਦਾਰ ਬਠਿੰਡਾ ਅਤੇ ਫਰੀਦਕੋਟ ਜ਼ਿਲ੍ਹਿਆਂ ਲਈ ਕ੍ਰਮਵਾਰ 83% ਅਤੇ 97% ਜ਼ਿਆਦਾ ਸੀ ਜਦੋਂਕਿ ਦੇਸੀ ਨਰਮੇ ਲਈ R^2 ਦੀ ਮਿਕਦਾਰ ਬਠਿੰਡਾ ਅਤੇ ਫਰੀਦਕੋਟ ਜ਼ਿਲ੍ਹਿਆਂ ਲਈ ਕ੍ਰਮਵਾਰ 82% ਅਤੇ 96% ਸੀ। ਬਠਿੰਡਾ ਵਿੱਚ ਕਣਕ ਲਈ ਐਸ ਪੀ ਐਸ ਐਸ ਸਾਫਟਵੇਅਰ ਸਭ ਤੋਂ ਵਧੀਆ ਸੀ ਅਤੇ R^2 ਦੀ ਮਿਕਦਾਰ 97% ਸੀ ਜਦੋਂਕਿ ਫਰੀਦਕੋਟ ਵਿੱਚ ਕਣਕ ਲਈ ਸੋਧਿਆ ਹੋਇਆ ਮਾਡਲ (ਮਾਡਲ 2) ਸਭ ਤੋਂ ਵਧੀਆ ਸੀ ਅਤੇ R^2 ਦੀ ਮਿਕਦਾਰ 95% ਸੀ।

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CHAPTER I

INTRODUCTION

Climate change means a change of climate which is attributed directly or indirectly to human activity that alters the composition of global atmosphere and also in addition to climate variability observed over comparable time periods. Change in climate associated with unabated increase in greenhouse gases, including fluorinated gases, nitrous oxide, carbon dioxide and methane. It can pose threats to agriculture productivity and food security by modifying the spatial and temporal distribution of rainfall, temperature and water availability (Ali *et al* 2017). Climate change is no longer a future phenomenon but is a reality. By starting of industrial revolution, concentration of CO₂ in the atmosphere has increased by more than 25 per cent. Along with deforestation, use of fossil fuels is one of major cause of it (Reicosky *et al* 2000 and Houghton *et al* 2001). The plant process affected by changes in atmospheric CO₂ concentration are photosynthesis, dark respiration and photorespiration (Fitter and Hay 1987). Elevated CO₂ generally enhance leaf and canopy photosynthesis because of increased concentrations of ribulose-1, 5-biphosphate carboxylase/oxygenase (Rubisco) repression of photorespiration in C₃ plants for example cotton, wheat and rice (Reddy *et al* 2000).

Climate affects the various activities involved in agricultural productivity build up thus is a very important parameter all over the world. Soon the greenhouse effect leading to global warming will cause changes in the climate of various regions on Earth leading to adversities on crop productivity. If the climate variability remains negligible then increased CO₂ will lead to a positive response of crops (Sushila, 2001) but the associated impacts of extreme events caused under changing temperatures and rainfall pattern may reduce yield and enhance risk in agricultural productivity. Aggarwal (2008) studied the impact of every 1°C rise on the wheat crop and found it to affect it by a possible yield loss of 4-5 million tonnes even after taking into account adaptations like carbon fertilization and changes in water availability through irrigation. By 2080-2100 reduction of up to 40 per cent in the food grain production in India is an assumption under increasing temperature (Fischer *et al* 2002, Parry *et al* 2004 and IPCC 2007).

The wheat productivity will be the most influenced and will suffer a negative impact as per the predictions by the warming scenarios. IPCC (2014) has predicted an increase in global surface temperature in the range of 0.4-2.6°C in 2046-2065 and 0.3-4.8°C in 2081-2100 relative to the reference time period of 1986-2005. During mid-century (MC) the most fertile Indo-Gangetic plain will suffer a rise of 0.5-1.0°C in mean temperature while during end century (EC) it will face a rise of 3.5-4.5°C, an increased frequency of extremely wet rainy seasons will also be experienced by the same (Gosain and Rao 2007).

The potential yield of crops tends to decrease with sudden rise in temperature in many tropical and subtropical regions. The increase of temperature particularly night time and CO₂ have profound impact on vegetative and reproductive phase of crops and leads to shift in insect pest and disease which will require higher farm resources to manage these changes to improve their living standard (Krupa 2003). Therefore, climate change is gaining importance for building up the future of mankind (Sant Ana, 2010). Unfortunately, no particular efforts on large scale have been made to overcome the negative effects of this changing climate (Goldman and Freebarin 1995).

Wheat (*Triticum aestivum* L.) is most staple cereal crop, belonging to Gramineae family. In India, it ranks second in area and production after rice. In Punjab, wheat is a major cereal crop during *rabi* season. In 2016-17 it was grown on area of 34.95 lac hectares with production of 176.36 lac tonnes and average yield of 50.46 quintals per hectare yield (Anonymous, 2018).

Huge variations in wheat productivity is being observed due to large weather variability observed in recent years. Wheat productivity is highly dependent on climatic changes and with the climate change and global warming scenarios having an adverse affect on crop productivity in different regions. In India, to meet the future food demands of increasing population, crop productivity should be maintained at a higher level. Wheat is a long day plant along with being a thermo-sensitive and photo-insensitive, it is sensitive to temperature and thus it affects the wheat production in India. Both the beginning and end of wheat crop season are limited by the onset and end of favourable temperature regimes which ultimately affects the quality and the yield of wheat. If the weather parameters are considered then moisture and radiation are basic meteorological parameters, the change of which impacts agriculture (Reddy 2006). Low temperature and dew formation during early phase promotes tillering, whereas, hot and humid condition encourages insects and diseases. Wheat yield reduced by 7.5 per cent for every 1.0°C increase of temperature (Gracila *et al* 2003).

Rao *et al* (2015) reported that during the post-anthesis in wheat the grain yield starts becoming sensitive to the minimum temperature thus a decrease in average wheat yield was observed from 1980-2011 by per cent 204 kg ha⁻¹ for 1°C increase in minimum temperature. For achieving higher wheat productivity thermal constraints involves an excessive increase in minimum temperature by 12°C for continuous six days and terminal heat stress with maximum temperature greater than 34°C for 7 days. Samara *et al* (2012) studied and noticed that wheat yield suffered average yield loss of 217 kg ha⁻¹ (4.5 per cent) during a heat wave year and 356 kg ha⁻¹ (7.4 per cent) during a cold wave year. Also, a productivity gain by 400 kg ha⁻¹ was obtained in the Punjab for relatively colder year (2011-2012).

Castro *et al* (2007) reported reduction in the length of grain filling period when wheat plants were exposed to high temperature. When there was a longer period of heat stress the grain filling period became the shortest but the duration showed no difference with respect to stress conditions. The heat stress also caused a reduction in 1000 grain weights devoid of any effect attributable to the duration of stress.

Cotton (*Gossypium* spp.) known as king of fibers is an important cash crop of India and World. It is belonging to the genus *Gossypium* under tribe *Gossypieae* of Malvaceae family. It is also called the backbone of textile industry. Cotton is a second major crop in the *Kharif* season and a major cash crop of the south-western districts of the Punjab State. Four cultivated species in India grown on commercial scale are *Gossypium arboreum*, *G. herbaceum*, *G. hirsutum* and *G. barbadense*. For germination of cotton 16°C temperature is required and 21 to 27°C temperature is required for proper crop growth. During 2017-18 total production was 12.71 lakh bales with an average yield of 7.53 quintals lint per hectare. At the time of fruiting phase, the day temperature ranging from 27 to 32°C and cool nights are required. Dry period is good for boll opening. The bright sunshine from mid September to November i.e picking periods assure a best quality of the produce (Anonymous 2019). India accounts for 75 per cent of the fibre used in the textile industry with 1500 rotating mills therefore contributing towards 4 per cent of GDP (Sankaranarayanan *et al* 2010).

In Punjab, sowing period of cotton is recommended from 1st April up to 15th May. Very early and too late sowing of cotton is not suitable and associated with the poor crop stand and decreased productivity. Therefore, any deviation in mean temperature or heat stress is expected to decrease the cotton yields (Singh *et al* 2007). For cotton crop the dry season is beneficial for the crop during boll opening and picking stages and simultaneously vegetative and reproductive growth is also occurring thus making interpretation of the crop's response to climate and management is difficult. The net effects increased CO₂ concentration, temperature, reduced water availability and increased demand for evaporation due to low rainfall and relative humidity will influence fibre yield and quality (Bange 2007).

Gwimbi and Mundoga (2010) observed that cotton production was reduced due to decrease in precipitation and increase in temperature. But, the effect of precipitation on the cotton yield depends only on the specific growth stages of the crop like germination, fruiting and maturity (Thakar 2014). Hence, as temperature sensitive crop cotton is considered as risky and prone to weather conditions (Reddy *et al* 1999). Leaf expansion, biomass production, internodes elongation and the partitioning of assimilates to different plant parts is significantly affected by temperature (Sankarnarayanan *et al* 2010).

Agriculture is particularly vulnerable to climate change. Therefore agricultural productivity needs to be vigorously increased in order to provide food and meet the demand

of growing population is the main outlook for coming decades under changing scenarios (IFPRI, 2009). So keeping these points in mind the present study was planned to study the impact of climate change on wheat and cotton crops. The present study aimed to analyze the change in climatic pattern and its impact on the wheat and cotton crop productivities in Punjab. The study was carried out with the following specific objectives:

1. To comprehend the changing pattern of the important weather parameters in two districts (Faridkot and Bathinda) of south west Punjab.
2. To analyze the impact of climate change on the productivity of wheat and cotton crops in south west Punjab.

CHAPTER II

REVIEW OF LITERATURE

A brief review of the literature relevant to the present research problem has been presented in this chapter. It provides an overview of various aspects of the research problem as revealed by different researchers over the time in India and abroad. The available literature been presented under following categories.

2.1 Change in climatic parameters

2.2 Impact of climate change on agriculture

2.3 Impact of climate change on wheat

2.4 Impact of climate change on cotton

2.1 Change in climatic parameters

With the beginning since 1880, 2010 tied with 2005 has been reported as warmest years of the global temperatures as per Anonymous (2011) and it has been found to be the 34th consecutive year in which the global temperature is above the 20th century average. For the tied with 2005 as the warmest period was recorded at 0.62°C ($\pm 0.07^\circ\text{C}$) above the 20th century of combined global land and ocean while only global land surface temperature for 2010 were tied for the second warmest on record at 0.96°C ($\pm 0.11^\circ\text{C}$) above the 20th century average.

India's CO₂ emission contribute to 4% of total global CO₂ emissions as per Anonymous (2009) India which is having a GDP growth every year of 8-9% per year, the per capita emissions for the next decade or two is likely to be below the averages of developed countries. Its energy intensity of production has been falling with improvements in energy efficiency autonomous technological changes and economical use of energy. The modeling studies for climate show the per capita emission to be around 2-2.5 tons of CO₂ equivalent by 2020 and around 3-3.5 tons of CO₂ equivalent by 2030 in comparison to present 1-1.2 tons at present.

Khan *et al* (2009) estimated that mean temperature increase for India as per projection is by 0.1-0.3°C during *kharif* and 0.3-0.7°C during *rabi* 0.4-2.0°C during *kharif* and 1.1-4.5°C during *rabi* by 2010 and 2070 respectively. While the mean rainfall projections show nil changes by 2010 but an increase will be seen upto 10 per cent during *kharif* and *rabi* by 2070. Besides this for the same time there is possibility of occurrence of climate extremes, time of onset of monsoon, intensities and frequencies of droughts and floods.

2.2 Impact of climate change on agriculture

Mitchell *et al* (1993) also obtained similar sign of lower yields for many important grain crops such as wheat, corn and oat when temperature increased at plant development

stage. The productivity responds negatively to increase in mean maximum temperature at vegetation stage in mixed zone in UK fields.

Kumar and Parikh (2001) predicted that climate change would have a huge impact on the production of rice and wheat by 2060, which would in turn affect the livelihood and food security of one million people in India. Excessive rainfall and drastic weather changes have adversely affected the production of Jowar, impacting the life of those dependent on farm in Karnataka. Geethalakshmi *et al* (2011) on the other hand, found that there has been a 41% decline in the rice production as a result of an increase in the temperature by 4 degree Celsius in Tamil Nadu.

Samara and Singh (2002) analyzed that droughts like floods, heavy rain, tropical cyclones and heat waves are known to negatively impact agricultural production and farmers. For example, in year 2002 led to decrease area reporting of more than 15 million hectares of the rainy season crops and resulted in a loss of more than 10 per cent in food production. The projected increases in these events the Oklahoma State University could result in greater instability in food production due to the cause of drought.

Kumar *et al* (2004) studied that strong link between parameters of climate and crop production. The crop climate relationships for India, using historic production of data for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for overall food grain, cereal, pulses and oilseed production. All India annual total production (except sorghum and sugarcane), production in the monsoon (except sorghum) and post-monsoon seasons (except sorghum and rice) were mainly related to all India summer rainfall.

Mall *et al* (2006) reported that climate change impact the food production of the country and many simulation models have been used to predict these changes due to climate change. These models can be used as a tool for sustainable development of strategies and help to make suitable decisions regarding farming operations. In India considerable work has been done in last decade aimed to determine the change in yield of different crops due to projected climate change.

Easterling *et al* (2007) found through an analysis of modelling that in mid to far above the ground latitude regions, a moderate local raise in temperature (1-3°C), along with related CO₂ increase and rainfall changes is possible to be beneficial for crop yields. As against this, in low latitude regions, a temperature increase of 1-2°C is likely to have negative yield impacts for main cereals.

Hundal and Prabhjyot-Kaur (2007) reported increased rainfall from 2.5 to 16.8 mm/year, decreased maximum temperature from 0.05 to 0.06°C /year and decreased or increased trend of 7 minimum temperature from -0.02 to +0.07°C /year in different regions of

Punjab for a climatic data of 30 years. A general observation determines a negligible effect of increased temperature above normal on the phenological development of rice than that of wheat, which was advanced. A temperature increase of 1.0°C cause a decrease in rice and wheat yield by 3 and 10 per cent, respectively. Also, a decrease in crop yields was seen with the decrease in radiation and vice-versa. The interaction effects of simultaneous increase/decrease in parameters were also simulated. An decrease in maximum temperature decreased by 0.25 to 1.0°C while a increase in minimum temperature increased by 1.0 to 3.0°C from normal, caused the rice and wheat yield to decrease by 0.8 and 3.0 per cent, respectively from normal. Also a decrease was seen in grain yield by 9 and 14 per cent, from normal for rice and wheat respectively under a temperature increase by 1.0°C and solar radiation decrease by 5 per cent from normal.

Aggarwal P K (2008) in India reported that increase in green house gasses emission due to anthropogenic activities result in increase in earth temperature which ultimately affecting the crop production as crop duration is changing. There is shift in insect pest and disease incidence under these changing conditions. They suggested the by incorporation the different adaptive strategies such as changing the sowing time of the crop or use of short duration varieties help to overcome the negative impact of climate change on productivity of crops. Some additional adaptive strategies can also be adopted by farmers such as by changing the land use or use of improved land use polices and crop insurance schemes etc.

According to the results computed by Aggarwal *et al* (2009) there can be 3 to 7 per cent decrease in the productivity of wheat, soybean, mustard, groundnut and potato due to a 1°C rise in the temperature. Consequently, a predicted rise in the temperature between 2.5 and 4.9°C by the year 2099 would lead to 10 to 40 per cent destruction of these crops.

Ashfaq *et al* (2011) concluded that climatic change as major factor determining the productivity of crops during entire crop period in mixed zone of Punjab. High temperature affects the reproductive stage of crop negatively while higher minimum temperature during the sowing of crop has positive effect on yield. Along with temperature, rainfall also acts as second main important factor determining the yield of crop. Adequate rainfall increases the productivity which in turn benefited the farmers economic condition.

Latha *et al* (2012) studied the impact of change in climate in different sites in the country. The result showed that the climate variations like drought have adverse effect on the yield of rainfed crop and it was found that this has great impact on agriculture sector in the country. The study suggested that climate change is having many adverse effects day by day so it should be taken into consideration through policy perspective at the earliest to avoid short term effect like yield and profit loss and long-term effects like stopping of doing agriculture by the rainfed farmers.

Harris *et al* (2013) studied and reported the accumulated greenhouse gases (GHGs) in the atmosphere to cause exposure to potential warming and its adversities. The study uses the INFOCROP model to determine the climate change impact on winter wheat and maize and also along with it simulation studies were performed using HADCM 3 factors for different time periods at four centres located in three different agroecological zones, with prevalent management practices. Wheat yield showed a decrease under the climate change conditions whereas the winter maize showed an increase due to warmer winters and enhanced CO₂ compared to baseline. The higher temperatures during the growing period cause the crop duration for both to reduce. The increased yield of winter maize can be seen as their suitability to the particular region for further cultivation in future, also it can be taken as a adaptation measure in regions where wheat yield will be decreasing under climate stress.

Singh and Nayak (2014) tried to link climatic parameters such as temperature and rainfall with production and productivity of major crops in India to examine the climate change and its impact on agriculture production, by using secondary data from 1951-2010. The results revealed that there was an increasing fluctuation in rainfall data over the study period. Increasing trends in day and night temperatures are also affecting the rainfall patterns which further prompt the frequent drought and floods in the country. There were shifting trends from pulses to food grains and year to year variations in rainfall, temperature and agriculture production & productivity had also been observed during 1995-96 to 2010-2011.

2.3 Impact of climate change on wheat

Miglietta and Porter (1992) from Italy used crop growth models and depicted that increase in temperature up to 3.5°F maximum will help in early development of tillers. However, temperature more than 3.5°C can result in premature senescence and less dry matter yield. Higher temperature means lower grain weights. It was due to the reason that growth rate increased rate is offset by grain set reduction or short grains fill time.

Wheeler *et al* (1996) at oxford university press observed that 15-55 per cent increases in wheat yields under doubled CO₂ concentrations (550 ppm). Rate of grain growth per ear was increased by 21-24 per cent in the doubled CO₂ concentration compared to the normal CO₂. However, a high number of undeveloped grains were found when temperature was more than 86°C for 5 days at normal CO₂ concentrations just flowering compared to ambient conditions.

Ferris *et al* (1998) carried out study at UK department of horticulture and landscape and reported that high temperature (>86°F) before flowering can reduce the number of seeds and after flowering can reduce time period of grain fill leading to loss of wheat yield. The low grain fertility occurred by exposure to temperatures above 86°F for little as one day during critical periods between booting and flowering the eight days with temperatures above 87°F at flowering was related to 50 per cent decline in grain yields.

Spiertz and Schapendonk (2001) conducted wheat experiments across many sites and years and reported raise in normal yield of 30 per cent due to double CO₂ levels up to 550 ppm while recreation models predicted an average increase of 25-40 per cent. Higher CO₂ is estimated to increase in rate of photosynthesis which resulted in high biomass yield fixed with increased water use effectiveness due to stomatal regulation.

Lawlor and Cornic (2002) determines the photosynthesis is most important physiological process in determination of plant yield and it is directly influenced by water stress. Photosynthetic rate of plant leaves decreases with reduce in relative water content and water potential of leaves. Due to generation of reactive oxygen species such as superoxide, hydroxyl and hydrogen peroxide water stress also leads to oxidative stress.

Pathak *et al* (2003) explained that negative trends of sun light, increase in minimum temperature resulted in decreased rice and wheat yield in the Indo-Gangetic plains of India. In Delhi, the minimum and maximum temperature showed an increasing trend both in summer or *kharif* growing season (June–October). Whereas winter or *rabi* growing season starts after summer monsoon. These changes showed warming trend. Since solar radiation is closely related to crop growth, any decreased in sunlight will considerably reduced productivity in agriculture.

Attri and Rathore (2003) revealed the impacts of changes in temperature and CO₂ on growth, development and yields of wheat in northwest India. They found an increase in yield by 16-28 per cent under irrigated conditions and 29-37 per cent under rainfed conditions. Any further increase beyond 3°C cancelled the beneficial impact of enhanced CO₂.

Das and Chaudhari (2004) reported the reducing in grain yield by 3 to 4 per cent per degree rise in temperature above 16°C. They also concluded that both maximum and minimum temperature showed significant negative correlation with grain filling periods, 1000-grain weight and number of grains/panicle.

Lobell *et al* (2005) used CERES-Wheat imitation model for the climate drift effects on wheat yield in the Mexico region. They establish that the climate had favored during the two decades and resulted in 25 per cent increase in wheat production.

Donnelly *et al* (2005) observed that ozone pollution can dramatically reduce the grain yield of wheat, but that atmospheric CO₂ enrichment can dramatically reverse its adverse effects and actually lead to a modest increase in grain yield. Consequently, in the nutshell of the researchers, "elevated CO₂ can be seen as protecting some yield components from the damaging effects of O₃," and that "the overall effect of increasing concentration of CO₂ will be positive for wheat production in Ireland.

Anwar *et al* (2007) studied global atmospheric model under three climate change scenarios which were Low, Mid and High for the time period of (2000-2070) for South-East

Australian location. The result showed that for all the three scenarios, the average wheat yield declined by about 29 per cent, though in the presence of high CO₂ production was declined from 29 to 25 per cent. CO₂ fertilization affect offset a very small level of low rain fall and high temperature. They optional that high yield productivity can be made during better agronomic strategy and breeds of wheat.

Haim *et al* (2007) concluded that wheat yield will increased under moderate scenarios and decreased under severe scenarios but this increase or decrease further depend on the nitrogen application. The amount and intensity of rainfall will also affect the wheat yield in Israel which ultimately causes significant reduction in wheat yield. This will cause economic losses upto -173 to -240 per cent as predicted by different scenarios.

Ortiz *et al* (2008) reported that global warming, can adversely affect the yield of wheat grain due to the climate change in North America and Eurasia. Thus, 20 per cent of food which is the wheat crop can be strongly affected by changing climate in turn 200 million hectares of farming land globally. Due to this, 15 per cent of worldwide production of wheat can be affected by shifting temperatures by 2050 in Indo Gangetic plains (IGPs) and this area would be reclassified as heat stressed, short yield mega environment. As a result, a significant reduction in the yield of wheat would be noticed.

Karl *et al* (2009) in US reported that plants require water in the particular amount to maintain their temperature and overcome the heat stress. In many regions the temperature of crop is reduced by the application of water. Irrigation is good for wheat in growing stage but critical for cotton. This reduction in yield will affect this plant growth.

Rahman *et al* (2009) seems that vegetative growth, development period, grain yield and all the yield components of wheat genotypes were influenced by high temperature. During grain-filling period high temperature stress is one of the major environmental constraints limiting the grain yield of wheat. High temperature enhanced the vegetative growth, flowering, development period and maturation, thus the number of days to booting, heading, anthesis and maturity of wheat were significantly decreased. Green leaf area and productive tillers per plant were drastically reduced under high temperature. The reduced number of grains per spike and smaller grain size resulted from reduction in growth duration which caused reduction in grain yield.

Modarresi *et al* (2010) conducted a study to assess heat stress effects on yield and yield related traits of wheat. The results showed that high temperature significantly reduced all traits specially grain yield (46.63 per cent), 1000-kernel weight (20.61 per cent) and grain filling duration (20.42 per cent). Grain yield was most influenced and spikelets per spike were least affected (11.77 per cent). Penicle length and grain filling duration showed the highest

correlation with yield under both normal and heat stress conditions suggesting that these two traits could be used as reliable screening tools for development of heat-tolerant genotypes.

Prabhjyot-Kaur and Hundal (2010) conducted a simulation study at Punjab Agricultural University, Ludhiana and observed that high temperature during February to March caused reduction in grain yield of wheat. Grain yield decreased from 0.69 to 3.30 per cent during second fortnight of February, 2.1 to 3.15 per cent during first fortnight of March, 1.24 to 3.4 per cent during second fortnight of March and 0.38 per cent during first week of April per 1°C increase in temperature.

Gill *et al* (2010) investigated that during 1984-2009, rainfall was below normal in seventeen years for Ballawal Saunkhri and eighteen years for Bathinda. In the last 40 years, Ludhiana received below normal rainfall for 24 years. The evaporation for Ballawal Saunkhri and Ludhiana revealed a decreasing trend over the years. At both the stations, average accumulated evaporation were 1606 and 1649 mm, which is more than average rainfall i.e. 1025 and 753 mm for both the locations, respectively.

Das (2010) reported that incidence of frost at the flowering stage and occurrence of hail storm at the grain ripening stage are hazardous for wheat crop and lead to heavy loss in yield. Heavy rainfall events at the time of maturity are also harmful for the wheat yield.

Kushwaha *et al* (2011) conducted in his pot study and found the high temperature stress on growth, biomass and yield of wheat genotypes. High temperature stress caused significant reductions in physiological parameters and yield. High temperature and late sowing induced decline in membrane stability index (31.1 per cent), plant height (17.1 per cent), biomass (39.2 per cent) and seed yield (51.7 per cent) in WH 730, HI 1535, WH 896 and RR 3, respectively.

Hatfield *et al* (2011) carried a study at US suggested that night time increases in temperature is critical for the reproduction of the crop because of the increased respiration rate and decreased in the level of CO₂ taken for photosynthesis during the day time. Thus, in 14 days of stress, night time temperatures increases causes a decrease in grain yield significantly. To illustrate, night time temperatures above 68°F lead to a decline in fertility of spikelet, grain per spike and size soft retained in the grain.

Mutlu (2011) reported that in the absence of changing climatic conditions had a slightly positive effect on wheat yields as well as the timing of critical growth stages indicated that increased atmospheric CO₂ concentrations This was due to both the stimulating function of CO₂ for photosynthesis and the regulatory function of CO₂ that enhances water use efficiency. However, these positive effects failed to counteract the significant decline in yields when temperature and precipitation were allowed to vary with increased atmospheric CO₂ concentrations. Under these conditions, winter wheat yields were predicted to decline between 5 and 35 per cent, depending on the GCM input used.

Farooq *et al* (2011) observed the impact of heat stress during reproductive and grain-filling stages of wheat. The study revealed that heat stress decreases plant photosynthetic capacity through metabolic limitations and oxidative damage to chloroplasts, with concomitant reductions in dry matter accumulation and grain yield. Genotypes expressing heat shock proteins are better able to withstand heat stress as they protect proteins from heat-induced damage.

Rasul *et al* (2011) revealed that during the last century, the temperature increase was noticed around 0.7°C which has been surpassed by the first decade of 21st century scoring about 1°C average global rise. Day and night temperature in Pakistan have followed a significant increase during the last 50 years due to which heat stress on plant growth and development has also enhanced. Higher night temperature has given rise to increase in respiration hence reducing the net gain in the form of grain yield. Sudden shoot up of air temperature in early spring when wheat and other winter crops were at reproductive stage of their life cycle caused significant reductions in the grain yield despite affecting the apparent health of the crops.

Ottman (2012) conducted an experiment at Maricopa on wheat growth in response to increased temperature from varied planting dates and supplemental infrared heating with the 12 planting dates from September to May. Supplemental heating was provided for 6 of the 12 planting dates using infrared heaters placed above the crop which increased canopy temperature by 1.3°C during the day and 2.7°C during the night. Grain yield declined 42 g m⁻² per 1°C increase in seasonal temperature above 16.3°C. However, in spring plantings where temperature (22.2°C) was above optimum, supplemental heating reduced grain yield from 510 to 368 g m⁻².

Vahdati and Leslie (2013) reported that under water stress conditions, cell water content of plant decreased due to unavailability of water from soil and atmosphere which resulted in decrease in plant physiological processes. Water deficit stress affects the yield of plant by modifying the morphology, anatomy and physiology.

Bala *et al* (2014) revealed that the high temperature is a major determinant of wheat development and growth and causes yield loss in many regions of the world. High temperature significantly decreased all traits specially grain yield (26 per cent and 54.2 per cent), 1000-kernel weight (24 per cent and 31 per cent) and grain filling duration (3 per cent and 9 per cent) in tolerant and susceptible genotypes, respectively. Grain yield (54 per cent) was most affected and grain filling duration (9 per cent) was least affected by heat stress.

Villegas *et al* (2015) studied the limitations imposed by day length, temperature and solar radiation on wheat yield in eight field experiments conducted at contrasting northern latitudes and involving 42 adapted spring durum wheat genotypes of divergent phenology,

and reduced or without photoperiod sensitivity. Air temperatures averaged from sowing to anthesis (SA) increased from northern to southern sites, while day length and minimum temperatures from anthesis to maturity (grain filling, GF) followed the opposite trend, due to differences in the latitude of sites. The site effect explained 96 per cent of the variation in the number of days SA, which was much smaller in southern sites. Average minimum daily temperatures above 6.9°C before anthesis and below 10.8°C during GF accompanied by photoperiods during GF of less than 14.2 ha resulted in less than 14000 kernels m², which was the threshold below which kernel number limited yield. Radiation during GF lower than 1.8 kJ kernel⁻¹day⁻¹ limited kernel weight, which was then a constraint to the achievement of yield potential.

2.4 Impact of climate change on cotton

Fitter and Hay (1987) carried out a study to understand the implications of climate change on cotton production in London and concluded that air temperature although not parameterized in GOSSYM between 45 and 55°C occur for 30 min, damaged leaves of the plant in most environments even at lower temperatures (35 to 40°C) can be harmful. Plant temperature above 40°C is linked with closure of stomata and high temperature effects. Temperatures above particular threshold limit for a few hours during anthesis resulted in less number of fruit, biomass reduction, and decreased economic production. Only harmful effects of average daily temperature above 32°C on cotton fruit abscission are mentioned in the cotton model.

Reddy *et al* (1999) at Mississippi state noticed that the boll retention of cotton was more sensitive to temperatures increase except for deficiency of nutrients, which is comparatively easy to correct. In contrast, if it is impossible to avoid the effect of high temperatures, it leads to the loss of fruit forms and causes bud shedding. Thus, the increase or decrease in the temperatures resulted in alter boll development, boll size and the maturation period.

To understand the implications of climate change on cotton production in the Mississippi Delta, Reddy *et al* (2002) reported that with increase in CO₂ concentration without any change in the other meteorological parameters there is increase in cotton yield by 10 per cent but if other parameters increased with same fashion then there will be decrease in cotton yield up to 10 per cent. As the average temperature continued to increase, it will increase the water requirement of the crop which ultimately effected the production of crop during water stress period.

Freeland *et al* (2004) found that untimely rainfall, irrigation and humid weather during later stages primarily at the beginning of boll opening may hurdle the defoliation,

reduce quality and decline yield of cotton. Parvin *et al* (2005) observed that with accumulated rainfall during harvest the cotton lint yield was decreased@ 10.10 kg/ha/cm.

Pettigrew (2007) concluded that the fibres content of cotton bolls increased with increase in temperature. The fibres quality traits were little affected by varying the temperature regimes 25°C for boll growth. With the increase in temperature the length of fibres increased while fineness and maturity increased linearly with increase in temperature up to 26°C.

Hebbar *et al* (2007) reported that the INFOCROP cotton model imitation the temperature rise in 8°C condensed the yield by 40 per cent though 8°C condensed temperature decreased the yield by 86 per cent in India. High temperature in addition reduced the crop period, condensed the retention of bolls and boll weight. Low temperature extend the crop period and exposed the reproductive phase to very low temperature.

Bange *et al* (2007) also reported that fibre length get affected by sustained periods of high temperatures as the time required for fibre elongation is reduced, not allowing fibre length to reach its genetic potential. Fibre length is reduced as temperature increased beyond 32°C. Increases in temperature also reduced the interval between flowering and boll opening, thus shortening the time to maturity that causes yield reduction.

A study at department of crop soil and Environment Sciences, University of Arkansas by Bibi *et al* (2008) revealed that Acala genotypes considered more tolerant to high temperature conditions under the changing climatic conditions. High temperature stress is major determinant of yield in cotton crop as temperature above the optimum level significantly reduced the crop yield.

Pettigrew (2008) conducted a study to show that two cotton genotype (SureGrow 125 and SureGrow 125 BR) when grown under an ambient temperature control and a warm temperature regime (about 1°C warmer). Nodes above white bloom data, dry matter partitioning data, lint yield, yield components and fiber quality data were collected. Genotypes responded similarly to the temperature regimes. Warmer temperatures resulted in lower data, the lint yield from the warm regime was 10 per cent lower then that of the control. This reduction was primarily caused by a 6 per cent smaller boll mass, with 7 per cent fewer seed produced per boll in the warm regime.

Jalota *et al* (2009) reported that in south-west Punjab, with increases in temperature from 28 to 32°C, seed cotton yield of could decreases from 4700 to 2300 kg/ha and among various growth stages, sowing to flowering period was more sensitive than other stages with respect to high temperature.

Rankja *et al* (2010) depicted that the afternoon relative humidity of 37th standard meteorological week (SMW) and sunshine hours of 33th SMW are beneficial to improve the

productivity of cotton whereas, afternoon relative humidity of 44th and sunshine hours of 46th SMW have negative impact on cotton yield.

Gwimbi and Mundoga (2010) reported that climate variability and change is a major threat to cotton production in Gokwe. Based on a time series trend analysis and correlation statistical analysis of the relationship between the climate variation scenarios and the cotton production level output over a 25 year period, and a random sample of 50 farmers; the results show that farmers are vulnerable to climate change. Cotton production levels declined as precipitation decreased and temperature increased across the district. Although other physical factors, such as soil fertility and farm management practices, among other factors, have an important influence on agriculture, climate remained the dominant influence on cotton production. Household revenues were also negatively affected by the decline in cotton production output.

Sankaranarayanan *et al* (2010) reported that cotton yield will increase upto 43 per cent at elevated CO₂ of 550 ppm during entire crop period. With increase in temperature there is reduction in crop duration. The increased CO₂ concentration has a positive effect on crop yield but temperature increase negatively correlated with the yield.

Ton (2011) reported heat stress ultimately resulted in decrease in yield of cotton in although crop can tolerate high temperature to some extent but after that it had negative impact on productivity of crop in particular China, Pakistan, Australia and the western United States. Crop also showed sensitivity to water stress as well as accumulated conditions which affect the flower and boll development of crop.

Li *et al* (2011) studied the Variations in soil temperature and water content at a depth of 10 cm at different phenological stages at two different treatments i.e. TC - traditional cultivation system of flood-irrigation with no mulching and MC - modern cultivation system using drip irrigation with plastic mulching. The study revealed that the highest soil temperature is found in mid June in both the treatments but the overall soil temperature was higher in MC than TC from mid April to July which is good for vegetative as well reproductive growth. But there is no significant difference during late growing periods in both the treatments. Similarly, moisture content is also more in MC than TC with minor difference during early growing periods.

Hebbar *et al* (2012) observed cotton crop yield will declined under different scenarios (A2, B2 and A1B) as predicted by different GCM by mid or late 21st century and this decrease in yield will be higher in northern zone over southern zone in India.

Puri *et al* (1992) studied the effect of Shisham windbreak on the number of cotton bolls/plant, seed cotton yield and cotton height growing at different distances from tree belt

and they had conducted experiment in four different farms viz. farm A, B, C and D among these, A is semiprotected, B and C are fully protected and D is unprotected by windbreak. Control is farm where there was no windbreak and H is the times the height of shisham tree. The study concluded that the no. of bolls/plant, yield and height was maximum under B and C farm which were fully protected. Also the no. of bolls/plant, yield and height was getting increased from 1H to 4H in all the farms and after that it got decreased.

While the first square to first flower period seems to be genotypic independent. Higher temperature in addition to reduced crop duration reduced the retention of bolls and boll weight. It is essential to study the quantitative relationships which account for the effects of plant and environmental factors on reproductive allocation (Sadras *et al* 1997). High temperatures or drought during the elongation phase of fiber development can shorten fiber length and reduce fiber uniformity and can cause high, or even under extreme conditions, low micronaire.

Brodrick *et al* (2012) conducted an experiment to derive RUE from the total dry matter Vs cumulative intercepted solar radiation under 2 different spacings i.e. UNR (40 cm) and conventionally spaced (100 cm). The study revealed that RUE was lower in UNR than conventionally spaced due to less penetration of solar radiations in plant canopy and poor distribution of light in UNR.

Buttar *et al* (2012) using CropSyst model revealed that with increase in temperature from 28 to 32°C, cotton seed yield could be reduced to half (from 4700 to 2300 kg/ha) following a linear manner. They further described that among different crop phenological stages, sowing to flowering phase was more vulnerable to increase in temperature than other phenol-phases. Total evapotranspiration (ET) during crop period and crop water productivity was also decreased with increased temperature.

Paul *et al* (2012) developed a regression model for prediction of cotton yield using 30 years (1980-2010) weather and yield data, in Punjab. They found that the maximum temperature of 38th standard meteorological week (SMW) had the significant negative correlation, whereas, during 45th SMW it showed significant Positive association with cotton yield.

The relationship of cotton seed yield was linear with ET and quadratic with total water supply including rain and water supplied through irrigation (Buttar *et al* 2012). Diffuse radiation index or cloudiness index, which is the ratio of diffuse radiation to the total solar radiation, is a useful parameter particularly for *khari* crops in India which affect total light period requirement of crops and finally affecting the total biomass production. During monsoon sometimes clouds may deplete about 90 per cent of the incoming solar radiation.

Jalota *et al* (2014) reported that relative small changes in annual temperature in semi-arid regions could markedly decrease the yield by reducing dry matter accumulation because of increased respiration reduced photosynthesis and cellular energy.

Sampath kumar *et al* (2014) showed that 24.3, 27.2 and 66.49 per cent reduction occurred in relative leaf water content, chlorophyll stability index and seed cotton yield respectively when irrigation was applied at 40 per cent ET_c (once in six days interval) as compared to control (irrigation at 100 per cent ET_c). Response of cotton to water stress varied with the stage of growth and development. Water deficit stress at first squaring, flowering and peak blooming stage decreased 18, 33 and 58 per cent in number of boll per m^2 respectively and it also reduced cotton yield by 61.3 and 39.9 per cent when occur at flowering and peak blooming stage.

Raju *et al* (2014) using time series data of 1990-2002 examined the effect of temperature and rainfall on cotton productivity and found that cotton yield significantly reduced 13kg/ha for every $1^\circ C$ increases in maximum temperature while it increased 0.7 kg/ha with increase in rainfall by 10 mm.

Thakar *et al* (2014) studied that during 2011-12, there was delayed monsoon, as well as during squaring and flowering stage in August 2011 there was high rainfall (595.6 mm), maximum and minimum temperatures were above normal, during development (June-August) and flowering stage of crop (October-December) which disturbed the crop physiology indirectly affecting the yield of cotton. The combined effect of rainfall and temperature was on relative humidity that created conducive atmosphere for insect and pest attacks on crops. That erratic monsoon or delayed monsoon hampers crop physiology ultimately yield due to erratic weather conditions.

Diarra *et al* (2016) conducted a study to show that when temperature increases by $1^\circ C$ cotton yield increases to 3 per cent relative to the mean yield but decreases when temperature is higher. They predict that a $4^\circ C$ increase in temperature can lead to cotton yield decrease by 25 per cent. The result shows a to cotton yield decreases of 13 per cent in cotton yield for $4^\circ C$ increase.

Xie *et al* (2016) conducted an experiment to determine canopy light interception (Li) of cotton in three growths stages between traditional (1 seed/hole) and cluster planting (3 seeds/hole) pattern and the study revealed that light interception was more under cluster planting than traditional planting because in cluster planting crop density was more which leads to more light interception.

Cotton seedling remains almost insensitive to temperature from 20/10 to 40/32 $^\circ C$ during first two weeks after emergence and thereafter becomes very sensitive to temperature.

Above 30/22°C (day/night) temperature do not favors to increase the number of fruiting branches whereas, temperatures at 40/32°C cause abscission of all flowering buds of cotton (Reddy *et al* 1992). A low temperature had been considered as the major influencing factor on root morphology and shoot growth of cotton cultivars (Brand *et al* 2016).

Venkatesh *et al* (2016) reported that cotton crop is affected by fungal, bacterial and viral diseases. In India foliar diseases have been estimated to cause yield losses up to 20 to 30 per cent. Negative correlation of Alternaria leaf spot intensity with maximum temperature, minimum temperature, evening relative humidity, and rainfall and positive correlation with morning relative humidity and sunshine hours.

Swati *et al* (2017) reported that direct damage includes feeding on the leaves resulting into leaf chlorosis, leaf withering and premature dropping of leaves that eventually leads to plant death. Yield and its attributes decreased significantly in all the varieties in response to water stress imposed at flowering stage. The flowering stage in cotton was found to be more critical to moisture stress.

Remzi *et al* (2017) reported that high temperature cause serious yield reduction in cotton by affecting its physiology, biochemistry and quality leading to poor agronomic produce. One hundred and sixty cotton genotypes obtained from genetic stocks was evaluated for high temperature tolerance based on some agronomic characters under field and controlled conditions. Genotypes showed differences for all investigated characters. Plant height, number of nodes and node ratio ranged from 68.38-136.45 cm, 18.22-30.10 number plant⁻¹, 2.89-6.31 node ratio respectively. Maximum and minimum values in terms of number of sympodial branches, boll abscission at first position, number of seed and seed cotton yield changed from 11.09-24.42 number plant⁻¹, 4.17-20.80 per cent, 20.39-44.11 number. Boll⁻¹ and 5.74-60.30 gr.plant⁻¹, respectively. Differences among genotypes were statistically significant for all characters under high temperature stress condition. Plant height, number of sympodial branches, boll retention at the first postion were decreased under both field and controlled condition due to high temperature stress.

Wang *et al* (2017) reported that the effect of water logging at different growth stages on the cotton decreased in the order of flowering, squaring, seedling and boll opening stages and the highest yield reduction rates for four stages were 38.8 per cent, 27.9 per cent, 18.3 per cent and 7.6 per cent. The effect of moisture deficit stress on reproductive growth, lint yield and yield components, boll distribution and fiber quality. The lint yield of dry land plants was reduced 25 and 19 per cent in reduction number of bolls.

CHAPTER III

MATERIAL AND METHODS

The details of materials used and methods employed for the research topic “Impact of climate change on productivity of wheat and cotton in south west Punjab” have been described in this chapter. For fulfilling the objectives, there was a need to empathize the climatic features and its impact on agriculture production with focus on south west Punjab namely Faridkot and Bathinda districts.

The present study was based on the statistical approach i.e. correlation regression technique. The process was preceded by analyzing the long term data on actual crop yield and climatic parameters (on weekly minimum and maximum temperature and rainfall) for developing the different statistical models to workout the shift in Punjab climate over the periods.

3.1 Study area

Analysis, interpretations and discussion of the result will help in meaningful inferences and the background for the same is provided through information of agro-climatic features of wheat and cotton cultivation in the region.

3.1.1 Climatic features of Punjab

Punjab is situated in northwestern parts of India and occupies 1.5 per cent geographical area of the nation. Punjab spreads over an area 50376 sq kilometers and lies between 29°33' and 32°31' North latitude and between 73°55' and 76°55' East longitude. Present study was conducted in the south west region which comprises of Faridkot and Bathinda districts.

3.1.2 Selection of the study area

Present study performed an investigation in two districts of south west Punjab namely Faridkot and Bathinda and data collected from the two research stations of PAU, Regional Research Station, Faridkot and Regional Research Station, Bathinda.

3.1.3 Selection of crops

Cotton (*Gossypium* spp.) and wheat (*Triticum aestivum* L.) crop are mainly grown in *Kharif* and *Rabi* season, respectively in Faridkot and Bathinda districts of Punjab. Therefore, these crops were included for an in detail analysis of the impact of climate change on the productivity of crops.

3.2.1 Collection of data

Keeping in view the objectives of the study the data was collected from the secondary sources for two different districts (Faridkot and Bathinda) of Punjab.

- (a) **Crop Data:** To study the change in climatic pattern and its impact on crop productivity (i.e. wheat and cotton) in Punjab. The yearly data on area, production and yield under wheat and cotton crops for the period of 37 years (1981-2017) at Bathinda and 17 years (2001-2017) at Faridkot has been collected from Statistical Abstract of Punjab. The data were tabulated and analyzed using suitable statistical methods.
- (b) **Climatic or weather Data:** The weather data for the period of 37 years (1981-2017) at Bathinda and 17 years (2001-2017) at Faridkot was collected on weekly basis for meteorological factors (maximum and minimum temperature and rainfall). The data covers the months during which the cotton and wheat crops completed their life cycle which is 14th to 47th standard meteorological weeks for cotton and 43rd to 12th standard meteorological weeks for wheat. The weather data collected from Faridkot district and Bathinda district was further carried out the objectives of the study. The study does not include data on relative humidity for the two districts due to its unavailability.

3.2.2 Analysis of the data

Examination of weather parameters for the past 37 (1981-2017) years period was conducted using collected data for the Bathinda district and it was averaged out on weekly, monthly and seasonal basis. Further division of data was done and it was grouped into 5 periods i.e. Period-I (1981-90), Period-II (1991-2000), Period-III (2001-10) and Period-IV (2011-17) and overall periods was given the name Period-V (1981-2017). Similar method is followed for Faridkot district. Mean, coefficient of variation, graphical methods and tabulation was used for drawing out change and deviation in weekly, monthly and seasonal weather parameters. This monthly analysis was preceded by grouping them into four seasons that are summer season (March, April and May), Monsoon season (June, July, August and Sept.), Post-monsoon season (Oct and Nov) and Winter season (Dec, Jan and Feb.), on the basis of weather system followed in India. Contribution of temperature and rainfall intensity per month was considered while monthly analysis of climatic parameters. Current study demarcates the *Rabi* season from 15th October to 30th April, while *Kharif* season delineates from 1st May to 14th October. Periodical deviation in climatic parameter was tested for their significance using t-test at 1, 5 and 10 per cent probability levels. Each possible deviation was obtained using t-test and these deviations are Period-II over base Period-I, Period-III over base Period-II and Period-III over base Period-I, Period-IV over base Period-III, Period-IV over base Period-II and Period-IV over base Period-I. The degree and nature of the relationship between the productivity of crops was evaluated with correlation techniques and it was also used for obtaining this relationship for weekly climate over their growing periods. On this basis, weeks with higher prospective effect the productivity and are selected for additional processing or examination of the climate impact. Finally, functional analysis was used to investigate the impact of climate on productivity of the crops. Linear and non-linear

functions, both are used for estimation of climatic impact on the crops. R-square value, number and significant level of variables and prior expected sign of coefficients are the criteria which have been used to select the better fit model in all cases. Regression technique was followed step by step for determining the impact. These models had been verified with independent data set for the years from 2008-2017 outside sampling series for wheat and cotton at Bathinda. At Faridkot the independent data set for the years from 2011-2017 outside sampling series for wheat and cotton. In case of desi cotton, models were calibrated from 2001-2008 and validated for the years 2009, 2010 and 2011 for Faridkot as yield data was not available from 2012 onwards. Performance of models had been examined by computing per cent deviation of actual yield between forecast yield. For locating the significant influential variables, firstly, the climatic impact on wheat and cotton productivity was studied. A combination of variables with significant effects was made and they were used in a single function for determining the overall climate impact. The climatic impact in partial or total way on productivity of the two crops is estimated using linear type of function. Though, the study used the better-suited model to explain the impact.

3.3 Yield forecast models

Linear and multiple-regression technique is used to develop statistical models while Pearson correlation technique was used for correlation analysis. Usage of data series of 37 years (1981 to 2017 for Bathinda and 17 years 2001 to 2017 for Faridkot districts) is made for developing the model and these models are verified with the independent data from 2007-2017 outside their sampling series. The percentage deviation of estimated productivity (from statistical abstract) and forecast yield figures is computed for critical examination of the model performance.

3.3.1 Basic model (model 1)

The sensitive period window for the crops is considered and a basic model is developed using the weather parameters. GStat is used for the development of multiple regression equation and correlation is developed for the sensitive crop periods. Dependent variable considered is the average reported crop yield while weather parameters are considered as independent. The correlation and regression technique gave significant correlation between yield and meteorological parameters on analysis of correlation coefficients for statistical and phenological significance. Further, for regression analysis statistically and phonologically significant sensitive periods are selected in terms of standard meteorological weeks (SMWs).

3.3.2 Modified model (model 2)

The basic model is then modified through inclusion of an assumed composite index while other independent variables are kept constant. The advancement in the various

agricultural technologies like the use of high yielding variety seeds, timely operations, better irrigation and drainage facilities, large scale use of fertilizers and pesticides, etc, have contributed to the yield of earlier years. Data, individually for these parameters is unavailable thus, they were clubbed together to form an index. Superimposition of the agricultural technology impact in the form of linear time scale dummy variable is done for improvement of the yield forecast accuracy.

3.3.3 SPSS software (model 3)

SPSS software was used as a model for wheat and cotton for forecast analysis. Analysis of regression is done using SPSS (Statistical Product and Service Solutions) software (model 3) is based on the same. Computation of Pearson's correlations is done for weather parameters and their combination along with the observed yield of crops i.e. *Rabi* season cereals crop i.e. wheat (*Triticum aestivum* L.) and one *Kharif* season fiber crop i.e. cotton (*Gossypium* spp.). Sum of weather parameter and sum-product of different weather parameter and correlation coefficient was derived. SPSS software is used to analyze the multiple regression between dependent variable (yield) and independent variables (time, sum and sum products for different weather parameters) while regression formula is used for formulation of regression equation.

Table 3.1: Basic data of composite index (CI) used in developing the modified model for cotton crop at Bathinda

Year	Composite index	Year	Composite index
1981	100	1998	165
1982	114	1999	170
1983	127	2000	171
1984	127	2001	72
1985	124	2002	172
1986	136	2003	88
1987	144	2004	176
1988	147	2005	196
1989	155	2006	196
1990	161	2007	204
1991	178	2008	204
1992	184	2009	202
1993	156	2010	205
1994	151	2011	103
1995	158	2012	215
1996	161	2013	221
1997	162	2014	89

Table 3.2: Basic data of composite index (CI) used in developing the modified model for wheat crop at Bathinda

Year	Composite index	Year	Composite index
1980-81	100	1997-98	171
1981-82	114	1998-99	172
1982-83	127	1999-2000	186
1983-84	137	2000-01	87
1984-85	140	2001-02	185
1985-86	146	2002-03	106
1986-87	158	2003-04	194
1987-88	156	2004-05	212
1988-89	165	2005-06	211
1989-90	172	2006-07	217
1990-91	190	2007-08	218
1991-92	199	2008-09	217
1992-93	163	2009-10	181
1993-94	163	2010-11	120
1994-95	167	2011-12	231
1995-96	167	2012-13	239
1996-97	168	2013-14	107

Table 3.3: Basic data of composite index (CI) used in developing the modified model for cotton crop at Faridkot

Year	Composite index	Year	Composite index
2001	100	2008	148
2002	158	2009	136
2003	118	2010	138
2004	131	2011	86
2005	141	2012	128
2006	151	2013	120
2007	153	2014	68

Table 3.4: Basic data of composite index (CI) used in developing the modified model for wheat crop at Faridkot

Year	Composite index	Year	Composite index
2000-01	100	2007-08	119
2001-02	106	2008-09	123
2002-03	112	2009-10	125
2003-04	118	2010-11	85
2004-05	126	2011-12	123
2005-06	125	2012-13	126
2006-07	120	2013-14	74

Regression equation for all the three models is given by:

$$y_e = a_0 + \sum a_i x_i + \sum a_j x_j$$

Where,

y_e = Estimated yield, kg/ha

a_0 = Regression constant

a_i = Regression coefficient for meteorological predictor variables

x_i = i th meteorological predictor variable $i=1, 2, 3, 4, 5, \dots, n$

a_j = Regression coefficient for technological trend variables $j = 1, 2, 3, 4, 5, \dots, n$

x_j = j th technological trend variables

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study has been analysed and presented as tables and graphs wherever necessary. Results obtained from the current research programme are summarized below under the following sub heads.

4.1 To comprehend the changing pattern of the important weather parameters in two districts (Faridkot and Bathinda) of south west Punjab.

4.2 To analyze the impact of climate change on productivity of wheat and cotton crops in south west Punjab.

4.1 To comprehend the changing pattern of the important weather parameters in two districts (Faridkot and Bathinda) of south west Punjab.

The objective of this analysis was obtaining information on the past climate from different districts of south west Punjab (Faridkot and Bathinda). Climate change analysis was done for the Punjab conditions by assessing the long-term data of Faridkot and Bathinda. The data for the various weather parameters was maximum temperature, minimum temperature and rainfall. Further study consisted of periodical average of data (Period-I, Period-II, Period-III and period-IV and period-V) of different weather parameters for weeks, months, seasonal (*kharif* and *rabi*) and seasons, analysis for four different seasons as per IMD i.e. summer seasons (march, April and May), monsoon season (June, July August, and September), post-monsoon (October and November) and winter season (December, January and February), on the basis of weather system followed in India. According to the crop growing seasons for the present study, it can be demarcated as *kharif* and *rabi*. Different ways were involved in analysis of changing climatic values over a period of last 37 years. Coefficient of variation was estimated and was used for determining the variability in each period.

4.1.1 Temperature in Bathinda

4.1.1.1 Maximum temperature

4.1.1.1.1 Weekly

The change in weekly average maximum temperature of Bathinda district of Punjab was studied out for the Period of 37 years (1981-2017). As it was pointed in weekly average maximum temperature analysis, 37 years were grouped into five periods (Period-I, Period-II, Period-III, Period-IV and overall Period-V) and summarized (Table 4.1). During the Period-I, the lowest average maximum temperature was observed during the 1st week (19.5°C) and highest average maximum temperature was recorded during the 22nd week which was 42.5°C.

The highest maximum temperature of 42.0°C was recorded during 22nd week of Period-II, while 17.7°C lowest temperature was observed during 3rd week. It was analysed that from Period-III to Period-V, lowest maximum temperature was lowest during 1st week and highest maximum temperature was during 20th, 21st, and 23rd week. The highest maximum temperature of 41.7, 42.0 and 41.5°C was observed Period-III, Period-IV and overall Period-V, respectively, whereas, lowest maximum temperature of 16.4°C was observed during Period-III, 15.6°C during Period-IV and 18.1°C during Period-V. The graph (Fig 4.1) showed that average maximum temperature during standard meteorological weeks during different periods of time. The value of highest maximum temperature during period-I was observed during 22nd SMW. The coefficient of variation (CV) of weekly average maximum temperature (Table 4.1) depicted that during Period-I minimum variation of 2.6 per cent observed during 43rd SMW, while maximum coefficient of variation of 13.6 per cent was observed during 9th SMW. During period-II, maximum and minimum coefficient of variation of 13.5 and 3.4 per cent was during 3rd and 41th SMW, respectively. During Period-III, maximum CV of 13.3 per cent was during 3rd SMW and minimum of 2.4 per cent during 34th SMW. Analysis of period-IV indicated maximum CV of 17.4 per cent during 2nd SMW, while minimum CV (2.0 per cent) was calculated during 39th SMW. The overall analysis of all Periods (Period-V) showed maximum CV of 11.4 per cent during 3rd SMW and least CV was (3.3 per cent) during 40th and 43rd SMW. Periodical deviation of average maximum temperature of Bathinda was analysed and represented as Table 4.2. The Periodical deviation of average maximum temperature during Period-II over base Period-I depicted mean difference of -1.4°C during 4th week which was significant at ten per cent level of significance and mean difference of -3.1°C was significant at one per cent level of significance during 3rd week. The mean difference of -1.5°C during 34th SMW and -2.0°C during 37th SMW which was significant at five per cent level of significance. During Period-III over Period-II, periodical deviation was significant at one per cent level of significance during 1st week (-3.8°C) and five per cent level of significance during the 15th and 26th week (2.9 and -2.7°C) and at ten per cent level of significance during the week of 9th, 19th, 22nd and 28th by 1.7, 2.3, -2.0 and -1.7°C, respectively. The periodical deviation of average maximum temperature during Period-III over base Period-I of -3.1, -3.3 and 3.7°C was observed during 1st, 3rd and 12th weeks which was significant at one per cent level of significance and mean difference of -2.6, 2.6, 3.1, -3.2, -3.4, -2.0, -2.8 and -1.7°C was significant at five per cent level of significance during week 2nd, 13th, 15th, 25th, 26th, 36th, 37th and 38th, respectively. The periodical deviation (-1.7°C) in average maximum temperature observed during week 28th was

observed significant at ten per cent level of significance. During Period-IV over base Period-III, periodical deviation was significant at five per cent level of significance during 48th and 49th week (1.6 and 2.0°C). The mean difference of Period-IV over base Period-II was significant at five per cent level of significance during the 1st week (-4.6°C) and ten per cent level of significance during the 45th week (-2.3°C). The average deviation during Period-IV over base Period-I was observed as -4.5, -2.4, -2.3°C during 3rd, 38th, 45th week, respectively, at one per cent level of significance. The mean difference of -3.9, -3.0, -3.0, 2.3, -2.5, -2.0 and -2.2°C was at five per cent significant level of significance during week 1st, 2nd, 4th, 12th, 25th, 33rd and 36th weeks, respectively. The mean difference of -1.3, -1.8, -2.0 and -1.7°C which was found significant at ten per cent level of significance during 34th, 35th, 46th and 50th weeks, respectively.

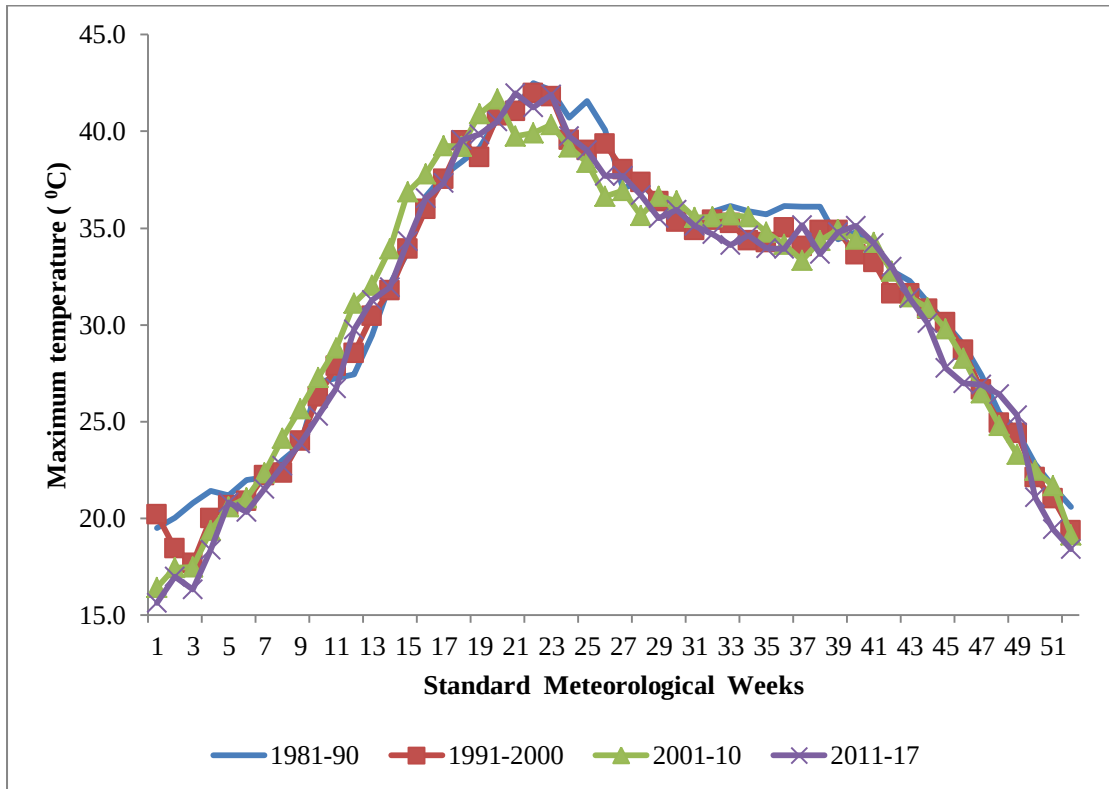


Fig. 4.1: Average weekly maximum temperature at Bathinda (1981-2017) during different periods

Table 4.1: Periodic average and coefficient of variations (%) of weekly maximum temperature at Bathinda (1981-2017)

Weeks	Maximum temperature(⁰ C)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
1	19.5	20.2	16.4	15.6	18.1	9.7	7.4	12.6	15.5	10.4
2	20.0	18.4	17.5	17.0	18.3	8.8	9.2	10.6	17.4	10.7
3	20.8	17.7	17.5	16.3	18.2	5.9	13.5	13.3	17.1	11.4
4	21.4	20.0	19.4	18.4	19.9	7.9	8.7	9.9	11.3	9.1
5	21.2	20.6	20.6	20.8	20.8	6.1	6.2	8.9	15.7	8.6
6	22.0	20.9	21.1	20.3	21.1	8.5	9.2	9.4	9.5	9.0
7	22.1	22.2	22.3	21.5	22.1	8.2	6.2	7.7	9.8	7.6
8	23.0	22.4	24.1	22.7	23.1	8.2	6.2	7.7	9.8	7.6
9	23.8	24.0	25.7	23.9	24.4	13.6	8.6	8.4	8.4	9.0
10	27.0	26.3	27.3	25.3	26.6	5.8	4.8	6.7	8.1	6.1
11	27.3	27.9	28.8	26.7	27.7	7.6	6.7	7.5	8.1	7.2
12	27.4	28.5	31.1	29.8	29.2	8.2	7.0	5.3	7.4	6.8
13	29.5	30.5	32.0	31.3	30.8	7.2	7.0	6.1	8.2	6.9
14	32.1	31.8	33.9	31.9	32.5	6.4	7.3	7.3	6.9	6.8
15	33.8	33.9	36.9	34.3	34.7	5.7	6.3	6.5	7.6	6.4
16	36.6	36.0	37.8	36.5	36.7	6.9	7.3	5.1	6.3	6.3
17	37.7	37.5	39.2	37.3	38.0	6.6	5.7	5.2	5.1	5.6

Weeks	Maximum temperature(⁰ C)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
18	38.4	39.5	39.2	39.6	39.1	5.1	4.5	6.8	6.0	5.4
19	39.2	38.7	40.9	39.9	39.6	6.3	5.8	5.0	7.0	5.8
20	40.6	40.8	41.7	40.5	40.9	6.4	4.6	6.5	6.0	5.7
21	41.1	41.0	39.7	42.0	40.9	5.5	5.1	7.3	6.2	5.8
22	42.5	42.0	39.9	41.2	41.4	4.3	5.5	7.8	6.9	5.9
23	42.1	41.8	40.3	41.9	41.5	6.9	5.4	6.9	11.4	7.2
24	40.7	39.6	39.2	39.7	39.8	8.0	7.4	8.4	6.2	7.4
25	41.6	39.0	38.4	39.0	39.5	5.5	8.5	6.7	9.1	7.1
26	40.1	39.4	36.7	37.7	38.5	8.2	6.0	11.9	9.5	8.5
27	37.1	38.0	36.9	37.7	37.4	8.0	5.6	6.6	7.2	6.6
28	37.4	37.4	35.7	36.7	36.8	6.5	7.3	7.3	8.0	7.2
29	36.3	36.4	36.6	35.5	36.3	6.4	5.4	5.1	9.0	6.1
30	35.7	35.3	36.4	35.9	35.8	6.1	6.7	4.9	4.6	5.6
31	35.3	34.9	35.6	35.1	35.2	7.0	5.9	4.5	5.6	5.7
32	35.9	35.4	35.6	34.7	35.4	5.3	4.8	4.1	7.0	5.1
33	36.1	35.3	35.7	34.1	35.4	4.3	5.2	4.8	5.3	4.8
34	35.9	34.4	35.6	34.6	35.1	4.0	5.8	2.4	6.9	4.5
35	35.7	34.3	34.8	33.9	34.7	4.3	5.1	5.6	6.0	5.1
36	36.1	35.0	34.2	33.9	34.9	3.7	4.3	6.5	5.2	4.7

Weeks	Maximum temperature(⁰ C)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
37	36.1	34.1	33.3	35.2	34.6	4.2	5.2	5.2	3.6	4.5
38	36.1	34.9	34.4	33.7	34.8	2.7	3.6	5.7	13.5	5.7
39	34.4	34.9	34.9	29.5	33.7	5.7	4.4	3.3	2.0	4.1
40	34.8	33.6	34.4	35.1	34.4	3.1	4.7	3.3	2.2	3.3
41	34.2	33.2	34.3	34.2	34.0	3.5	3.4	3.6	3.4	3.4
42	32.8	31.6	32.8	33.0	32.5	4.6	6.4	4.8	3.8	4.9
43	32.3	31.6	31.4	31.4	31.7	2.6	4.1	2.5	4.3	3.3
44	31.2	30.8	30.9	30.1	30.8	4.1	4.0	3.3	4.2	3.8
45	30.1	30.1	29.8	27.8	29.6	4.0	4.1	3.9	5.5	4.2
46	29.0	28.7	28.3	27.0	28.3	4.0	4.9	5.0	3.6	4.4
47	27.4	26.6	26.5	26.9	26.9	6.6	6.0	5.0	4.5	5.6
48	25.4	24.9	24.8	26.4	25.3	4.1	6.9	4.7	9.0	5.9
49	24.5	24.4	23.3	25.3	24.3	5.8	5.8	6.2	5.1	5.7
50	22.8	22.1	22.5	21.1	22.2	9.0	8.2	6.5	12.6	8.4
51	21.6	21.0	21.7	19.4	21.1	6.7	7.9	7.8	11.5	7.9
52	20.6	19.4	19.1	18.4	19.5	9.0	9.7	10.3	13.0	9.8

Table 4.2: Periodical deviation in average weekly maximum temperature at Bathinda (1981-2017)

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
1	0.7	0.507	0.678 ^{NS}	-3.8	0.001	3.833***	-3.1	0.003	3.445***	-0.8	0.634	0.485 ^{NS}	-4.6	0.018	2.650**	-3.9	0.033	2.346**
2	-1.6	0.107	1.696 ^{NS}	-1.0	0.424	0.818 ^{NS}	-2.6	0.025	2.445**	-0.5	0.735	0.345 ^{NS}	-1.4	0.261	1.169 ^{NS}	-3.0	0.010	2.934**
3	-3.1	0.004	3.353***	-0.2	0.857	0.183 ^{NS}	-3.3	0.005	3.217***	-1.2	0.297	1.081 ^{NS}	-1.4	0.169	1.445 ^{NS}	-4.5	0.000	5.223***
4	-1.4	0.090	1.791*	-0.6	0.545	0.616 ^{NS}	-2.0	0.059	2.017 ^{NS}	-1.0	0.453	0.771 ^{NS}	-1.6	0.141	1.555 ^{NS}	-3.0	0.010	2.943**
5	-0.5	0.576	0.570 ^{NS}	-0.1	0.958	0.054 ^{NS}	-0.6	0.646	0.468 ^{NS}	0.2	0.868	0.170 ^{NS}	0.2	0.850	0.192 ^{NS}	-0.4	0.700	0.393 ^{NS}
6	-1.1	0.299	1.070 ^{NS}	0.2	0.873	0.162 ^{NS}	-0.9	0.477	0.727 ^{NS}	-0.7	0.581	0.564 ^{NS}	-0.5	0.598	0.539 ^{NS}	-1.6	0.146	1.533 ^{NS}
7	0.1	0.918	0.104 ^{NS}	0.1	0.900	0.127 ^{NS}	0.2	0.833	0.215 ^{NS}	-0.8	0.491	0.706 ^{NS}	-0.7	0.536	0.634 ^{NS}	-0.6	0.641	0.476 ^{NS}
8	-0.7	0.580	0.563 ^{NS}	1.8	0.137	1.555 ^{NS}	1.1	0.382	0.896 ^{NS}	-1.4	0.295	1.085 ^{NS}	0.4	0.756	0.317 ^{NS}	-0.3	0.833	0.215 ^{NS}
9	0.2	0.886	0.145 ^{NS}	1.7	0.096	1.757*	1.9	0.212	1.295 ^{NS}	-1.8	0.147	1.530 ^{NS}	-0.1	0.914	0.109 ^{NS}	0.1	0.967	0.042 ^{NS}
10	-0.8	0.511	0.670 ^{NS}	1.0	0.310	1.046 ^{NS}	0.2	0.846	0.196 ^{NS}	-2.0	0.104	1.733 ^{NS}	-1.0	0.388	0.888 ^{NS}	-1.8	0.218	1.285 ^{NS}
11	0.6	0.558	0.597 ^{NS}	0.9	0.462	0.751 ^{NS}	1.5	0.215	1.284 ^{NS}	-2.1	0.125	1.627 ^{NS}	-1.2	0.297	1.079 ^{NS}	-0.5	0.625	0.499 ^{NS}
12	1.1	0.311	1.042 ^{NS}	2.6	0.054	2.060 ^{NS}	3.7	0.002	3.694***	-1.4	0.241	1.222 ^{NS}	1.2	0.328	1.012 ^{NS}	2.3	0.010	2.946**
13	1.0	0.423	0.821 ^{NS}	1.6	0.213	1.291 ^{NS}	2.6	0.030	2.352**	-0.8	0.540	0.627 ^{NS}	0.8	0.565	0.589 ^{NS}	1.8	0.155	1.496 ^{NS}
14	-0.3	0.775	0.290 ^{NS}	2.1	0.111	1.674 ^{NS}	1.8	0.109	1.684 ^{NS}	-2.0	0.169	1.444 ^{NS}	0.1	0.921	0.100 ^{NS}	-0.2	0.878	0.157 ^{NS}
15	0.1	0.914	0.109 ^{NS}	2.9	0.035	2.283**	3.1	0.022	2.513**	-2.5	0.052	2.112 ^{NS}	0.4	0.770	0.298 ^{NS}	0.5	0.671	0.433 ^{NS}
16	-0.7	0.676	0.425 ^{NS}	1.8	0.212	1.295 ^{NS}	1.1	0.504	0.683 ^{NS}	-1.2	0.466	0.748 ^{NS}	0.6	0.714	0.373 ^{NS}	-0.1	0.957	0.054 ^{NS}
17	-0.2	0.846	0.197 ^{NS}	1.7	0.167	1.440 ^{NS}	1.5	0.211	1.297 ^{NS}	-1.9	0.213	1.301 ^{NS}	-0.2	0.870	0.167 ^{NS}	-0.4	0.748	0.327 ^{NS}

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
18	1.1	0.364	0.931 ^{NS}	-0.3	0.848	0.194 ^{NS}	0.8	0.544	0.618 ^{NS}	0.3	0.816	0.237 ^{NS}	0.1	0.968	0.041 ^{NS}	1.1	0.213	1.300 ^{NS}
19	-0.5	0.746	0.328 ^{NS}	2.3	0.082	1.844*	1.7	0.251	1.186 ^{NS}	-1.1	0.387	0.892 ^{NS}	1.2	0.382	0.901 ^{NS}	0.7	0.684	0.415 ^{NS}
20	0.2	0.913	0.111 ^{NS}	0.9	0.385	0.891 ^{NS}	1.0	0.523	0.651 ^{NS}	-1.2	0.371	0.921 ^{NS}	-0.3	0.788	0.274 ^{NS}	-0.1	0.940	0.076 ^{NS}
21	-0.1	0.943	0.073 ^{NS}	-1.3	0.459	0.756 ^{NS}	-1.4	0.433	0.802 ^{NS}	2.2	0.252	1.192 ^{NS}	0.9	0.531	0.641 ^{NS}	0.8	0.593	0.546 ^{NS}
22	-0.5	0.700	0.392 ^{NS}	-2.0	0.078	1.866*	-2.6	0.053	2.066 ^{NS}	1.3	0.265	1.158 ^{NS}	-0.7	0.573	0.576 ^{NS}	-1.3	0.402	0.862 ^{NS}
23	-0.3	0.771	0.296 ^{NS}	-1.5	0.323	1.017 ^{NS}	-1.8	0.154	1.488 ^{NS}	1.6	0.315	1.040 ^{NS}	0.1	0.936	0.082 ^{NS}	-0.2	0.844	0.201 ^{NS}
24	-1.1	0.412	0.839 ^{NS}	-0.4	0.739	0.338 ^{NS}	-1.5	0.207	1.309 ^{NS}	0.6	0.681	0.420 ^{NS}	0.2	0.914	0.110 ^{NS}	-1.0	0.555	0.603 ^{NS}
25	-2.5	0.128	1.596 ^{NS}	-0.6	0.739	0.338 ^{NS}	-3.2	0.041	2.206**	0.7	0.701	0.392 ^{NS}	0.0	0.994	0.008 ^{NS}	-2.5	0.043	2.215**
26	-0.7	0.551	0.607 ^{NS}	-2.7	0.029	2.373**	-3.4	0.013	2.770**	1.0	0.444	0.787 ^{NS}	-1.7	0.203	1.332 ^{NS}	-2.4	0.104	1.731 ^{NS}
27	1.0	0.508	0.675 ^{NS}	-1.1	0.392	0.877 ^{NS}	-0.1	0.938	0.079 ^{NS}	0.8	0.565	0.589 ^{NS}	-0.3	0.807	0.249 ^{NS}	0.6	0.685	0.413 ^{NS}
28	0.0	0.991	0.012 ^{NS}	-1.7	0.098	1.748*	-1.7	0.072	1.910*	1.1	0.304	1.064 ^{NS}	-0.7	0.593	0.546 ^{NS}	-0.7	0.567	0.586 ^{NS}
29	0.1	0.948	0.066 ^{NS}	0.3	0.766	0.302 ^{NS}	0.3	0.768	0.299 ^{NS}	-1.1	0.199	1.345 ^{NS}	-0.8	0.295	1.084 ^{NS}	-0.8	0.515	0.667 ^{NS}
30	-0.4	0.673	0.429 ^{NS}	1.1	0.299	1.068 ^{NS}	0.7	0.364	0.932 ^{NS}	-0.5	0.607	0.525 ^{NS}	0.6	0.551	0.610 ^{NS}	0.3	0.692	0.404 ^{NS}
31	-0.4	0.704	0.386 ^{NS}	0.7	0.512	0.668 ^{NS}	0.3	0.737	0.341 ^{NS}	-0.5	0.657	0.453 ^{NS}	0.2	0.843	0.201 ^{NS}	-0.2	0.873	0.162 ^{NS}
32	-0.4	0.646	0.468 ^{NS}	0.2	0.845	0.198 ^{NS}	-0.3	0.710	0.377 ^{NS}	-0.9	0.252	1.193 ^{NS}	-0.7	0.510	0.675 ^{NS}	-1.2	0.177	1.417 ^{NS}
33	-0.9	0.255	1.176 ^{NS}	0.4	0.633	0.485 ^{NS}	-0.5	0.418	0.830 ^{NS}	-1.6	0.118	1.657 ^{NS}	-1.2	0.313	1.044 ^{NS}	-2.0	0.025	2.488**
34	-1.5	0.044	2.163**	1.2	0.133	1.573 ^{NS}	-0.3	0.613	0.514 ^{NS}	-1.0	0.259	1.172 ^{NS}	0.3	0.783	0.281 ^{NS}	-1.3	0.099	1.758*
35	-1.4	0.137	1.557 ^{NS}	0.5	0.550	0.609 ^{NS}	-0.9	0.254	1.178 ^{NS}	-0.8	0.335	0.995 ^{NS}	-0.3	0.762	0.308 ^{NS}	-1.8	0.083	1.860*

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
36	-1.1	0.290	1.089 ^{NS}	-0.9	0.401	0.860 ^{NS}	-2.0	0.045	2.154**	-0.2	0.820	0.231 ^{NS}	-1.1	0.346	0.973 ^{NS}	-2.2	0.045	2.189**
37	-2.0	0.018	2.612**	-0.7	0.474	0.732 ^{NS}	-2.8	0.014	2.725**	1.8	0.127	1.618 ^{NS}	1.1	0.198	1.346 ^{NS}	-0.9	0.268	1.149 ^{NS}
38	-1.2	0.178	1.401 ^{NS}	-0.5	0.614	0.513 ^{NS}	-1.7	0.050	2.104**	-0.7	0.483	0.720 ^{NS}	-1.2	0.256	1.181 ^{NS}	-2.4	0.006	3.201***
39	0.5	0.619	0.506 ^{NS}	0.0	0.958	0.053 ^{NS}	0.5	0.530	0.641 ^{NS}	-5.4	0.208	1.317 ^{NS}	-5.4	0.215	1.295 ^{NS}	-4.9	0.256	1.180 ^{NS}
40	-1.2	0.224	1.260 ^{NS}	0.8	0.481	0.719 ^{NS}	-0.4	0.660	0.447 ^{NS}	0.7	0.471	0.740 ^{NS}	1.5	0.180	1.405 ^{NS}	0.3	0.609	0.522 ^{NS}
41	-1.0	0.285	1.101 ^{NS}	1.0	0.179	1.398 ^{NS}	0.0	0.988	0.015 ^{NS}	0.0	0.954	0.059 ^{NS}	1.0	0.222	1.275 ^{NS}	0.0	0.980	0.026 ^{NS}
42	-1.2	0.177	1.404 ^{NS}	1.2	0.190	1.362 ^{NS}	0.0	0.963	0.047 ^{NS}	0.2	0.746	0.329 ^{NS}	1.4	0.222	1.273 ^{NS}	0.2	0.763	0.307 ^{NS}
43	-0.6	0.550	0.609 ^{NS}	-0.2	0.880	0.154 ^{NS}	-0.8	0.276	1.123 ^{NS}	0.0	0.959	0.052 ^{NS}	-0.2	0.861	0.178 ^{NS}	-0.9	0.188	1.379 ^{NS}
44	-0.4	0.696	0.398 ^{NS}	0.1	0.958	0.053 ^{NS}	-0.3	0.728	0.354 ^{NS}	-0.8	0.427	0.816 ^{NS}	-0.7	0.491	0.706 ^{NS}	-1.1	0.113	1.681 ^{NS}
45	0.1	0.958	0.053 ^{NS}	-0.4	0.751	0.323 ^{NS}	-0.3	0.662	0.444 ^{NS}	-2.0	0.051	2.121 ^{NS}	-2.3	0.082	1.861*	-2.3	0.007	3.135***
46	-0.3	0.734	0.345 ^{NS}	-0.4	0.640	0.476 ^{NS}	-0.7	0.391	0.879 ^{NS}	-1.3	0.271	1.144 ^{NS}	-1.7	0.153	1.505 ^{NS}	-2.0	0.072	1.935*
47	-0.8	0.206	1.311 ^{NS}	-0.2	0.851	0.190 ^{NS}	-0.9	0.313	1.039 ^{NS}	0.4	0.691	0.406 ^{NS}	0.3	0.695	0.400 ^{NS}	-0.5	0.469	0.742 ^{NS}
48	-0.5	0.505	0.681 ^{NS}	-0.2	0.847	0.196 ^{NS}	-0.7	0.266	1.149 ^{NS}	1.6	0.042	2.226**	1.5	0.129	1.606 ^{NS}	1.0	0.131	1.596 ^{NS}
49	-0.1	0.909	0.116 ^{NS}	-1.1	0.229	1.245 ^{NS}	-1.2	0.122	1.624 ^{NS}	2.0	0.035	2.323**	0.9	0.265	1.157 ^{NS}	0.8	0.116	1.666 ^{NS}
50	-0.7	0.490	0.704 ^{NS}	0.4	0.728	0.353 ^{NS}	-0.3	0.641	0.475 ^{NS}	-1.4	0.170	1.442 ^{NS}	-1.0	0.435	0.802 ^{NS}	-1.7	0.078	1.892*
51	-0.6	0.638	0.479 ^{NS}	0.6	0.627	0.495 ^{NS}	0.0	0.958	0.053 ^{NS}	-2.3	0.148	1.524 ^{NS}	-1.6	0.421	0.827 ^{NS}	-2.2	0.143	1.544 ^{NS}
52	-1.2	0.340	0.979 ^{NS}	-0.2	0.861	0.177 ^{NS}	-1.4	0.134	1.568 ^{NS}	-0.7	0.608	0.524 ^{NS}	-1.0	0.588	0.554 ^{NS}	-2.2	0.141	1.552 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significance, P-Probability, t-Test.

4.1.1.1.2 Monthly

Monthly average maximum temperature data for 37 years (1981-2017) was analyzed and the same has been set out as Table 4.3. During Period-I the lowest average maximum temperature was observed during the month of January (20.4°C) and highest average maximum temperature was recorded during the month of June and July which was 41.2°C . It was analysed that from Period-II to Period-V, lowest maximum temperature was recorded during January month and highest maximum temperature was during the month of May. The highest maximum temperature of 40.4 , 40.3 , 40.7 and 40.4°C was observed during Period-II, Period-III, Period-IV and overall Period-V respectively, during the month of May, whereas, lowest maximum temperature of 19.2°C (Period-II), 18.0°C (Period-III), 17.2°C (Period-IV) and 18.8°C (Period-V) was observed during the month of January. The average maximum temperature on monthly basis is during different periods of time is depicted in Fig 4.2. The highest maximum temperature of 41.2°C was recorded during the months of May during period-I. Analysis of coefficient of variation (Table 4.3) on monthly basis depicted that during Period-I, maximum coefficient of variation of 13.1 per cent was calculated during February and minimum of 5.4 per cent was during September month. It was observed that maximum and minimum CV of 13.9 and 5.8 per cent was during the month of January and September, respectively for Period-II. During Period-III, maximum coefficient of variation of 17.4 per cent was during January, while 5.4 per cent was during August, which was minimum. Analysis of Period-IV indicated maximum coefficient of variation of 24.1 per cent (January) and minimum coefficient of variation of 6.6 per cent (October).

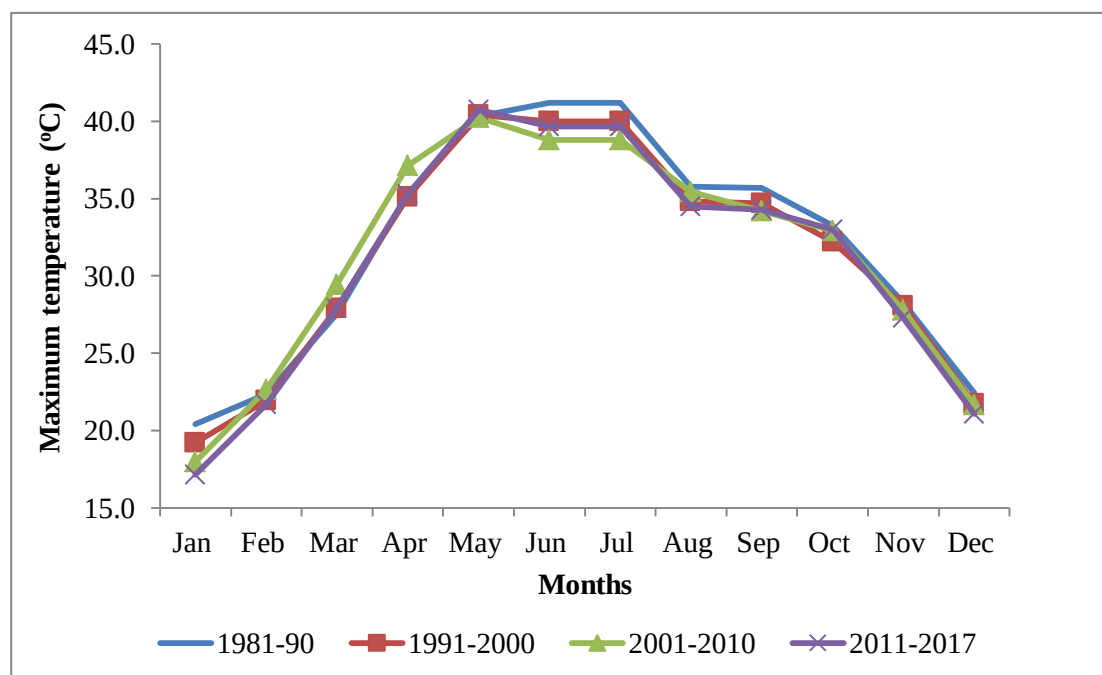


Fig. 4.2: Average monthly maximum temperature at Bathinda (1981-2017) during different periods

Table 4.3: Periodic average and coefficient of variations (%) of monthly maximum temperature at Bathinda (1981-2017)

Months	Maximum temperature ($^{\circ}\text{C}$)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
January	20.4	19.2	18.0	17.2	18.8	11.2	13.9	17.4	24.1	15.7
February	22.3	21.9	22.7	21.7	22.2	13.1	11.4	12.6	14.1	12.5
March	27.5	27.9	29.4	27.9	28.2	10.0	10.5	11.6	13.3	11.1
April	35.3	35.1	37.2	35.3	35.7	10.8	10.1	10.1	10.7	10.3
May	40.3	40.4	40.3	40.7	40.4	8.1	7.9	9.3	8.3	8.3
June	41.2	40.0	38.8	39.7	39.9	9.1	9.6	11.0	11.4	10.1
July	36.5	36.6	36.4	36.3	36.4	8.5	8.0	7.3	8.9	8.0
August	35.8	34.8	35.4	34.5	35.2	5.9	6.3	5.4	7.9	6.2
September	35.7	34.7	34.2	34.3	34.7	5.4	5.8	7.3	12.4	7.4
October	33.3	32.2	32.9	33.0	32.8	6.0	7.2	6.7	6.6	6.6
November	28.3	28.1	27.8	27.3	27.9	9.0	9.5	9.9	8.5	9.3
December	22.4	21.7	21.7	21.1	21.8	11.6	13.5	12.4	20.6	13.7

Table 4.4: Periodical deviation in average Monthly maximum temperature at Bathinda (1981-2017)

Months	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
January	-1.2	0.036	2.273**	-1.2	0.079	1.861*	-2.5	0.000	4.443***	-0.8	0.270	1.145 ^{NS}	-2.0	0.009	2.995***	-3.3	0.000	6.335***
February	-0.4	0.620	0.504 ^{NS}	0.7	0.388	0.884 ^{NS}	0.3	0.740	0.337 ^{NS}	-1.0	0.346	0.972 ^{NS}	-0.2	0.746	0.329 ^{NS}	-0.6	0.514	0.668 ^{NS}
March	0.4	0.681	0.418 ^{NS}	1.5	0.095	1.765*	1.9	0.027	2.410**	-1.5	0.051	2.118 ^{NS}	0.0	0.993	0.009 ^{NS}	0.4	0.649	0.464 ^{NS}
April	-0.2	0.821	0.230 ^{NS}	2.0	0.038	2.239**	1.8	0.035	2.276**	-1.9	0.037	2.291 ^{NS}	0.2	0.868	0.169 ^{NS}	0.0	0.958	0.053 ^{NS}
May	0.1	0.930	0.089 ^{NS}	-0.2	0.826	0.223 ^{NS}	-0.1	0.945	0.070 ^{NS}	0.5	0.557	0.600 ^{NS}	0.3	0.651	0.462 ^{NS}	0.4	0.738	0.341 ^{NS}
June	-1.2	0.117	1.648 ^{NS}	-1.2	0.194	1.350 ^{NS}	-2.4	0.004	3.330***	0.9	0.367	0.929 ^{NS}	-0.3	0.725	0.358 ^{NS}	-1.5	0.044	2.198**
July	0.1	0.910	0.115 ^{NS}	-0.2	0.762	1.307 ^{NS}	-0.1	0.859	0.180 ^{NS}	-0.1	0.918	0.105 ^{NS}	-0.3	0.716	0.370 ^{NS}	-0.2	0.803	0.254 ^{NS}
August	-1.0	0.192	1.357 ^{NS}	0.6	0.428	0.811 ^{NS}	-0.3	0.525	0.649 ^{NS}	-1.0	0.131	1.598 ^{NS}	-0.3	0.680	0.421 ^{NS}	-1.3	0.020	2.596**
September	-1.0	0.191	1.359 ^{NS}	-0.5	0.400	0.863 ^{NS}	-1.5	0.015	2.691**	0.1	0.830	0.218 ^{NS}	-0.4	0.543	0.622 ^{NS}	-1.4	0.040	2.248**
October	-1.0	0.167	1.441 ^{NS}	0.7	0.401	0.860 ^{NS}	-0.4	0.448	0.775 ^{NS}	0.1	0.833	0.215 ^{NS}	0.8	0.370	0.924 ^{NS}	-0.2	0.542	0.625 ^{NS}
November	-0.2	0.725	0.357 ^{NS}	-0.3	0.677	0.423 ^{NS}	-0.5	0.321	1.020 ^{NS}	-0.5	0.500	0.692 ^{NS}	-0.8	0.354	0.957 ^{NS}	-1.0	0.083	1.857*
December	-0.7	0.391	0.880 ^{NS}	-0.1	0.936	0.081 ^{NS}	-0.8	0.118	1.644 ^{NS}	-0.6	0.452	0.771 ^{NS}	-0.6	0.559	0.597 ^{NS}	-1.4	0.067	1.975*

***, ** and * indicates 1,5 and 10 % level of significance respectively, NS:Non-significan, P-Probability, t-Test.

During the overall Period-V from 1981-2017, it was observed that during the month of January, coefficient of variation was maximum (15.7%) whereas, least coefficient of variation of 6.2 was observed during the month of August. Periodical deviation of average maximum temperature of Bathinda was analysed and represented as Table 4.4. The deviation of average maximum temperature during Period-II over base Period-I depicted maximum deviation of -1.2°C observed during January was significant at five per cent level of significance. During Period-III over base Period-II, periodical deviation was significant at ten per cent level of significance during January (-1.2°C) and March (1.5°C) and five per cent significant during the month of April (2.0°C). The deviation of average maximum temperature during Period-III over base Period-I was -2.5°C during January and -2.4°C (June and July) which was significant at one per cent level of significance and five per cent level of significance during the month of March (1.9°C), April (1.8°C) and September (-1.5°C). The Periodical deviation in average maximum temperature was statically non-significant during the Period-IV over base Period-III. During Period-IV over base Period-II, periodical deviation was significant at one per cent level of significance during January (-2.0°C). The periodical deviation of average maximum temperature during Period-IV over base Period-I had maximum deviation of -3.3°C observed during January which was significant at one per cent level of significance and significance at five per cent level during month of June, August and September was calculated as -1.5 , -1.3 and -1.4°C respectively. The periodical deviation was significant at ten per cent level of significance during November (-1.0°C) and December (-1.4°C).

4.1.1.1.3 Seasonal

The change in seasonal average maximum temperature for *kharif* and *rabi* season during the period of 37 years (1981-2017) was carried out to comprehend the change in average maximum temperature at Bathinda (Table 4.5). Present study has defined that the *kharif* season starts from 1st May and ends on 14th October, whereas *rabi* crop growing season commenced from 15th October and terminated on 30th April. The average maximum temperature was recorded as 37.6, 37.0, 36.8, 36.9 and 37.1°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively during *kharif* season. During *rabi* season the average maximum temperature of 26.6, 26.1, 26.7, 25.6 and 26.3°C was recorded during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Coefficient of variation during *kharif* season was 10.8 per cent (Period-I), 10.9 per cent (Period-II and Period-III), 13.8 per cent (Period-IV) and 11.4 per cent (Period-V). During *rabi* season coefficient of variation was 22.2, 23.6, 26.2, 27.3 and 24.6 per cent during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Periodical deviation in average seasonal maximum

temperature of Bathinda was analysed and represented as Table 4.6. During *kharif* season, the mean difference of -0.7°C observed during Period-III over base Period-I which was significant at five per cent level of significance and -0.7°C at five per cent level of significance during Period-IV over base Period-I. The average deviation of maximum temperature during Period-IV over base Period-III depicted maximum deviation of -1.0°C observed during *rabi* season was significant at five per cent level of significance. Khan *et al* (2009) also estimated mean temperature increase for India.

4.1.1.1.4 Meteorological seasons during the year

The change in seasons average maximum temperature of Bathinda district of Punjab was carried out for the Period of 37 years (1981-2017) and represented as Table 4.7. In this content, the seasons were grouped as summer (March, April and May), monsoon (June, July, August and September), post-monsoon (October and November) and winter (December, January and February) on the basis of weather system moving across India. It was observed that highest average maximum temperature was during monsoon season and was 37.3, 36.6, 36.2, 36.2 and 36.6°C and lowest average maximum temperature was during winter season and was 21.7, 20.9, 20.6, 20.3 and 20.9°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Coefficient of variation was highest during summer season and was recorded as 18.7, 18.3, 17.2, 19.1 and 18.2 per cent and lowest CV was during monsoon season and was 10.2, 10.2, 9.9, 13.8 and 10.8 per cent during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Periodical deviation of season wise maximum temperature of Bathinda was analysed and represented as Table 4.8. The deviation in average season wise maximum temperature during summer season was observed as 1.2°C during Period-III over base Period-I and -1.0°C during Period-IV over base Period-III which was significant at ten per cent level of significance. During monsoon season deviation in maximum temperature was observed as -1.1°C during Period-III over base Period-I and -1.10°C during Period-IV over base Period-I which was significant at five per cent level of significance. The periodical deviation in average maximum temperature was statistically non-significant during the post monsoon season. The deviation in average season wise maximum temperature during winter season was observed as -1.1°C during Period-III over base Period-I and -1.35°C during Period-IV over base Period-III which was significant at five per cent level of significance.

Table 4.5: Periodic average and coefficient of variations (%) of seasonal maximum temperature at Bathinda (1981-2017)

Seasonal	Maximum temperature ($^{\circ}\text{C}$)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
<i>Rabi</i>	26.6	26.1	26.7	25.6	26.3	22.2	23.6	26.2	27.3	24.6
<i>Kharif</i>	37.6	37.0	36.8	36.9	37.1	10.8	10.9	10.9	13.8	11.4

Table 4.6: Periodical deviation in average seasonal maximum temperature at Bathinda (1981-2017)

Seasonal	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
<i>Rabi</i>	-0.4	0.281	1.111 ^{NS}	0.5	0.191	1.358 ^{NS}	-0.9	0.805	0.250 ^{NS}	-1.0	0.040	2.244 ^{**}	-0.5	0.303	1.068 ^{NS}	-0.9	0.060	2.034 ^{NS}
<i>Kharif</i>	-0.6	0.193	1.353 ^{NS}	-0.2	0.701	0.389 ^{NS}	-0.7	0.026	2.435 ^{**}	0.1	0.762	0.308 ^{NS}	-0.1	0.882	0.151 ^{NS}	-0.7	0.033	2.354 ^{**}

** indicates 5 % level of significance respectively, NS:Non-significant, P-Probability, t-Test.

Table 4.7: Periodic average and coefficient of variations (%) of maximum temperature during different meteorological seasons at Bathinda (1981-2017)

Seasons	Maximum temperature ($^{\circ}\text{C}$)					Variation in maximum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
Summer	34.2	34.3	35.4	34.4	34.6	18.7	18.3	17.2	19.1	18.2
Monsoon	37.3	36.6	36.2	36.2	36.6	10.2	10.2	9.9	13.8	10.8
Post-monsoon	31.0	30.3	30.5	30.3	30.6	11.0	11.0	11.9	12.8	11.5
Winter	21.7	20.9	20.6	20.3	20.9	13.8	16.1	18.1	22.1	17.0

Table 4.8: Periodical deviation in average maximum temperature during different meteorological seasons at Bathinda (1981-2017)

Seasons	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
Summer	0.1	0.891	0.139 ^{NS}	1.1	0.060	2.003 ^{NS}	1.2	0.091	1.786*	-1.0	0.093	1.776*	0.1	0.802	0.254 ^{NS}	0.2	0.749	0.325 ^{NS}
Monsoon	-0.7	0.207	1.309 ^{NS}	-0.3	0.555	0.602 ^{NS}	-1.1	0.016	2.661**	0.0	0.955	0.058 ^{NS}	-0.4	0.587	0.553 ^{NS}	-1.10	0.029	2.373**
Post monsoon	-0.6	0.345	0.970 ^{NS}	0.2	0.793	0.266 ^{NS}	-0.4	0.275	1.125 ^{NS}	-0.3	0.681	0.417 ^{NS}	-0.1	0.993	0.009 ^{NS}	-0.70	0.053	2.069 ^{NS}
Winter	-0.8	0.126	1.605 ^{NS}	-0.3	0.570	0.579 ^{NS}	-1.1	0.030	2.362**	-0.2	0.697	0.396 ^{NS}	-0.6	0.397	0.868 ^{NS}	-1.35	0.026	2.424**

**and * indicates 5 and 10 % level of significance respectively, NS:Non-significant, P-Probability, t-Test.

4.1.1.2 Minimum temperature

4.1.1.2.1 Weekly

The change in weekly average minimum temperature of Bathinda district of Punjab was carried out for the Period of 37 years (1981-2017). As it was pointed in weekly average minimum temperature analysis, 37 years has been grouped into five periods (Period-I, Period-II, Period-III, Period-IV and overall Period-V) and summarized as Table 4.9. During the Period-I the lowest average minimum temperature was observed during the 2nd week (4.1°C) and highest average minimum temperature was recorded during the 26th week which was 27.7°C. The highest minimum temperature of 28.0°C was recorded during 26th week of Period-II, while 4.6°C lowest minimum temperature was observed during 1st week. During the Period-III the lowest average minimum temperature was observed during the 1st week (4.0°C) and highest average minimum temperature was recorded during the 26th week which was 27.4°C. Analysis of period-IV revealed that the highest minimum temperature of 27.4°C was recorded during 27th week, while lowest minimum temperature (3.9°C) was observed during 52nd week. During the overall Period-V the lowest average minimum temperature was observed during the 2nd week (4.6°C) and highest average minimum temperature was recorded during the 26th week which was 27.5°C. The graph (Fig 4.3) showed average minimum temperature during standard meteorological weeks during different periods of time. The value of highest minimum temperature during Period-II was observed during 26th week. The coefficient of variation (CV) of weekly average minimum temperature (Table 4.9) depicted that during Period-I minimum coefficient variation of 3.4 per cent was observed during 36th SMW, while maximum coefficient of variation of 77.3 per cent was analysed during 52nd SMW. During period-II, maximum and minimum coefficient of variation was 58.0 and 3.6 per cent was during 3rd and 32nd SMW, respectively. During Period-III, maximum CV of 55.0 per cent was calculated during 2nd SMW and minimum of 4.1 per cent during 34th SMW. Analysis of period-IV indicated maximum CV of 60.5 per cent during 2nd SMW, while minimum CV (3.1 per cent) was calculated during 31st SMW. The overall analysis of all Period (Period-V) showed maximum CV of 43.6 per cent during 3rd SMW and least CV was calculated (4.0 per cent) during 34th SMW. Periodical deviation of average maximum temperature of Bathinda was analysed and represented as Table 4.10. The deviation of average minimum temperature during Period-II over base Period-I depicted mean difference of 1.3°C during 27th and 43rd week which was significant at ten per cent level of significance and mean difference of 2.0°C was significant at five per cent level of significance during 49th week. During Period-III over Period-II periodical deviation of -0.4, -1.2, and 1.3°C was significant at five per cent level of significance during 2nd, 23rd and 46th week, respectively and ten per cent level of significance during the 12th and 44th week respectively, (2.0 and

1.4°C). The periodical deviation of average minimum temperature during Period-III over base Period-I depicted mean difference of -1.5 and 2.2°C during 22nd and 44th week, respectively, which was significant at one per cent level of significance and mean difference of 2.4, 1.9 and 1.6°C was significant at five per cent level of significance during week 12th, 42nd and 49th, respectively. The periodical deviation of 1.8, -0.6 and 1.3°C was observed at ten per cent level of significance during week 9th, 25th and 43rd respectively. During Period-IV over base Period-III, deviation was significant at five per cent level of significance during 5th week (0.2°C) and mean difference of 0.3 and 0.8°C was significant at ten per cent level of significance during week 22nd and 23rd, respectively. The average deviation in minimum temperature was observed during week 37th which was observed significant at one per cent level by 1.4°C. The mean difference of Period-IV over base Period-II was significant at five per cent level of significance during the 3rd week (1.6°C) and ten per cent level of significance during the 5th, 12th, 40th and 41st week, which was observed as 1.6, 1.2, 2.2 and 2.0°C, respectively. The deviation of average minimum temperature during Period-IV over base Period-I depicted minimum deviation of 2.1°C during 48th week, which was significant at one per cent level of significance and mean difference of 1.5, 1.9, 1.2, 2.1, 1.9, 1.6, 2.0 and 2.6°C was significant at five per cent level of significance during week 12th, 13th, 37th, 40th, 43rd, 44th, 45th and 49th, respectively. The mean difference was 1.9, 2.1, 1.1, 0.4, 2.1 and 1.9°C during 5th, 14th, 32nd, 35th, 41st and 42nd week which was found significant at ten per cent level of significance.

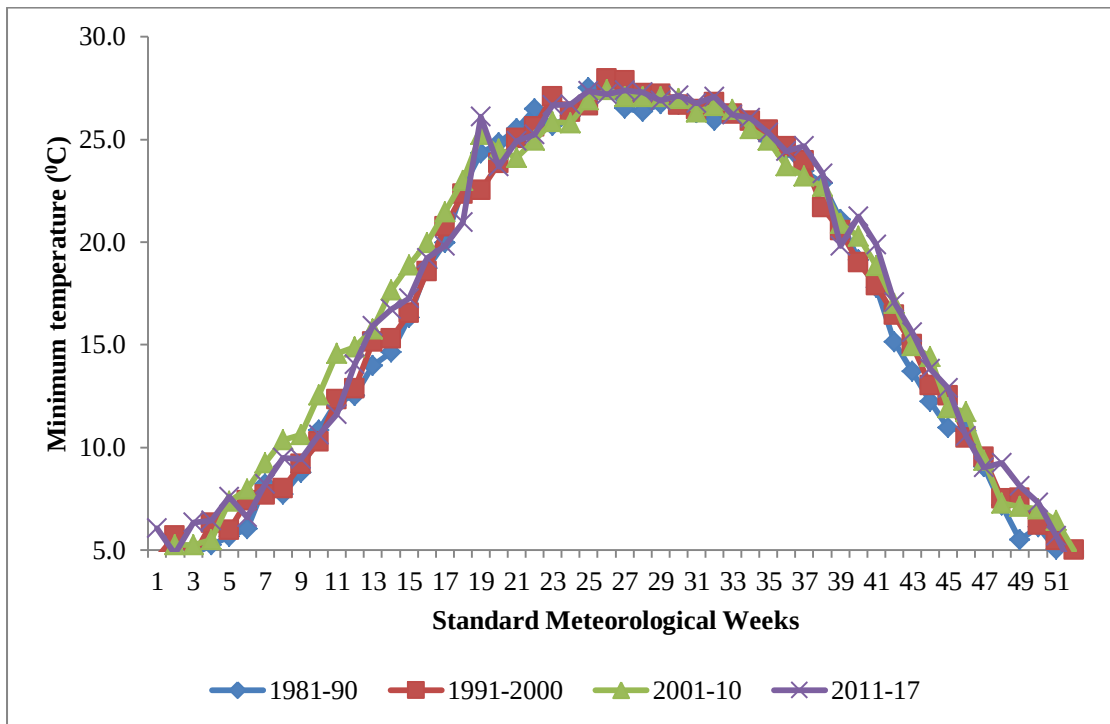


Fig. 4. 3: Average weekly minimum temperature at Bathinda (1981-2017) during different periods

Table 4.9: Periodic average and coefficient of variations (%) of weekly minimum temperature at Bathinda (1981-2017)

Weeks	Minimum temperature ($^{\circ}\text{C}$)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
1	4.7	4.6	4.0	6.1	4.9	49.6	53.5	53.7	35.9	42.1
2	4.1	5.7	5.3	4.8	4.6	51.3	42.5	55.0	60.5	42.9
3	4.8	4.7	5.2	6.3	5.2	46.9	58.0	44.4	42.1	43.6
4	5.3	6.3	5.5	6.4	5.8	57.8	47.7	21.2	31.6	41.2
5	5.7	6.0	7.4	7.6	6.1	42.5	37.3	39.6	35.8	35.1
6	6.0	7.4	8.0	6.6	6.9	42.8	33.6	32.4	43.8	33.2
7	8.2	7.7	9.2	8.2	8.0	25.8	25.4	25.9	37.1	26.4
8	7.7	8.0	10.4	9.5	8.5	37.8	27.0	19.6	22.9	24.2
9	8.8	9.2	10.6	9.4	9.4	26.3	27.3	16.8	19.3	21.7
10	10.8	10.3	12.5	10.6	10.6	22.4	19.6	15.3	19.0	18.8
11	12.2	12.3	14.6	11.6	12.2	20.4	16.9	13.6	18.8	16.8
12	12.5	12.8	14.9	14.0	13.5	21.7	16.4	9.9	15.4	15.5
13	14.0	15.1	15.8	15.9	14.9	12.7	17.0	12.8	8.6	12.8
14	14.6	15.3	17.7	16.7	15.5	15.5	16.5	10.0	10.4	12.9
15	16.3	16.5	18.9	17.3	16.9	11.8	11.7	12.3	11.3	11.4
16	18.7	18.6	20.0	19.2	18.8	11.2	14.6	8.1	11.3	11.2
17	20.0	20.7	21.5	19.8	20.1	11.7	10.5	10.6	11.4	10.9

Weeks	Minimum temperature (°C)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
18	22.6	22.3	23.0	21.0	21.9	11.7	7.4	9.3	10.1	9.7
19	24.3	22.5	25.2	27.1	24.0	8.2	10.5	6.9	26.9	16.0
20	24.8	23.9	24.5	23.7	24.5	9.4	7.9	8.6	8.9	8.6
21	25.5	25.1	24.1	24.9	25.0	9.4	7.4	9.6	8.6	8.7
22	26.5	25.6	25.0	25.2	25.4	8.9	8.2	9.7	8.3	8.8
23	25.7	27.1	25.9	26.7	26.1	8.6	7.6	11.8	8.1	9.0
24	26.1	26.3	25.8	26.7	26.2	8.8	8.3	7.1	7.9	8.0
25	27.5	26.6	26.9	27.3	26.8	6.0	8.9	8.7	8.1	7.8
26	27.7	28.0	27.4	27.2	27.5	8.5	6.4	7.7	7.8	7.5
27	26.5	27.9	27.1	27.4	27.3	9.2	5.7	6.0	6.6	6.8
28	26.4	27.2	27.1	27.3	27.0	6.9	6.3	6.8	5.5	6.4
29	26.7	27.2	27.1	26.9	27.0	4.8	5.2	6.5	6.5	5.7
30	26.7	26.7	27.0	27.1	26.9	4.9	4.6	5.3	4.1	4.8
31	26.3	26.5	26.3	26.8	26.4	5.6	5.1	5.0	3.1	4.7
32	25.9	26.8	26.7	27.1	26.6	7.6	3.6	4.4	4.8	4.9
33	26.4	26.2	26.5	26.2	26.3	4.2	4.3	4.3	3.7	4.1
34	25.8	25.9	25.5	26.1	25.8	3.7	4.1	4.1	4.4	4.0
35	25.0	25.4	25.0	25.3	25.2	4.4	4.1	5.3	3.9	4.5
36	24.5	24.6	23.7	24.4	24.3	3.4	4.8	5.8	4.6	4.6

Weeks	Minimum temperature (°C)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
37	23.4	24.0	23.2	24.7	23.8	4.4	5.5	5.6	3.8	4.9
38	22.9	21.7	22.7	23.3	22.6	5.5	6.3	6.2	6.1	5.9
39	21.1	20.6	20.9	18.8	20.5	6.1	6.7	5.5	3.3	5.7
40	19.1	19.0	20.3	21.2	19.8	7.2	8.1	5.1	4.1	6.2
41	17.8	17.9	18.9	19.9	18.5	7.7	5.4	7.4	7.7	7.0
42	15.1	16.4	17.0	17.1	16.4	13.2	7.7	7.1	7.3	8.9
43	13.7	15.0	15.0	15.6	14.8	8.8	10.0	9.2	11.6	9.7
44	12.2	13.0	14.4	13.8	13.3	13.3	10.2	8.7	7.3	9.8
45	10.9	12.5	11.9	12.9	12.0	10.5	12.6	10.2	14.7	11.7
46	10.8	10.5	11.7	10.6	10.9	12.3	14.6	12.3	13.8	13.2
47	9.0	9.5	9.4	9.0	9.3	17.5	22.2	15.2	11.5	16.8
48	7.2	7.5	7.3	9.2	7.7	23.6	22.9	16.0	15.5	19.3
49	5.5	7.5	7.1	8.1	7.0	27.9	30.7	28.7	18.8	24.8
50	6.1	6.2	7.0	7.3	6.6	43.8	35.8	27.9	41.7	31.6
51	5.0	5.5	6.4	5.7	5.7	70.7	33.2	27.7	32.7	30.1
52	4.4	5.0	5.0	3.9	4.6	77.3	38.8	30.4	60.4	39.7

Table 4.10: Periodical deviation in average weekly minimum temperature at Bathinda (1981-2017)

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
1	-0.1	0.961	0.050 ^{NS}	-0.7	0.810	0.244 ^{NS}	-0.7	0.812	0.242 ^{NS}	2.1	0.101	1.746 ^{NS}	1.4	0.175	1.423 ^{NS}	1.4	0.287	1.103 ^{NS}
2	1.5	0.130	1.585 ^{NS}	-0.4	0.046	2.145 ^{**}	1.1	0.855	0.185 ^{NS}	-0.5	0.408	0.852 ^{NS}	-0.9	0.359	0.946 ^{NS}	0.7	0.588	0.553 ^{NS}
3	-0.1	0.928	0.092 ^{NS}	0.5	0.525	0.649 ^{NS}	0.5	0.626	0.496 ^{NS}	1.1	0.244	1.212 ^{NS}	1.6	0.044	2.195 ^{**}	1.6	0.108	1.710 ^{NS}
4	1.1	0.490	0.705 ^{NS}	-0.8	0.505	0.681 ^{NS}	0.2	0.990	0.013 ^{NS}	0.9	0.364	0.937 ^{NS}	0.1	0.947	0.068 ^{NS}	1.2	0.314	1.042 ^{NS}
5	0.3	0.703	0.388 ^{NS}	1.4	0.635	0.483 ^{NS}	1.7	0.845	0.198 ^{NS}	0.2	0.039	2.260 ^{**}	1.6	0.089	1.817 [*]	1.9	0.009	3.018 [*]
6	1.4	0.169	1.432 ^{NS}	0.6	0.984	0.020 ^{NS}	1.9	0.243	1.208 ^{NS}	-1.4	0.525	0.650 ^{NS}	-0.8	0.422	0.826 ^{NS}	0.6	0.572	0.578 ^{NS}
7	-0.5	0.608	0.522 ^{NS}	1.5	0.794	0.265 ^{NS}	1.0	0.804	0.252 ^{NS}	-1.0	0.819	0.233 ^{NS}	0.5	0.652	0.460 ^{NS}	0.0	0.985	0.019 ^{NS}
8	0.3	0.759	0.312 ^{NS}	2.4	0.145	1.523 ^{NS}	2.7	0.131	1.583 ^{NS}	-0.9	0.778	0.287 ^{NS}	1.5	0.124	1.628 ^{NS}	1.8	0.129	1.607 ^{NS}
9	0.4	0.569	0.580 ^{NS}	1.4	0.227	1.251 ^{NS}	1.8	0.077	1.878 [*]	-1.2	0.343	0.979 ^{NS}	0.2	0.775	0.291 ^{NS}	0.6	0.312	1.047 ^{NS}
10	-0.6	0.475	0.730 ^{NS}	2.3	0.612	0.516 ^{NS}	1.7	0.758	0.313 ^{NS}	-1.9	0.994	0.007 ^{NS}	0.4	0.667	0.438 ^{NS}	-0.2	0.801	0.256 ^{NS}
11	0.1	0.911	0.113 ^{NS}	2.2	0.812	0.242 ^{NS}	2.3	0.697	0.396 ^{NS}	-3.0	0.368	0.928 ^{NS}	-0.7	0.497	0.696 ^{NS}	-0.6	0.487	0.712 ^{NS}
12	0.3	0.643	0.471 ^{NS}	2.0	0.062	1.991 [*]	2.4	0.036	2.270 ^{**}	-0.8	0.588	0.553 ^{NS}	1.2	0.074	1.917 [*]	1.5	0.045	2.185 ^{**}
13	1.1	0.176	1.409 ^{NS}	0.6	0.779	0.285 ^{NS}	1.8	0.419	0.827 ^{NS}	0.2	0.305	1.063 ^{NS}	0.8	0.134	1.585 ^{NS}	1.9	0.049	2.145 ^{**}
14	0.6	0.503	0.684 ^{NS}	2.4	0.592	0.546 ^{NS}	3.0	0.267	1.145 ^{NS}	-0.9	0.330	1.007 ^{NS}	1.5	0.144	1.541 ^{NS}	2.1	0.075	1.915 [*]
15	0.2	0.786	0.276 ^{NS}	2.3	0.372	0.915 ^{NS}	2.6	0.284	1.104 ^{NS}	-1.6	0.773	0.294 ^{NS}	0.7	0.363	0.938 ^{NS}	0.9	0.218	1.284 ^{NS}
16	-0.2	0.866	0.171 ^{NS}	1.4	0.830	0.218 ^{NS}	1.2	0.917	0.105 ^{NS}	-0.7	0.826	0.224 ^{NS}	0.6	0.513	0.670 ^{NS}	0.5	0.612	0.518 ^{NS}

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
17	0.8	0.189	1.364 ^{NS}	0.7	0.242	1.209 ^{NS}	1.5	0.994	0.007 ^{NS}	-1.7	0.831	0.217 ^{NS}	-0.9	0.198	1.348 ^{NS}	-0.1	0.810	0.244 ^{NS}
18	-0.3	0.842	0.202 ^{NS}	0.7	0.251	1.187 ^{NS}	0.3	0.456	0.762 ^{NS}	-2.0	0.560	0.596 ^{NS}	-1.4	0.125	1.623 ^{NS}	-1.7	0.377	0.910 ^{NS}
19	-1.8	0.406	0.851 ^{NS}	2.7	0.704	0.385 ^{NS}	0.9	0.546	0.615 ^{NS}	1.9	0.226	1.263 ^{NS}	4.6	0.172	1.435 ^{NS}	2.8	0.488	0.711 ^{NS}
20	-1.0	0.640	0.475 ^{NS}	0.7	0.160	1.464 ^{NS}	-0.3	0.841	0.204 ^{NS}	-0.8	0.165	1.459 ^{NS}	-0.2	0.862	0.177 ^{NS}	-1.2	0.643	0.473 ^{NS}
21	-0.4	0.774	0.291 ^{NS}	-0.9	0.503	0.684 ^{NS}	-1.4	0.528	0.644 ^{NS}	0.8	0.619	0.508 ^{NS}	-0.1	0.877	0.158 ^{NS}	-0.6	0.753	0.320 ^{NS}
22	-0.9	0.383	0.895 ^{NS}	-0.6	0.111	1.675 ^{NS}	-1.5	0.006	3.126 ^{***}	0.3	0.072	1.934 [*]	-0.4	0.700	0.393 ^{NS}	-1.2	0.121	1.643 ^{NS}
23	1.4	0.114	1.662 ^{NS}	-1.2	0.035	2.274 ^{**}	0.2	0.398	0.866 ^{NS}	0.8	0.087	1.830 [*]	-0.4	0.649	0.464 ^{NS}	1.0	0.237	1.230 ^{NS}
24	0.2	0.813	0.240 ^{NS}	-0.5	0.535	0.633 ^{NS}	-0.3	0.751	0.322 ^{NS}	0.9	0.315	1.039 ^{NS}	0.4	0.609	0.522 ^{NS}	0.6	0.533	0.638 ^{NS}
25	-0.9	0.351	0.958 ^{NS}	0.3	0.335	0.991 ^{NS}	-0.6	0.086	1.818 [*]	0.4	0.108	1.708 ^{NS}	0.7	0.423	0.823 ^{NS}	-0.2	0.873	0.163 ^{NS}
26	0.2	0.751	0.322 ^{NS}	-0.5	0.145	1.523 ^{NS}	-0.3	0.389	0.883 ^{NS}	-0.2	0.743	0.334 ^{NS}	-0.8	0.219	1.284 ^{NS}	-0.5	0.578	0.569 ^{NS}
27	1.3	0.095	1.764 [*]	-0.8	0.569	0.580 ^{NS}	0.6	0.238	1.221 ^{NS}	0.3	0.989	0.014 ^{NS}	-0.5	0.544	0.620 ^{NS}	0.9	0.209	1.311 ^{NS}
28	0.9	0.159	1.470 ^{NS}	-0.2	0.804	0.252 ^{NS}	0.7	0.211	1.296 ^{NS}	0.2	0.744	0.333 ^{NS}	0.1	0.940	0.077 ^{NS}	0.9	0.137	1.571 ^{NS}
29	0.5	0.393	0.875 ^{NS}	-0.1	0.808	0.247 ^{NS}	0.3	0.520	0.656 ^{NS}	-0.2	0.720	0.365 ^{NS}	-0.3	0.560	0.596 ^{NS}	0.2	0.748	0.327 ^{NS}
30	0.0	0.932	0.087 ^{NS}	0.3	0.549	0.611 ^{NS}	0.3	0.430	0.808 ^{NS}	0.1	0.732	0.349 ^{NS}	0.5	0.483	0.719 ^{NS}	0.4	0.330	1.008 ^{NS}
31	0.2	0.744	0.332 ^{NS}	-0.1	0.790	0.270 ^{NS}	0.0	0.973	0.035 ^{NS}	0.4	0.468	0.745 ^{NS}	0.3	0.539	0.629 ^{NS}	0.5	0.409	0.850 ^{NS}
32	0.8	0.203	1.321 ^{NS}	-0.1	0.804	0.252 ^{NS}	0.7	0.269	1.140 ^{NS}	0.4	0.395	0.875 ^{NS}	0.3	0.587	0.555 ^{NS}	1.1	0.097	1.770 [*]
33	-0.1	0.685	0.412 ^{NS}	0.2	0.516	0.663 ^{NS}	0.1	0.749	0.325 ^{NS}	-0.2	0.558	0.600 ^{NS}	0.0	0.932	0.087 ^{NS}	-0.1	0.689	0.409 ^{NS}
34	0.0	0.930	0.089 ^{NS}	-0.4	0.473	0.733 ^{NS}	-0.3	0.424	0.818 ^{NS}	0.5	0.193	1.362 ^{NS}	0.2	0.734	0.346 ^{NS}	0.2	0.553	0.607 ^{NS}

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
35	0.5	0.343	0.974 ^{NS}	-0.5	0.407	0.848 ^{NS}	0.0	0.965	0.045 ^{NS}	0.4	0.532	0.640 ^{NS}	-0.1	0.845	0.199 ^{NS}	0.4	0.444	0.786*
36	0.2	0.786	0.275 ^{NS}	-0.9	0.152	1.496 ^{NS}	-0.8	0.197	1.339 ^{NS}	0.7	0.254	1.185 ^{NS}	-0.2	0.713	0.375 ^{NS}	-0.1	0.903	0.125 ^{NS}
37	0.5	0.254	1.177 ^{NS}	-0.7	0.059	2.017 ^{NS}	-0.2	0.592	0.546 ^{NS}	1.4	0.003	3.487***	0.7	0.134	1.585 ^{NS}	1.2	0.029	2.420**
38	-1.2	0.269	1.141 ^{NS}	1.0	0.337	0.985 ^{NS}	-0.1	0.794	0.265 ^{NS}	0.6	0.334	0.998 ^{NS}	1.7	0.198	1.346 ^{NS}	0.5	0.428	0.815 ^{NS}
39	-0.5	0.656	0.453 ^{NS}	0.3	0.768	0.299 ^{NS}	-0.2	0.788	0.273 ^{NS}	-2.1	0.446	0.783 ^{NS}	-1.8	0.548	0.614 ^{NS}	-2.3	0.412	0.845 ^{NS}
40	-0.1	0.888	0.143 ^{NS}	1.3	0.217	1.278 ^{NS}	1.1	0.172	1.423 ^{NS}	1.0	0.357	0.951 ^{NS}	2.2	0.074	1.923*	2.1	0.037	2.291**
41	0.1	0.939	0.078 ^{NS}	1.0	0.242	1.210 ^{NS}	1.1	0.216	1.282 ^{NS}	1.0	0.189	1.377 ^{NS}	2.0	0.073	1.927*	2.1	0.068	1.967*
42	1.3	0.167	1.440 ^{NS}	0.6	0.446	0.780 ^{NS}	1.9	0.032	2.327**	0.1	0.928	0.092 ^{NS}	0.6	0.496	0.698 ^{NS}	1.9	0.072	1.936*
43	1.3	0.099	1.738*	-0.1	0.932	0.087 ^{NS}	1.3	0.100	1.735*	0.7	0.383	0.900 ^{NS}	0.6	0.454	0.769 ^{NS}	1.9	0.035	2.318**
44	0.8	0.333	0.996 ^{NS}	1.4	0.079	1.860*	2.2	0.002	3.603***	-0.6	0.278	1.124 ^{NS}	0.8	0.351	0.963 ^{NS}	1.6	0.025	2.496**
45	1.6	0.055	2.048 ^{NS}	-0.6	0.414	0.835 ^{NS}	1.0	0.145	1.524 ^{NS}	1.0	0.142	1.549 ^{NS}	0.4	0.666	0.440 ^{NS}	2.0	0.013	2.825**
46	-0.3	0.604	0.528 ^{NS}	1.3	0.030	2.351**	0.9	0.190	1.362 ^{NS}	-1.2	0.134	1.585 ^{NS}	0.1	0.879	0.155 ^{NS}	-0.2	0.786	0.276 ^{NS}
47	0.5	0.517	0.660 ^{NS}	-0.1	0.848	0.195 ^{NS}	0.3	0.665	0.441 ^{NS}	-0.4	0.676	0.426 ^{NS}	-0.5	0.540	0.628 ^{NS}	0.0	0.973	0.034 ^{NS}
48	0.3	0.622	0.502 ^{NS}	-0.2	0.809	0.245 ^{NS}	0.1	0.877	0.157 ^{NS}	2.0	0.053	2.103 ^{NS}	1.7	0.054	2.089 ^{NS}	2.1	0.006	3.210***
49	2.0	0.049	2.115**	-0.4	0.689	0.406 ^{NS}	1.6	0.033	2.308**	1.0	0.297	1.080 ^{NS}	0.6	0.625	0.499 ^{NS}	2.6	0.012	2.876**
50	0.1	0.924	0.097 ^{NS}	0.8	0.551	0.608 ^{NS}	0.9	0.405	0.854 ^{NS}	0.3	0.804	0.253 ^{NS}	1.1	0.397	0.871 ^{NS}	1.2	0.183	1.395 ^{NS}
51	0.4	0.704	0.386 ^{NS}	1.0	0.356	0.948 ^{NS}	1.4	0.284	1.105 ^{NS}	-0.8	0.542	0.624 ^{NS}	0.2	0.804	0.253 ^{NS}	0.7	0.616	0.512 ^{NS}
52	0.6	0.441	0.787 ^{NS}	0.0	0.958	0.053 ^{NS}	0.6	0.503	0.684 ^{NS}	-1.0	0.220	1.281 ^{NS}	-1.1	0.141	1.555 ^{NS}	-0.5	0.683	0.417 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.1.2.2 Monthly

Monthly average minimum temperature data for 37 years (1981-2017) was analyzed and the same has been set out as Table 4.11. During Period-I the lowest average minimum temperature was observed during the month of January (4.8°C) and highest average minimum temperature was recorded during the month of June (26.7°C). It was analysed that from Period-II to Period-V, lowest minimum temperature was recorded during January month and highest minimum temperature was analysed during the month of July. The highest minimum temperature of 27.2 , 27.1 , 27.2 and 27.0°C was observed during Period-II, Period-III, Period-IV and overall Period-V respectively, whereas, lowest minimum temperature of 5.4°C (Period-II), 4.9°C (Period-III), 6.0°C (Period-IV) and 5.2°C (Period-V) was observed during the month of January. The average minimum temperature on monthly basis during different periods of time is depicted in Fig 4.4. The highest minimum temperature was recorded during Period-II the months of June which was (26.7°C). Analysis of coefficient of variation (Table 15) on monthly basis depicted that during Period-I, maximum coefficient of variation of 63.0 per cent was calculated during January and minimum of 6.4 per cent was during August month. It was observed that maximum and minimum CV of 57.7 and 5.1 per cent was recorded during the month of January and August, respectively, for Period-II. During Period-III, maximum coefficient of variation of 60.6 per cent during January, while 6.2 per cent was during August, which was minimum. Analysis of Period-IV indicated maximum coefficient of variation of 49.3 per cent (December) and minimum coefficient of variation of 5.2 per cent (August). During the overall Period-V, it was observed that during the month of January, coefficient of variation was maximum (58.0 per cent) whereas, least coefficient of variation of 5.8 was observed during the month of August. Periodical deviation of average minimum temperature of Bathinda was analysed and represented as Table 4.12. The deviation in average minimum temperature was statistically non-significant during the Period-II over base Period-I. During Period-III over base Period-II, periodical deviation of mean difference was statistically non-significant. The deviation of average minimum temperature during Period-III over base Period-I depicted mean difference of 1.5°C during October, which was significant at one per cent level of significance and ten per cent significant level of significance during the month of November (0.7°C). The Periodical deviation in average minimum temperature was 1.0°C during the month September at five per cent level of significance and mean difference of 1.1 (January) and -1.3°C (February) at ten per cent level of significance during the Period-IV over base Period-III. During Period-IV over base Period-II, periodical deviation was significant at one per cent level of significance during February (-0.9°C). The deviation of average minimum temperature during Period-IV over base Period-I was 1.2 and 0.5°C during January and August which was significant at one per cent level of significance and significance at five per cent level of significance during November month was 1.0°C and October which significant at ten per cent level of significance by 1.9°C .

Table 4.11: Periodic average and coefficient of variations (%) of monthly minimum temperature at Bathinda (1981-2017)

Months	Minimum temperature ($^{\circ}\text{C}$)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
January	4.8	5.4	4.9	6.0	5.2	63.0	57.7	60.6	47.8	58.0
February	7.3	7.6	8.0	6.7	7.5	40.2	36.2	37.3	42.3	38.8
March	11.4	11.4	12.2	11.7	11.7	27.5	27.6	21.7	26.5	25.8
April	17.8	18.2	18.3	18.4	18.1	20.2	19.8	16.1	14.9	18.0
May	24.8	23.8	23.7	24.6	24.2	12.1	11.1	11.4	26.3	14.4
June	26.7	26.9	25.9	26.8	26.6	10.2	10.0	10.7	9.2	10.1
July	26.6	27.2	27.1	27.2	27.0	7.1	6.2	7.1	5.9	6.6
August	25.8	26.1	26.0	26.3	26.0	6.4	5.1	6.2	5.2	5.8
September	22.9	22.7	22.6	23.6	22.9	8.6	11.4	8.7	7.5	9.1
October	15.9	16.5	17.3	17.7	16.8	20.0	15.3	14.7	17.8	16.9
November	9.8	10.4	10.6	10.8	10.4	24.2	25.9	26.4	23.2	25.1
December	5.3	6.1	6.4	6.3	6.0	54.6	44.4	39.3	49.3	46.7

***, **and * indicates 1,5 and 10 percent level of significance respectively, NS: Non-significant

Table 4.12: Periodical deviation in average monthly minimum temperature at Bathinda (1981-2017)

Months	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
January	0.6	0.418	0.828 ^{NS}	-0.5	0.426	0.814 ^{NS}	0.1	0.909	0.116 ^{NS}	1.1	0.063	2.007*	0.6	0.391	0.884 ^{NS}	1.2	0.098	1.766*
February	0.3	0.613	0.515 ^{NS}	0.4	0.531	0.639 ^{NS}	0.7	0.339	0.982 ^{NS}	-1.3	0.085	1.842*	-0.9	0.095	1.781*	-0.6	0.356	0.952 ^{NS}
March	0.0	0.982	0.022 ^{NS}	0.8	0.249	1.192 ^{NS}	0.8	0.203	1.321 ^{NS}	-0.5	0.528	0.647 ^{NS}	0.3	0.643	0.473 ^{NS}	0.3	0.575	0.573 ^{NS}
April	0.4	0.443	0.785 ^{NS}	0.1	0.865	0.172 ^{NS}	0.5	0.513	0.667 ^{NS}	0.1	0.906	0.120 ^{NS}	0.3	0.624	0.500 ^{NS}	0.7	0.161	1.476 ^{NS}
May	-1.0	0.547	0.614 ^{NS}	-0.1	0.838	0.207 ^{NS}	-1.2	0.495	0.697 ^{NS}	1.0	0.287	1.105 ^{NS}	0.8	0.344	0.976 ^{NS}	-0.2	0.925	0.096 ^{NS}
June	0.2	0.671	0.431 ^{NS}	-1.0	0.048	2.120 ^{NS}	-0.8	0.170	1.431 ^{NS}	1.0	0.132	1.592 ^{NS}	-0.1	0.872	0.165 ^{NS}	0.1	0.823	0.228 ^{NS}
July	0.5	0.242	1.211 ^{NS}	-0.1	0.899	0.129 ^{NS}	0.5	0.139	1.550 ^{NS}	0.0	0.904	0.123 ^{NS}	0.0	0.969	0.040 ^{NS}	0.5	0.162	1.472 ^{NS}
August	0.3	0.430	0.807 ^{NS}	-0.1	0.758	0.313 ^{NS}	0.2	0.489	0.706 ^{NS}	0.3	0.201	1.338 ^{NS}	0.2	0.632	0.489 ^{NS}	0.5	0.097	1.771*
September	-0.2	0.737	0.341 ^{NS}	-0.1	0.883	0.149 ^{NS}	-0.3	0.473	0.733 ^{NS}	1.0	0.017	2.689**	0.9	0.204	1.329 ^{NS}	0.7	0.108	1.707 ^{NS}
October	0.7	0.291	1.088 ^{NS}	0.8	0.203	1.321 ^{NS}	1.5	0.005	3.178***	0.4	0.420	0.830 ^{NS}	1.2	0.114	1.681 ^{NS}	1.9	0.004	3.394***
November	0.6	0.293	1.084 ^{NS}	0.2	0.729	0.352 ^{NS}	0.7	0.090	1.791*	0.2	0.596	0.542 ^{NS}	0.4	0.479	0.726 ^{NS}	1.0	0.040	2.253**
December	0.8	0.178	1.401 ^{NS}	0.3	0.661	0.445 ^{NS}	1.1	0.121	1.627 ^{NS}	-0.1	0.875	0.160 ^{NS}	0.2	0.747	0.329 ^{NS}	1.0	0.104	1.728 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS:Non-significant, P-Probability, t-Test.

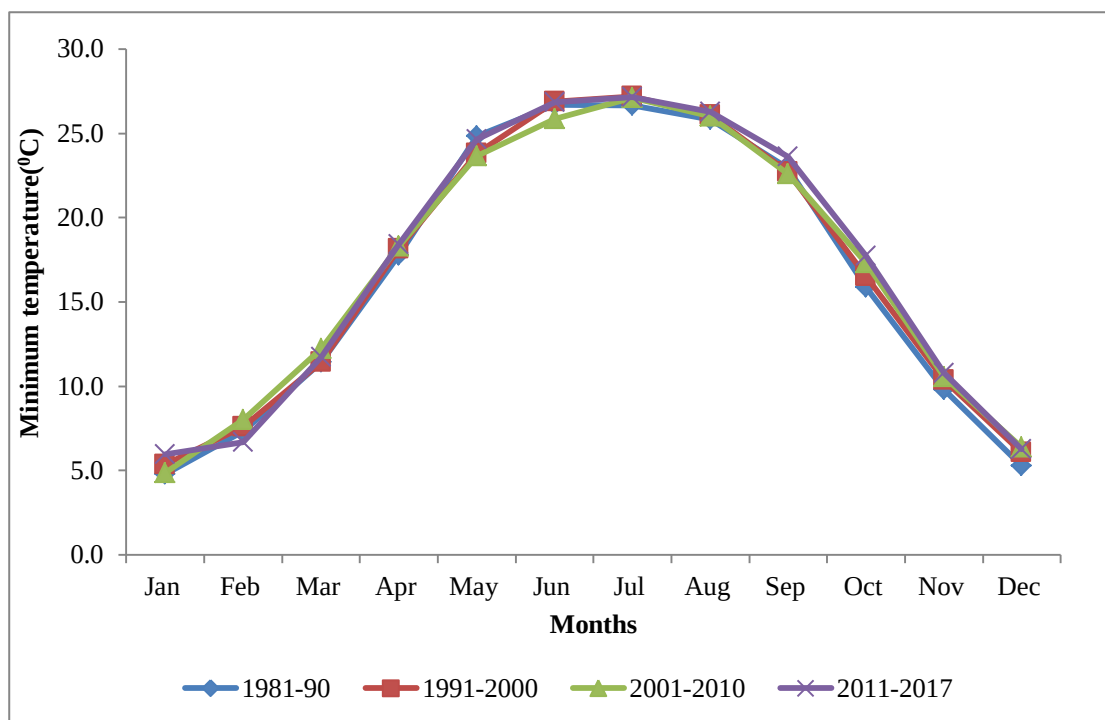


Fig. 4.4: Average monthly minimum temperature at Bathinda (1981-2017) during different periods

4.1.1.2.3 Seasonal

The change in average seasonal minimum temperature for *kharif* and *rabi* season during the period of 37 years (1981-2017) was studied to comprehend the change in average minimum temperature at Bathinda district of Punjab (Table 4.13). During *kharif* season the average minimum temperature of 24.8, 24.8, 24.6, 25.3 and 24.9°C was recorded during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. The average minimum temperature was recorded as 26.6, 26.1, 26.7, 25.6 and 26.3°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively during *rabi* season. Coefficient of variation during *kharif* season was 14.9, 14.2, 13.0, 18.0 and 14.9°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. During *rabi* season coefficient of variation was 22.2 per cent during Period-I, 23.6 per cent during Period-II, 26.2 per cent during Period-III, 27.3 during Period-IV and 24.6 during overall Period-V. Periodical deviation in average crop seasonal minimum temperature of Bathinda was analysed and represented as Table 4.14. During *kharif* season, the mean difference of 0.7°C was observed which was significant at five per cent level of significance during Period-IV over base Period-III. The average deviation of minimum temperature during Period-IV over base Period-III was -1.0°C observed during *rabi* season, which was significant at five per cent level of significance.

4.1.1.2.4 Meteorological seasons during the year

The change in average seasons minimum temperature of Bathinda district of Punjab was studied for the Period of 37 years (1981-2017) and represented as Table 4.15. It was observed that highest average minimum temperature was during monsoon season and was 25.6, 25.8, 25.4, 26.0 and 25.7°C and lowest average minimum temperature was during winter season and was recorded as 5.8, 6.3, 6.4, 6.8 and 6.3°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. The average minimum temperature was recorded 18.0, 17.9, 18.2, 18.4 and 18.1°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively during summer season. During post-monsoon season the average minimum temperature of 13.1, 13.7, 14.2, 14.4 and 13.8°C was recorded during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Analysis of coefficient of variation (Table 4.15) on seasons basis depicted that the coefficient of variation was highest during winter season and was 54.6, 50.7, 50.0, 46.8 and 49.3 per cent and lowest coefficient of variation was during monsoon season and was 10.1, 10.9, 10.6, 8.8 and 10.2 per cent during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Coefficient of variation during summer season was 34.2, 31.9, 29.4, 40.4 and 33.8 per cent during period-I, II, III, IV and overall Period-V, respectively. During post-monsoon season coefficient of variation was 31.9, 29.4, 30.6, 32.0 and 30.7°C during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Periodical deviation of average minimum temperature at Bathinda was analysed and represented as Table 4.16. The periodical deviation in average minimum temperature was statistically non-significant during the summer season. The deviation in average minimum temperature during monsoon season was 0.6°C during Period-IV over base Period-III, which was significant at five per cent level of significance. During post-monsoon season deviation in minimum temperature was 1.1°C during Period-III over base Period-I and was significant at one per cent level of significance and 1.3°C during Period-IV over base Period-I which was significant at one per cent level of significance. The periodical deviation in average minimum temperature was statistically non-significant during the winter season.

Table 4.13: Periodic average and coefficient of variations (%) of seasonal minimum temperature at Bathinda (1981-2017)

Seasonal	Minimum temperature (°C)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
<i>Rabi</i>	26.6	26.1	26.7	25.6	26.3	22.2	23.6	26.2	27.3	24.6
<i>Kharif</i>	24.8	24.8	24.6	25.3	24.9	14.9	14.2	13.0	18.2	14.9

Table 4.14: Periodical deviation in average seasonal minimum temperature at Bathinda (1981-2017)

Seasons	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
<i>Rabi</i>	-0.4	0.281	1.111 ^{NS}	0.5	0.191	1.358 ^{NS}	0.1	0.805	0.250 ^{NS}	-1.0	0.040	2.244**	-0.5	0.303	1.068 ^{NS}	-0.9	0.060	2.034 ^{NS}
<i>Kharif</i>	0.0	0.944	0.072 ^{NS}	-0.2	0.530	0.640 ^{NS}	-0.2	0.569	0.581 ^{NS}	0.7	0.035	2.315**	0.5	0.118	1.660 ^{NS}	0.5	0.283	1.115 ^{NS}

** indicates 5% level of significance respectively, NS: Non-significant, P-Probability, t-Test.

Table 4.15: Periodic average and coefficient of variations (%) of minimum temperature during different meteorological seasons at Bathinda (1981-2017)

Seasons	Minimum temperature (°C)					Variation in minimum temperature (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
Summer	18.0	17.9	18.2	18.4	18.1	34.2	31.9	29.4	40.4	33.8
Monsoon	25.6	25.8	25.4	26.0	25.7	10.1	10.9	10.6	8.8	10.2
Post-monsoon	13.1	13.7	14.2	14.4	13.8	31.9	29.4	30.6	32.0	30.7
Winter	5.8	6.3	6.4	6.8	6.3	54.6	50.7	50.0	46.8	49.3

Table 4.16: Periodical deviation in average minimum temperature during different meteorological seasons at Bathinda (1981-2017)

Seasons	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value
Summer	-0.1	0.866	0.171 ^{NS}	0.2	0.699	0.392 ^{NS}	0.1	0.883	0.149 ^{NS}	0.3	0.689	0.407 ^{NS}	0.5	0.240	1.216 ^{NS}	0.4	0.607	0.523 ^{NS}
Monsoon	0.2	0.443	0.785 ^{NS}	-0.4	0.223	1.262 ^{NS}	-0.1	0.631	0.489 ^{NS}	0.6	0.047	2.129**	0.3	0.399	0.863 ^{NS}	0.5	0.113	1.665 ^{NS}
Post-monsoon	0.6	0.258	1.169 ^{NS}	0.5	0.327	1.008 ^{NS}	1.1	0.010	2.900***	0.2	0.458	0.758 ^{NS}	0.7	0.173	1.419 ^{NS}	1.3	0.002	3.538***
Winter	0.6	0.235	1.230 ^{NS}	0.0	0.961	0.049 ^{NS}	0.6	0.218	1.276 ^{NS}	0.4	0.415	0.834 ^{NS}	0.4	0.388	0.886 ^{NS}	1.0	0.054	2.058 ^{NS}

*** and ** indicates 1 and 5 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.1.3 Rainfall

4.1.1.3.1 Weekly

The change in average weekly rainfall at Bathinda during the period of 1981-2017, is shown in Table 4.17. During the Period-I the lowest average rainfall was observed during the 48th and 49th week (0.0 mm) and highest average rainfall was recorded during the 27th week which was 71.2 mm. The highest rainfall of 55.9 mm was recorded during 34th week of Period-II, while 0.1 mm lowest rainfall was observed during 46th week. It was analysed that from Period-III to Period-V, lowest rainfall was recorded during 45th, 46th, 40th and 48th week and highest rainfall was during 29th and 31st week. The highest rainfall of 43.0, 44.0 and 33.5 mm was observed during Period-III, Period-IV and overall Period-V, respectively, whereas, lowest rainfall of 0.0 mm was observed during Period-III, Period-IV and 0.1 mm during Period-V. The graph (Fig 4.5) showed that average rainfall during standard meteorological weeks during different periods of time. The value of highest rainfall was observed during 27th week of Period-I. The coefficient of variation (CV) of weekly average rainfall (Table 4.17) depicted that during Period-I minimum variation of 0.0 per cent observed during 48th SMW, while maximum coefficient of variation of 173.2 per cent was during 7th SMW. During period-II, maximum and minimum coefficient of variation of 222.8 and 17.3 per cent was analysed during 29th and 44th SMW, respectively. During Period-III, maximum CV of 211.7 per cent was during 36th SMW and minimum of 0.0 per cent was during 43rd, 45th and 46th SMW. Analysis of period-IV indicated maximum CV of 217.1 per cent during 34th SMW, while minimum CV (0.0 per cent) was during 47th, 51st and 52nd SMW, respectively. The overall analysis of all Periods (Period-V) showed maximum CV of 264.6 per cent during 45th SMW and least CV (148.1 per cent) during 39th SMW. Periodical deviation of average rainfall of Bathinda was analysed and represented as Table 4.18.

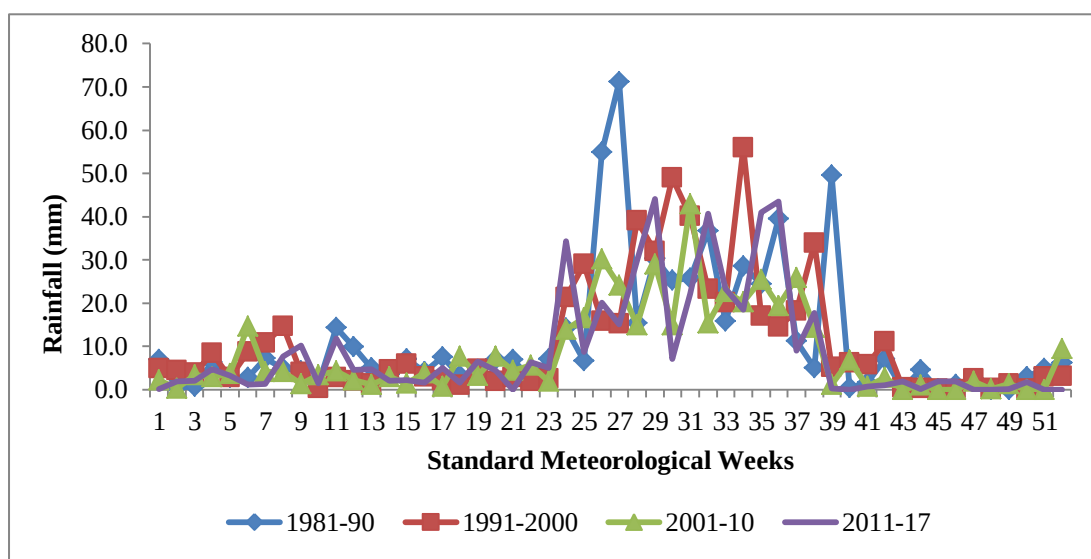


Fig. 4.5: Average weekly rainfall at Bathinda (1981-2017) during different periods

Table 4.17: Periodic average and coefficient of variations (%) of weekly rainfall at Bathinda (1981-2017)

Weeks	Rainfall (mm)					Variation in rainfall (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
1	7.0	4.9	2.3	0.2	3.8	121.9	22.8	45.0	37.8	236.0
2	0.5	4.4	0.3	1.9	1.8	45.2	124.5	26.5	109.6	245.2
3	0.8	3.9	3.5	2.1	2.6	52.9	93.3	98.8	151.2	229.7
4	6.3	8.4	3.0	4.7	5.7	112.7	150.3	51.0	101.7	199.2
5	2.8	2.8	3.7	3.3	3.1	87.7	44.2	90.6	73.3	208.4
6	2.8	8.7	14.6	1.1	7.2	124.7	137.6	100.4	101.8	206.8
7	7.3	10.8	4.2	1.4	6.2	173.2	165.6	77.0	96.4	241.1
8	4.9	14.6	4.1	7.7	7.9	114.5	138.6	52.9	171.3	232.8
9	4.4	4.0	1.3	10.2	4.6	126.7	87.0	93.0	146.8	249.7
10	1.2	0.3	3.4	1.5	1.6	47.1	26.5	61.9	49.7	189.0
11	14.4	2.9	4.3	11.9	8.1	122.5	116.0	44.3	137.7	224.4
12	9.9	2.1	2.3	4.6	4.7	172.1	120.7	65.7	86.9	181.2
13	5.1	1.4	1.1	4.8	3.0	121.6	58.9	40.5	91.7	228.6
14	3.6	4.6	2.9	2.0	3.4	117.0	60.4	45.5	131.1	200.5
15	7.1	5.9	1.4	2.3	4.3	85.8	70.4	26.5	74.2	199.8
16	4.1	2.9	3.8	1.6	3.2	66.2	83.2	19.0	53.5	175.1
17	7.5	2.1	0.8	5.0	3.8	82.5	132.3	52.9	73.0	211.2

Weeks	Rainfall (mm)					Variation in rainfall (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
18	3.3	1.1	7.7	1.7	3.6	77.9	74.2	157.7	75.6	254.2
19	4.7	4.8	3.2	6.4	4.7	43.9	151.1	72.2	113.4	230.4
20	7.0	1.9	7.7	4.5	5.3	144.8	105.8	56.4	108.2	218.8
21	7.0	2.9	4.5	0.0	3.9	61.6	111.3	41.5	0.0	218.0
22	2.5	1.9	5.6	6.3	3.9	74.7	102.2	87.6	149.9	224.9
23	7.0	2.5	1.9	5.0	4.0	153.7	70.2	85.7	62.9	223.5
24	14.3	21.3	13.9	34.4	20.0	181.7	169.2	101.8	206.8	217.4
25	6.7	29.0	16.6	8.8	15.7	146.9	127.5	149.8	131.0	180.0
26	54.9	15.9	30.2	20.2	31.0	153.2	154.9	215.6	182.0	181.2
27	71.2	15.3	24.1	15.0	32.6	160.8	87.6	112.2	209.2	223.7
28	15.4	39.0	15.0	29.9	24.5	163.1	129.4	171.4	173.4	206.8
29	30.4	31.9	29.0	44.0	33.1	135.5	222.8	162.8	171.7	196.8
30	25.3	48.9	14.9	7.1	25.3	172.5	151.4	164.0	90.2	184.8
31	25.8	40.2	43.0	22.1	33.5	144.6	145.7	173.3	185.4	185.4
32	36.6	23.3	15.4	40.8	28.1	140.3	169.9	128.2	186.4	213.1
33	15.8	20.1	22.6	23.4	20.3	164.8	141.0	131.9	112.0	204.9
34	28.6	55.9	20.3	18.5	31.7	100.3	145.3	109.1	217.1	178.4
35	24.5	17.0	25.4	40.9	25.9	142.9	142.1	144.4	126.5	183.3

Weeks	Rainfall (mm)					Variation in rainfall (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
36	39.5	14.5	19.3	43.5	28.2	43.6	122.3	211.7	115.5	179.1
37	11.3	18.3	25.9	9.0	16.6	79.4	75.3	145.7	126.8	198.8
38	5.1	33.9	14.4	17.8	17.8	155.1	73.7	102.7	142.8	214.5
39	49.6	5.2	1.1	0.3	15.1	129.0	85.9	45.6	37.8	148.1
40	0.5	6.2	6.8	0.0	3.6	52.9	57.9	31.5	0.0	186.6
41	1.6	5.8	0.8	0.8	2.3	70.7	67.6	43.8	37.8	253.0
42	7.1	11.0	2.9	1.0	5.8	103.3	89.5	52.9	37.8	228.0
43	0.1	0.5	0.0	2.0	0.5	26.5	109.0	0.0	75.6	256.8
44	4.6	0.2	1.0	0.1	1.6	17.5	17.3	18.9	37.8	178.8
45	0.1	0.2	0.0	2.0	0.5	26.5	26.5	0.0	75.6	264.6
46	1.2	0.1	0.0	2.0	0.7	17.6	17.6	0.0	24.5	173.5
47	2.5	2.6	2.0	0.0	1.9	63.2	55.2	52.9	0.0	229.4
48	0.0	0.3	0.2	0.1	0.1	0.0	52.9	26.5	37.8	264.6
49	0.0	1.3	1.3	0.1	0.7	0.0	53.8	52.9	37.8	214.9
50	2.9	0.2	0.0	1.7	1.2	149.1	42.3	0.0	67.7	235.6
51	4.9	3.0	0.0	0.0	2.1	48.2	61.3	0.0	0.0	227.3
52	6.2	3.1	9.5	0.0	5.0	94.2	96.0	59.7	0.0	167.0

Table 4.18: Periodical deviation in average weekly rainfall at Bathinda (1981-2017)

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
1	-2.1	0.777	0.288 ^{NS}	-2.6	0.620	0.504 ^{NS}	-4.7	0.413	0.838 ^{NS}	-2.1	0.319	1.030 ^{NS}	-4.7	0.439	0.794 ^{NS}	-6.8	0.310	1.050 ^{NS}
2	3.9	0.176	1.409 ^{NS}	-4.1	0.158	1.475 ^{NS}	-0.2	0.716	0.369 ^{NS}	1.6	0.214	1.297 ^{NS}	-2.5	0.488	0.711 ^{NS}	1.4	0.270	1.145 ^{NS}
3	3.1	0.193	1.353 ^{NS}	-0.4	0.909	0.115 ^{NS}	2.7	0.301	1.065 ^{NS}	-1.4	0.662	0.446 ^{NS}	-1.8	0.540	0.628 ^{NS}	1.3	0.320	1.028 ^{NS}
4	2.1	0.707	0.382 ^{NS}	-5.4	0.247	1.197 ^{NS}	-3.3	0.483	0.716 ^{NS}	1.7	0.650	0.463 ^{NS}	-3.7	0.464	0.752 ^{NS}	-1.6	0.752	0.322 ^{NS}
5	0.0	0.993	0.009 ^{NS}	0.9	0.792	0.268 ^{NS}	0.9	0.766	0.302 ^{NS}	-0.4	0.898	0.131 ^{NS}	0.5	0.894	0.136 ^{NS}	0.5	0.880	0.153 ^{NS}
6	5.9	0.113	1.667 ^{NS}	5.9	0.460	0.756 ^{NS}	11.9	0.120	1.634 ^{NS}	-13.5	0.138	1.567 ^{NS}	-7.6	0.076	1.904*	-1.6	0.385	0.894 ^{NS}
7	3.5	0.542	0.621 ^{NS}	-6.6	0.228	1.248 ^{NS}	-3.1	0.464	0.747 ^{NS}	-2.8	0.389	0.888 ^{NS}	-9.4	0.112	1.688 ^{NS}	-5.9	0.153	1.504 ^{NS}
8	9.7	0.197	1.339 ^{NS}	-10.5	0.206	1.312 ^{NS}	-0.8	0.861	0.178 ^{NS}	3.6	0.514	0.669 ^{NS}	-6.9	0.445	0.784 ^{NS}	2.8	0.438	0.797 ^{NS}
9	-0.3	0.941	0.075 ^{NS}	-2.7	0.478	0.725 ^{NS}	-3.0	0.147	1.517 ^{NS}	8.9	0.072	1.934*	6.1	0.348	0.970 ^{NS}	5.8	0.266	1.156 ^{NS}
10	-0.9	0.383	0.894 ^{NS}	3.1	0.174	1.416 ^{NS}	2.2	0.372	0.915 ^{NS}	-1.8	0.523	0.653 ^{NS}	1.3	0.225	1.266 ^{NS}	0.4	0.817	0.235 ^{NS}
11	-11.5	0.185	1.377 ^{NS}	1.4	0.685	0.413 ^{NS}	-10.1	0.267	1.145 ^{NS}	7.6	0.245	1.209 ^{NS}	9.0	0.107	1.712 ^{NS}	-2.6	0.821	0.230 ^{NS}
12	-7.9	0.100	1.734*	0.2	0.927	0.092 ^{NS}	-7.7	0.115	1.655 ^{NS}	2.3	0.458	0.761 ^{NS}	2.5	0.387	0.890 ^{NS}	-5.3	0.363	0.938 ^{NS}
13	-3.7	0.254	1.178 ^{NS}	-0.3	0.861	0.178 ^{NS}	-3.9	0.209	1.304 ^{NS}	3.6	0.246	1.207 ^{NS}	3.4	0.302	1.068 ^{NS}	-0.3	0.952	0.062 ^{NS}
14	1.0	0.832	0.215 ^{NS}	-1.6	0.745	0.330 ^{NS}	-0.6	0.845	0.199 ^{NS}	-0.9	0.786	0.277 ^{NS}	-2.5	0.636	0.483 ^{NS}	-1.5	0.550	0.612 ^{NS}
15	-1.2	0.880	0.154 ^{NS}	-4.5	0.413	0.838 ^{NS}	-5.7	0.386	0.889 ^{NS}	0.8	0.740	0.337 ^{NS}	-3.6	0.582	0.562 ^{NS}	-4.9	0.540	0.627 ^{NS}
16	-1.2	0.769	0.298 ^{NS}	0.9	0.829	0.219 ^{NS}	-0.3	0.962	0.048 ^{NS}	-2.3	0.642	0.474 ^{NS}	-1.3	0.546	0.618 ^{NS}	-2.5	0.580	0.566 ^{NS}
17	-5.5	0.402	0.859 ^{NS}	-1.3	0.472	0.735 ^{NS}	-6.7	0.293	1.084 ^{NS}	4.2	0.153	1.505 ^{NS}	3.0	0.384	0.897 ^{NS}	-2.5	0.757	0.315 ^{NS}

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
18	-2.2	0.339	0.983 ^{NS}	6.6	0.250	1.188 ^{NS}	4.4	0.459	0.756 ^{NS}	-6.1	0.380	0.905 ^{NS}	0.6	0.742	0.336 ^{NS}	-1.7	0.541	0.625 ^{NS}
19	0.1	0.978	0.027 ^{NS}	-1.6	0.579	0.565 ^{NS}	-1.4	0.762	0.308 ^{NS}	3.2	0.453	0.770 ^{NS}	1.7	0.707	0.383 ^{NS}	1.8	0.779	0.286 ^{NS}
20	-5.1	0.107	1.698 ^{NS}	5.8	0.364	0.931 ^{NS}	0.7	0.915	0.108 ^{NS}	-3.2	0.693	0.402 ^{NS}	2.5	0.535	0.636 ^{NS}	-2.5	0.592	0.548 ^{NS}
21	-4.1	0.405	0.853 ^{NS}	1.6	0.679	0.420 ^{NS}	-2.5	0.671	0.432 ^{NS}	-4.5	0.309	1.052 ^{NS}	-2.9	0.101	1.749 ^{NS}	-7.0	0.227	1.259 ^{NS}
22	-0.7	0.771	0.296 ^{NS}	3.7	0.322	1.019 ^{NS}	3.0	0.452	0.770 ^{NS}	0.8	0.892	0.138 ^{NS}	4.5	0.303	1.066 ^{NS}	3.8	0.419	0.832 ^{NS}
23	-4.6	0.190	1.363 ^{NS}	-0.6	0.732	0.348 ^{NS}	-5.1	0.130	1.585 ^{NS}	3.1	0.445	0.785 ^{NS}	2.5	0.543	0.622 ^{NS}	-2.0	0.707	0.383 ^{NS}
24	7.0	0.516	0.663 ^{NS}	-7.3	0.514	0.665 ^{NS}	-0.4	0.972	0.036 ^{NS}	20.5	0.394	0.877 ^{NS}	13.1	0.587	0.555 ^{NS}	20.1	0.396	0.875 ^{NS}
25	22.3	0.093	1.774*	-12.4	0.388	0.885 ^{NS}	9.9	0.195	1.347 ^{NS}	-7.8	0.424	0.823 ^{NS}	-20.2	0.213	1.300 ^{NS}	2.1	0.728	0.354 ^{NS}
26	-39.0	0.378	0.903 ^{NS}	14.3	0.160	1.466 ^{NS}	-24.7	0.576	0.570 ^{NS}	-10.0	0.429	0.813 ^{NS}	4.3	0.704	0.387 ^{NS}	-34.7	0.516	0.664 ^{NS}
27	-55.9	0.198	1.335 ^{NS}	8.8	0.617	0.509 ^{NS}	-47.1	0.300	1.067 ^{NS}	-9.0	0.647	0.467 ^{NS}	-0.3	0.978	0.028 ^{NS}	-56.1	0.279	1.124 ^{NS}
28	23.6	0.150	1.502 ^{NS}	-24.0	0.136	1.561 ^{NS}	-0.4	0.965	0.044 ^{NS}	14.9	0.217	1.290 ^{NS}	-9.1	0.654	0.458 ^{NS}	14.5	0.254	1.187 ^{NS}
29	1.5	0.929	0.090 ^{NS}	-2.9	0.849	0.194 ^{NS}	-1.4	0.937	0.080 ^{NS}	15.1	0.421	0.827 ^{NS}	12.1	0.455	0.767 ^{NS}	13.6	0.503	0.687 ^{NS}
30	23.6	0.189	1.365 ^{NS}	-34.0	0.053	2.068 ^{NS}	-10.4	0.275	1.125 ^{NS}	-7.9	0.340	0.985 ^{NS}	-41.9	0.047	2.160 ^{NS}	-18.2	0.097	1.771*
31	14.4	0.566	0.584 ^{NS}	2.8	0.915	0.109 ^{NS}	17.2	0.319	1.026 ^{NS}	-20.8	0.248	1.201 ^{NS}	-18.0	0.528	0.647 ^{NS}	-3.6	0.813	0.240 ^{NS}
32	-13.4	0.558	0.597 ^{NS}	-7.9	0.567	0.584 ^{NS}	-21.3	0.303	1.061 ^{NS}	25.4	0.090	1.810*	17.5	0.359	0.947 ^{NS}	4.1	0.874	0.161 ^{NS}
33	4.3	0.726	0.356 ^{NS}	2.5	0.875	0.159 ^{NS}	6.8	0.589	0.550 ^{NS}	0.8	0.962	0.048 ^{NS}	3.2	0.843	0.202 ^{NS}	7.6	0.516	0.665 ^{NS}
34	27.3	0.266	1.147 ^{NS}	-35.6	0.059	2.015 ^{NS}	-8.3	0.697	0.396 ^{NS}	-1.8	0.901	0.126 ^{NS}	-37.3	0.074	1.922 ^{NS}	-10.1	0.678	0.424 ^{NS}
35	-7.5	0.674	0.428 ^{NS}	8.5	0.609	0.521 ^{NS}	1.0	0.945	0.069 ^{NS}	15.5	0.466	0.748 ^{NS}	24.0	0.338	0.990 ^{NS}	16.5	0.469	0.744 ^{NS}

Weeks	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
36	-25.0	0.386	0.888 ^{NS}	4.8	0.588	0.552 ^{NS}	-20.1	0.476	0.729 ^{NS}	24.2	0.315	1.039 ^{NS}	29.0	0.247	1.206 ^{NS}	4.0	0.920	0.102 ^{NS}
37	7.0	0.569	0.580 ^{NS}	7.7	0.596	0.540 ^{NS}	14.7	0.220	1.270 ^{NS}	-16.9	0.213	1.301 ^{NS}	-9.2	0.510	0.675 ^{NS}	-2.2	0.816	0.237 ^{NS}
38	28.8	0.193	1.353 ^{NS}	-19.5	0.393	0.876 ^{NS}	9.3	0.302	1.062 ^{NS}	3.4	0.796	0.263 ^{NS}	-16.1	0.555	0.605 ^{NS}	12.7	0.225	1.265 ^{NS}
39	-44.4	0.341	0.979 ^{NS}	-4.0	0.167	1.440 ^{NS}	-48.4	0.299	1.070 ^{NS}	-0.9	0.395	0.876 ^{NS}	-4.9	0.154	1.501 ^{NS}	-49.3	0.381	0.902 ^{NS}
40	5.6	0.176	1.408 ^{NS}	0.6	0.916	0.107 ^{NS}	6.3	0.187	1.370 ^{NS}	-6.8	0.237	1.232 ^{NS}	-6.2	0.221	1.278 ^{NS}	-0.5	0.311	1.049 ^{NS}
41	4.2	0.394	0.873 ^{NS}	-5.1	0.303	1.061 ^{NS}	-0.8	0.435	0.798 ^{NS}	0.0	0.956	0.056 ^{NS}	-5.0	0.398	0.869 ^{NS}	-0.8	0.552	0.609 ^{NS}
42	4.0	0.604	0.528 ^{NS}	-8.2	0.230	1.243 ^{NS}	-4.2	0.380	0.899 ^{NS}	-1.9	0.448	0.778 ^{NS}	-10.1	0.206	1.321 ^{NS}	-6.1	0.257	1.178 ^{NS}
43	0.4	0.089	1.797*	-0.5	0.016	2.658**	-0.1	0.331	1.000 ^{NS}	2.0	0.214	1.298 ^{NS}	1.5	0.339	0.987 ^{NS}	1.9	0.238	1.228 ^{NS}
44	-4.4	0.357	0.945 ^{NS}	0.8	0.476	0.728 ^{NS}	-3.6	0.453	0.767 ^{NS}	-0.9	0.476	0.732 ^{NS}	-0.1	0.674	0.428 ^{NS}	-4.5	0.432	0.808 ^{NS}
45	0.1	0.736	0.343 ^{NS}	-0.2	0.331	1.000 ^{NS}	-0.1	0.331	1.000 ^{NS}	2.0	0.109	1.705 ^{NS}	1.8	0.154	1.500 ^{NS}	1.9	0.133	1.589 ^{NS}
46	-1.1	0.357	0.946 ^{NS}	-0.1	0.331	1.000 ^{NS}	-1.2	0.331	1.000 ^{NS}	2.0	0.244	1.213 ^{NS}	1.9	0.259	1.174 ^{NS}	0.8	0.703	0.388 ^{NS}
47	0.1	0.955	0.057 ^{NS}	-0.6	0.776	0.289 ^{NS}	-0.5	0.806	0.249 ^{NS}	-2.0	0.233	1.243 ^{NS}	-2.6	0.240	1.222 ^{NS}	-2.5	0.201	1.337 ^{NS}
48	0.3	0.304	1.057 ^{NS}	-0.1	0.653	0.457 ^{NS}	0.2	0.331	1.000 ^{NS}	-0.1	0.686	0.413 ^{NS}	-0.2	0.523	0.654 ^{NS}	0.1	0.244	1.213 ^{NS}
49	1.3	0.201	1.326 ^{NS}	0.0	0.993	0.009 ^{NS}	1.3	0.151	1.500 ^{NS}	-1.1	0.290	1.097 ^{NS}	-1.1	0.347	0.970 ^{NS}	0.1	0.244	1.213 ^{NS}
50	-2.7	0.111	1.677 ^{NS}	-0.2	0.207	1.308 ^{NS}	-2.9	0.087	1.809 ^{NS}	1.7	0.080	1.879*	1.5	0.125	1.626 ^{NS}	-1.2	0.586	0.557 ^{NS}
51	-1.9	0.693	0.401 ^{NS}	-3.0	0.222	1.264 ^{NS}	-4.9	0.239	1.217 ^{NS}	0.0	0.000	0.000 ^{NS}	-3.0	0.312	1.047 ^{NS}	-4.9	0.329	1.008 ^{NS}
52	-3.2	0.369	0.922 ^{NS}	6.5	0.197	1.338 ^{NS}	3.3	0.555	0.601 ^{NS}	-9.5	0.103	1.739 ^{NS}	-3.1	0.148	1.524 ^{NS}	-6.2	0.108	1.707 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

The average rainfall was recorded significant at ten per cent level of significance during 12th (-7.9 mm), 25th (22.3 mm) and 43rd (0.4 mm) week during Period-II over base Period-I. The deviation of average rainfall was -0.5 mm during 43rd week and was significant at five per cent level of significance during Period-III over base Period-II. The periodical deviation in average rainfall was statistically non-significant during Period-III over Period-I. During, Period-IV over base Period-III periodical deviation was significant at ten per cent level of significance during the week of 9th, 32nd and 50th by 8.9, 25.4 and 1.7 mm, respectively. The periodical deviation of average rainfall during Period-IV over base Period-II was -7.6 mm observed during 6th week which was significant at ten per cent level of significance. During Period-IV over base Period-I, periodical deviation was significant at ten per cent level of significance during week 30th which was found -18.2 mm.

4.1.1.3.2 Monthly

The change in monthly average rainfall over the Periods has been shown in Table 4.19. During Period-I the lowest average rainfall was observed during the month of November (8.4 mm) and highest average rainfall was recorded during the month of July which was 147.2 mm. It was analysed that from Period-II to Period-V, lowest rainfall was recorded during November and December month and highest rainfall was analysed during the month of July and August. The highest rainfall of 146.0, 101.6, 142.1 and 126.8 mm was observed during Period-II, Period-III, Period-IV and overall Period-V, respectively, whereas, lowest rainfall of 2.8 mm (Period-II), 2.1 mm (Period-III), 1.9 mm (Period-IV) and 4.4 mm (Period-V) was observed during the month of November. The average rainfall on monthly basis during different periods of time is depicted in Fig 4.6. The highest rainfall was recorded during the months of July which was (147.2 mm). Analysis of coefficient of variation (Table 23) on monthly basis depicted that during Period-I, highest coefficient of variation of 405.1 per cent was during October and lowest of 208.5 per cent was during November month. It was observed that highest and lowest CV of 385.3 and 138.4 per cent was during the month of October and November, respectively for Period-II. During Period-III, highest coefficient of variation of 380.1 per cent was during June, while 142.8 per cent was during December, which was lowest. Analysis of Period-IV indicated highest coefficient of variation of 472.2 per cent (January) and lowest coefficient of variation of 220.5 per cent (December). During the overall Period-V, it was observed that during the month of October, coefficient of variation was highest (444.4 per cent) whereas, least coefficient of variation of 270.9 was observed during the month of August. Periodical deviation of average rainfall of Bathinda was analysed and represented as Table 4.20. The average deviation of rainfall during Period-

II over base Period-I depicted mean difference of -25.2 mm observed during March which was significant at five per cent level of significance. The Periodical deviation in average rainfall was statically non-significant during the Period-III over base Period-II. The deviation of average rainfall during Period-III over base Period-I depicted mean difference of -20.1 mm during March, which was significant at ten per cent level. The Periodical deviation in average rainfall was statically non-significant during the Period-IV over base Period-III. During Period-IV over base Period-II, periodical deviation was significant at ten per cent level during March and October (21.3 and -19.6 mm). The average deviation of -12.2 mm rainfall during Period-IV over base Period-I observed during December which was significant at ten per cent level of significance.

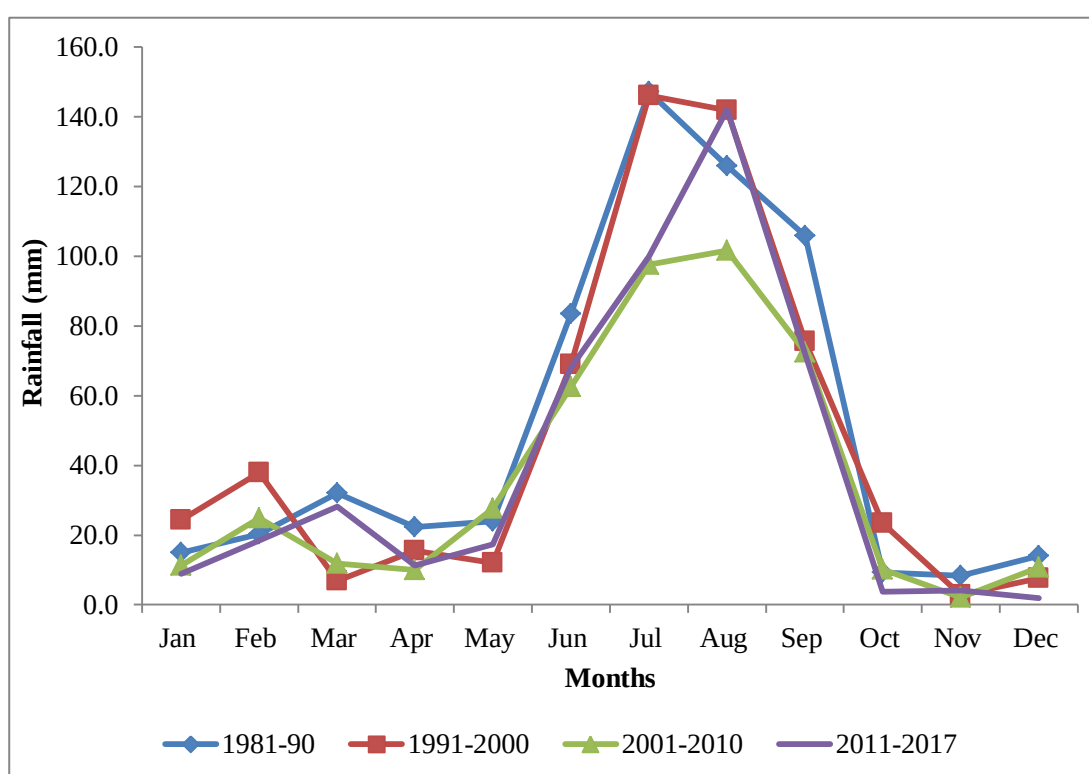


Fig. 4.6: Average monthly rainfall at Bathinda (1981-2017) during different periods

Table 4.19: Periodic average and coefficient of variations (%) of monthly rainfall at Bathinda (1981-2017)

Months	Rainfall (mm)					Variation in rainfall (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
January	15.0	24.3	11.3	8.9	15.3	394.4	358.1	296.3	472.2	392.6
February	20.3	37.9	24.9	18.4	25.9	386.5	322.2	340.4	252.8	346.3
March	32.0	6.8	11.9	28.1	19.1	385.8	386.1	293.3	180.0	340.8
April	22.4	15.5	10.0	11.2	15.0	358.0	229.6	282.9	350.5	360.5
May	23.9	12.0	27.7	17.4	20.5	341.9	374.5	306.1	427.4	364.0
June	83.4	69.0	62.6	68.1	71.0	362.5	323.6	380.1	331.6	317.4
July	147.2	146.0	97.5	100.0	124.4	323.2	290.3	338.9	330.9	303.6
August	125.9	141.9	101.6	142.1	126.8	331.9	338.9	335.9	292.4	270.9
September	105.9	75.5	72.5	71.8	82.2	388.4	335.2	375.8	325.2	318.7
October	9.3	23.4	10.2	3.7	12.2	405.1	385.3	285.2	230.5	444.4
November	8.4	2.8	2.1	4.2	4.4	208.5	138.4	161.6	272.7	433.7
December	14.0	7.5	10.8	1.9	9.0	371.0	268.4	142.8	220.5	370.4

Table 4.20: Periodical deviation in average monthly rainfall at Bathinda (1981-2017)

Months	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value
January	9.3	0.348	0.964 ^{NS}	-13.0	0.161	1.460 ^{NS}	-3.7	0.636	0.481 ^{NS}	-2.4	0.700	0.392 ^{NS}	-15.4	0.121	1.645 ^{NS}	-6.1	0.436	0.800 ^{NS}
February	17.6	0.155	1.485 ^{NS}	-13.0	0.387	0.886 ^{NS}	4.6	0.681	0.417 ^{NS}	-6.6	0.619	0.507 ^{NS}	-19.6	0.182	1.400 ^{NS}	-2.0	0.801	0.257 ^{NS}
March	-25.2	0.024	2.466**	5.0	0.438	0.794 ^{NS}	-20.1	0.099	1.740*	16.2	0.252	1.192 ^{NS}	21.3	0.095	1.782*	-3.9	0.820	0.232 ^{NS}
April	-6.8	0.583	0.558 ^{NS}	-5.5	0.500	0.688 ^{NS}	-12.4	0.299	1.069 ^{NS}	1.2	0.865	0.173 ^{NS}	-4.3	0.627	0.496 ^{NS}	-11.1	0.415	0.839 ^{NS}
May	-11.9	0.349	0.962 ^{NS}	15.7	0.162	1.457 ^{NS}	3.8	0.812	0.242 ^{NS}	-10.3	0.463	0.753 ^{NS}	5.4	0.466	0.748 ^{NS}	-6.5	0.681	0.420 ^{NS}
June	-14.4	0.744	0.332 ^{NS}	-6.4	0.741	0.336 ^{NS}	-20.8	0.636	0.481 ^{NS}	5.5	0.855	0.186 ^{NS}	-0.9	0.976	0.031 ^{NS}	-15.3	0.786	0.276 ^{NS}
July	-1.2	0.980	0.025 ^{NS}	-48.5	0.120	1.632 ^{NS}	-49.7	0.302	1.064 ^{NS}	2.4	0.935	0.083 ^{NS}	-46.1	0.151	1.513 ^{NS}	-47.3	0.388	0.890 ^{NS}
August	16.1	0.759	0.312 ^{NS}	-40.3	0.435	0.799 ^{NS}	-24.3	0.582	0.561 ^{NS}	40.5	0.425	0.821 ^{NS}	0.2	0.998	0.003 ^{NS}	16.2	0.754	0.319 ^{NS}
September	-30.4	0.616	0.510 ^{NS}	-3.0	0.912	0.112 ^{NS}	-33.4	0.572	0.575 ^{NS}	-0.7	0.984	0.020 ^{NS}	-3.7	0.923	0.098 ^{NS}	-34.1	0.645	0.470 ^{NS}
October	14.1	0.142	1.536 ^{NS}	-13.1	0.164	1.451 ^{NS}	1.0	0.867	0.169 ^{NS}	-6.5	0.215	1.295 ^{NS}	-19.6	0.068	1.967*	-5.5	0.321	1.025 ^{NS}
November	-5.6	0.282	1.109 ^{NS}	-0.7	0.753	0.319 ^{NS}	-6.3	0.212	1.293 ^{NS}	2.0	0.398	0.870 ^{NS}	1.3	0.641	0.476 ^{NS}	-4.2	0.486	0.714 ^{NS}
December	-6.5	0.277	1.120 ^{NS}	3.3	0.591	0.547 ^{NS}	-3.2	0.668	0.436 ^{NS}	-8.9	0.189	1.375 ^{NS}	-5.7	0.108	1.712 ^{NS}	-12.2	0.072	1.935*

** and * indicates 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.1.3.3 Seasonal

The change of average seasonal rainfall for *kharif* and *rabi* season during the period of 37 years (1981-2017) was carried out to comprehend the change in average rainfall at Bathinda district of Punjab (Table 4.21). The average rainfall was recorded as 488.4, 456.5, 368.5, 400.1 and 430.4 mm during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively during *kharif* season. During *rabi* season the average rainfall of 116.6, 110.3, 73.2, 74.8 and 95.1 mm was observed during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Coefficient of variation during *kharif* season was 459.1, 406.5, 391.3, 398.7 and 411.6 per cent during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively, whereas, during *rabi* season was 552.1, 568.1, 583.2, 609.8 and 552.2 per cent during Period-I, II, III, IV and overall Period-V, respectively. Periodical deviation in average seasonal rainfall at Bathinda was analysed and represented as Table 4.22. The periodical deviation of average rainfall was statistically non-significant during *kharif* and *rabi* season.

4.1.1.3.4 Meteorological seasons during the year

The change in seasons average rainfall at Bathinda district of Punjab was studied the Period of 37 years (1981-2017) and presented in Table 4.23. It was observed that highest average rainfall during monsoon season was recorded as 462.4, 433.6, 333.4, 382.1 and 404.4 mm and lowest average rainfall during post-monsoon season was recorded as 17.6, 26.9, 13.5, 6.9 and 17.1 mm during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Coefficient of variation was highest during winter season and was 554.6, 478.5, 514.4, 531.4 and 475.5 per cent and lowest CV was during monsoon season and was 416.5, 360.6, 356.1, 350.1 and 365.0 per cent during Period-I, Period-II, Period-III, Period-IV and Period-V, respectively. Periodical deviation of season wise rainfall of Bathinda was analysed and represented as Table 4.24. The deviation in average seasons rainfall during summer season was observed as -45.7 mm during Period-II over base Period-I was significant at ten per cent level of significance. During winter season deviation in rainfall was 25.9 mm during Period-II over base Period-I which was significant at ten per cent level of significant. The periodical deviation in average rainfall was statistically non-significant during the post-monsoon season. The highest deviation in average seasons rainfall during monsoon season was observed as - 129.0 mm during Period-III over base Period-I, which was statistically non-significant.

Table 4.21: Periodic average and coefficient of variations (%) of seasonal rainfall at Bathinda (1981-2017)

Seasonal	Rainfall (mm)					Variation in rainfall (Coefficient of Variation %)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
<i>Rabi</i>	116.6	110.3	73.2	74.8	95.1	552.1	568.1	583.2	609.8	552.2
<i>Kharif</i>	488.4	456.5	368.5	400.1	430.4	459.1	406.5	391.3	398.7	411.6

Table 4.22: Periodical deviation in average seasonal rainfall at Bathinda (1981-2017)

Seasonal	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean Difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
<i>Rabi</i>	-6.3	0.788	0.273 ^{NS}	-37.1	0.149	1.508 ^{NS}	-43.4	0.138	1.553 ^{NS}	1.6	0.604	0.059 ^{NS}	-35.5	0.101	1.749 ^{NS}	-41.8	0.127	1.616 ^{NS}
<i>Kharif</i>	-32.0	0.745	0.331 ^{NS}	-88.0	0.223	1.263 ^{NS}	-120.0	0.177	1.405 ^{NS}	31.7	0.954	0.529 ^{NS}	-56.3	0.498	0.695 ^{NS}	-88.3	0.394	0.878 ^{NS}

NS: Non-significant, P-Probability, t-Test.

Table 4.23: Periodic average and coefficient of variations (%) of rainfall during different meteorological seasons at Bathinda (1981-2017)

Seasons	Rainfall(mm)					Variation in rainfall (Coefficient of Variation%)				
	Period I	Period II	Period III	Period IV	Period V	Period I	Period II	Period III	Period IV	Period V
	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)	(1981-90)	(1991-2000)	(2001-2010)	(2011-2017)	(1981-2017)
Summer	78.8	33.1	49.1	56.8	54.3	481.7	447.4	584.4	574.6	454.7
Monsoon	462.4	433.6	333.4	382.1	404.4	416.5	360.6	356.1	350.1	365.0
Post-monsoon	17.6	26.9	13.5	6.9	17.1	616.8	501.5	425.3	364.7	558.1
Winter	46.6	72.5	45.5	32.9	50.1	554.6	478.5	514.4	531.4	475.5

Table 4.24: Periodical deviation in average rainfall during different meteorological seasons at Bathinda (1981-2017)

Seasons	1991-2000 over 1981-1990			2001-10 over 1991-2000			2001-10 over 1981-90			2011-17 over 2001-10			2011-17 over 1991-2000			2011-17 over 1981-90		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
Summer	-45.7	0.081	1.846*	16.0	0.349	0.962 ^{NS}	-29.7	0.284	1.105 ^{NS}	7.7	0.735	0.345 ^{NS}	23.7	0.216	1.292 ^{NS}	-22.0	0.494	0.701 ^{NS}
Monsoon	-28.7	0.775	0.290 ^{NS}	-100.2	0.178	1.403 ^{NS}	-129.0	0.164	1.452 ^{NS}	48.7	0.447	0.781 ^{NS}	-51.5	0.537	0.632 ^{NS}	-80.3	0.450	0.776 ^{NS}
Post-monsoon	9.3	0.396	0.869 ^{NS}	-13.3	0.215	1.284 ^{NS}	-4.1	0.572	0.576 ^{NS}	-6.7	0.367	0.930 ^{NS}	-20.0	0.115	1.674 ^{NS}	-10.7	0.167	1.453 ^{NS}
Winter	25.9	0.089	1.798*	-27.0	0.143	1.532 ^{NS}	-1.1	0.947	0.067 ^{NS}	-12.6	0.402	0.862 ^{NS}	-39.6	0.011	2.912**	-13.7	0.223	1.272 ^{NS}

** and * indicates 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.2.1 Faridkot

4.1.2.1.1 Maximum temperature

4.1.2.1.1.1 Weekly

The change in weekly average maximum temperature at Faridkot district in Punjab was analyzed for the Period of 17 years (2001-2017) to know the change in maximum temperature of Faridkot district and represented as Fig 7. The seventeen year weather data has been grouped into four periods (Period-I, Period-II, Period-III, and overall Period-IV) and summarized as in Table 4.25. The SMW data showed that the lowest average maximum temperature recorded was 15.3, 16.3, 15.4 and 16.2°C during Period-I, Period-II, Period-III and overall Period-IV, respectively. The highest average maximum temperature was 41.2°C (Period-I), 40.3°C (Period-II), 40.8°C (Period-III) and 40.5°C (Period-IV). The coefficient of variation (CV) of weekly average maximum temperature (Table 4.25) depicted that during Period-I minimum CV of 3.3 per cent was observed during 36th SMW, while maximum coefficient of variation of 19.6 per cent was observed during 1st SMW. During period-II, maximum and minimum coefficient of variation of 15.0 and 4.0 per cent was observed during 3rd and 34th SMW, respectively. During Period-III, maximum CV of 16.2 per cent was during 3rd SMW and minimum of 2.4 per cent was during 40th SMW. Analysis of period-IV indicated maximum CV of 15.1 per cent during 3rd SMW, while minimum CV (3.9 per cent) was during 36th SMW. Periodical deviation of average maximum temperature at Faridkot was analysed and represented as Table 4.26.

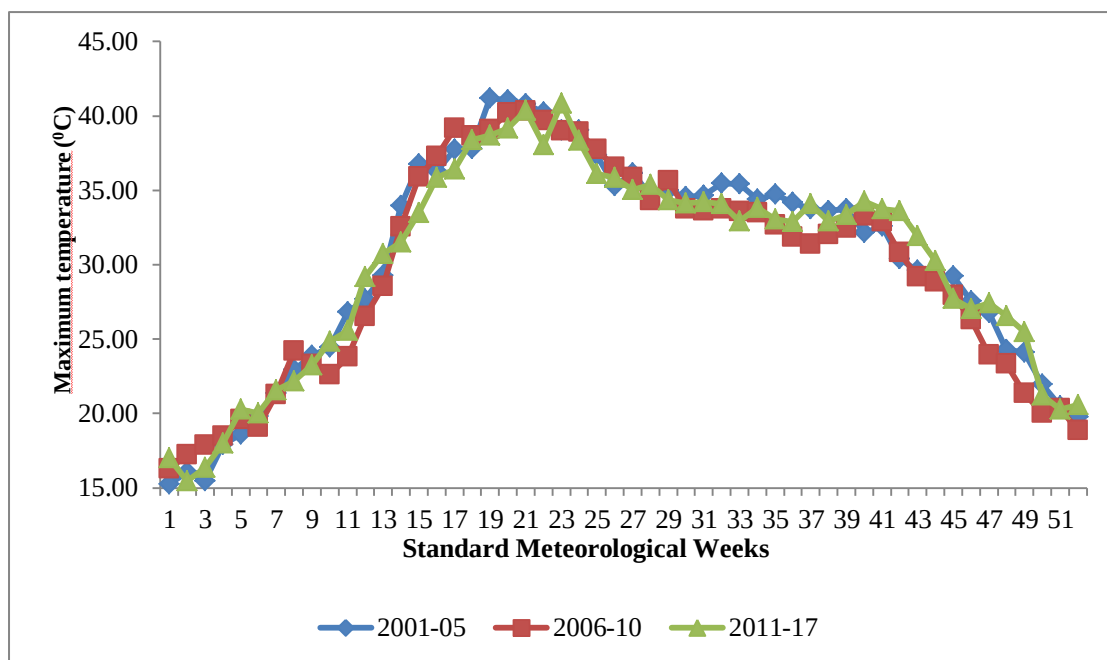


Fig. 4.7: Average weekly maximum temperature at Faridkot (2001-2017) during different periods

Table 4.25: Periodic average and coefficient of variations (%) of weekly maximum temperature at Faridkot (2001-2017)

Weeks	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-2017	2001-17	2001-05	2006-10	2011-2017	2001-17
1	15.3	16.3	17.0	16.3	19.6	13.2	13.5	15.0
2	16.0	17.2	15.4	16.2	12.2	13.1	13.1	12.7
3	15.4	17.9	16.4	16.5	15.5	15.0	16.2	15.1
4	17.9	18.5	18.0	18.1	7.2	13.8	11.5	10.6
5	18.6	19.6	20.3	19.6	7.9	11.5	5.5	7.9
6	19.8	19.1	20.0	19.7	7.8	12.2	6.6	8.5
7	21.3	21.3	21.6	21.4	7.4	9.5	6.8	7.7
8	22.9	24.2	22.2	23.0	9.1	5.5	6.3	6.8
9	23.9	23.3	23.2	23.4	8.8	14.9	5.5	9.0
10	24.5	22.6	24.8	24.0	10.4	10.5	8.9	9.7
11	26.8	23.8	25.5	25.4	8.4	7.5	8.6	8.0
12	27.7	26.5	29.2	27.9	10.5	8.5	7.8	8.7
13	29.2	28.5	30.7	29.6	8.0	14.3	6.6	8.6
14	34.0	32.5	31.5	32.6	4.9	7.9	5.8	6.1
15	36.7	35.9	33.5	35.2	4.1	6.0	7.3	5.9
16	36.3	37.3	35.8	36.4	6.5	6.8	5.6	6.1
17	37.8	39.1	36.4	37.6	5.8	4.6	5.5	5.3

Weeks	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-2017	2001-17	2001-05	2006-10	2011-2017	2001-17
18	37.8	38.7	38.4	38.3	7.0	8.0	6.3	7.0
19	41.2	39.1	38.7	39.6	4.5	4.8	6.8	5.4
20	41.1	40.2	39.2	40.0	5.8	6.9	6.4	6.2
21	40.8	40.3	40.4	40.5	5.3	5.9	5.1	5.4
22	40.2	39.7	38.1	39.2	5.9	5.4	7.7	6.4
23	39.0	39.0	40.8	39.7	7.2	5.6	6.8	6.4
24	39.0	38.9	38.4	38.7	4.6	6.6	7.3	6.2
25	37.3	37.8	36.1	37.0	7.0	5.9	9.5	7.6
26	35.3	36.5	35.9	35.9	6.2	7.0	7.7	7.0
27	36.2	35.8	35.0	35.6	4.4	6.3	7.9	6.3
28	34.7	34.3	35.4	34.9	5.0	8.2	5.7	6.2
29	35.0	35.6	34.4	34.9	4.4	4.5	5.1	4.7
30	34.6	33.7	34.1	34.1	3.5	6.5	5.0	5.0
31	34.7	33.6	34.2	34.2	5.6	4.6	5.1	5.1
32	35.5	33.7	34.1	34.4	3.8	5.3	4.4	4.5
33	35.4	33.6	32.9	33.9	3.8	4.4	5.1	4.5
34	34.4	33.5	33.8	33.9	4.0	4.0	6.0	4.8
35	34.7	32.7	33.1	33.4	3.4	5.0	6.0	4.9

Weeks	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-2017	2001-17	2001-05	2006-10	2011-2017	2001-17
36	34.2	31.9	32.9	33.0	3.3	5.3	3.6	3.9
37	33.8	31.4	34.1	33.2	4.9	5.6	3.8	4.5
38	33.6	32.0	32.9	32.9	4.3	6.4	4.3	4.8
39	33.7	32.5	33.4	33.2	4.0	8.8	3.5	5.0
40	32.1	33.3	34.3	33.3	5.2	5.5	2.4	4.1
41	32.6	32.9	33.7	33.1	7.4	5.6	3.8	5.3
42	30.4	30.8	33.6	31.8	5.1	5.7	3.0	4.3
43	29.6	29.2	31.9	30.4	8.0	6.7	4.0	5.8
44	29.1	28.8	30.2	29.5	6.2	5.7	4.8	5.3
45	29.2	27.9	27.7	28.2	4.3	7.7	6.9	6.2
46	27.5	26.3	27.0	27.0	6.4	7.7	3.1	5.3
47	26.8	23.9	27.4	26.2	6.8	8.2	3.6	5.7
48	24.3	23.3	26.6	24.9	5.8	9.2	4.3	6.0
49	24.1	21.4	25.5	23.8	5.1	12.1	6.7	7.5
50	22.0	20.0	21.2	21.1	7.4	11.7	10.8	9.6
51	20.5	20.3	20.3	20.4	14.1	7.2	6.1	8.6
52	19.8	18.9	20.6	19.8	6.6	10.0	6.8	7.4

Table 4.26: Periodical deviation in average weekly maximum temperature at Faridkot (2001-2017)

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
1	1.0	0.429	0.809 ^{NS}	0.7	0.698	0.394 ^{NS}	1.7	0.375	0.909 ^{NS}
2	1.2	0.457	0.760 ^{NS}	-1.8	0.365	0.930 ^{NS}	-0.6	0.741	0.335 ^{NS}
3	2.4	0.078	1.871*	-1.5	0.229	1.245 ^{NS}	0.9	0.549	0.610 ^{NS}
4	0.6	0.477	0.726 ^{NS}	-0.5	0.682	0.417 ^{NS}	0.1	0.937	0.080 ^{NS}
5	1.0	0.298	1.073 ^{NS}	0.7	0.526	0.646 ^{NS}	1.7	0.074	1.894*
6	-0.7	0.619	0.506 ^{NS}	0.9	0.527	0.645 ^{NS}	0.2	0.826	0.223 ^{NS}
7	-0.1	0.937	0.080 ^{NS}	0.3	0.816	0.236 ^{NS}	0.2	0.859	0.180 ^{NS}
8	1.3	0.248	1.193 ^{NS}	-2.0	0.125	1.609 ^{NS}	-0.8	0.570	0.579 ^{NS}
9	-0.6	0.720	0.364 ^{NS}	-0.1	0.977	0.029 ^{NS}	-0.7	0.662	0.444 ^{NS}
10	-1.9	0.495	0.696 ^{NS}	2.3	0.388	0.884 ^{NS}	0.4	0.789	0.272 ^{NS}
11	-3.0	0.318	1.026 ^{NS}	1.7	0.511	0.671 ^{NS}	-1.3	0.283	1.107 ^{NS}
12	-1.2	0.692	0.403 ^{NS}	2.7	0.319	1.024 ^{NS}	1.5	0.212	1.293 ^{NS}
13	-0.7	0.800	0.256 ^{NS}	2.2	0.409	0.846 ^{NS}	1.5	0.257	1.170 ^{NS}
14	-1.4	0.283	1.107 ^{NS}	-1.0	0.534	0.635 ^{NS}	-2.4	0.112	1.670 ^{NS}
15	-0.9	0.454	0.765 ^{NS}	-2.4	0.051	2.089 ^{NS}	-3.3	0.001	4.079***
16	1.0	0.626	0.496 ^{NS}	-1.4	0.492	0.702 ^{NS}	-0.5	0.848	0.195 ^{NS}
17	1.4	0.124	1.614 ^{NS}	-2.8	0.060	2.011 ^{NS}	-1.4	0.325	1.013 ^{NS}

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
18	0.9	0.538	0.628 ^{NS}	-0.3	0.798	0.260 ^{NS}	0.6	0.684	0.414 ^{NS}
19	-2.1	0.115	1.656 ^{NS}	-0.4	0.769	0.298 ^{NS}	-2.5	0.079	1.860*
20	-0.9	0.536	0.631 ^{NS}	-1.0	0.536	0.631 ^{NS}	-1.9	0.284	1.105 ^{NS}
21	-0.5	0.633	0.485 ^{NS}	0.0	0.983	0.021 ^{NS}	-0.4	0.789	0.271 ^{NS}
22	-0.6	0.397	0.868 ^{NS}	-1.6	0.255	1.176 ^{NS}	-2.2	0.151	1.498 ^{NS}
23	-0.1	0.960	0.050 ^{NS}	1.9	0.219	1.274 ^{NS}	1.8	0.186	1.374 ^{NS}
24	-0.1	0.891	0.139 ^{NS}	-0.6	0.642	0.473 ^{NS}	-0.7	0.528	0.643 ^{NS}
25	0.4	0.803	0.254 ^{NS}	-1.7	0.209	1.304 ^{NS}	-1.2	0.326	1.009 ^{NS}
26	1.2	0.284	1.103 ^{NS}	-0.6	0.553	0.605 ^{NS}	0.6	0.496	0.695 ^{NS}
27	-0.3	0.762	0.308 ^{NS}	-0.8	0.428	0.811 ^{NS}	-1.1	0.148	1.511 ^{NS}
28	-0.4	0.570	0.579 ^{NS}	1.1	0.262	1.158 ^{NS}	0.7	0.430	0.807 ^{NS}
29	0.6	0.510	0.673 ^{NS}	-1.3	0.073	1.905*	-0.6	0.347	0.967 ^{NS}
30	-0.8	0.303	1.060 ^{NS}	0.4	0.620	0.504 ^{NS}	-0.5	0.375	0.910 ^{NS}
31	-1.1	0.333	0.994 ^{NS}	0.6	0.525	0.649 ^{NS}	-0.5	0.379	0.903 ^{NS}
32	-1.7	0.319	1.026 ^{NS}	0.4	0.803	0.254 ^{NS}	-1.4	0.097	1.748 ^{NS}
33	-1.9	0.210	1.301 ^{NS}	-0.7	0.683	0.415 ^{NS}	-2.5	0.067	1.952*
34	-0.9	0.355	0.948 ^{NS}	0.4	0.646	0.467 ^{NS}	-0.5	0.367	0.925 ^{NS}
35	-2.1	0.054	2.059 ^{NS}	0.4	0.689	0.407 ^{NS}	-1.7	0.044	2.161 ^{NS}
36	-2.3	0.095	1.761 ^{NS}	1.0	0.404	0.855 ^{NS}	-1.3	0.163	1.453 ^{NS}

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
37	-2.4	0.095	1.762 ^{NS}	2.7	0.037	2.257**	0.3	0.728	0.353 ^{NS}
38	-1.6	0.308	1.049 ^{NS}	0.9	0.526	0.647 ^{NS}	-0.7	0.412	0.839 ^{NS}
39	-1.3	0.357	0.946 ^{NS}	0.9	0.463	0.750 ^{NS}	-0.4	0.500	0.688 ^{NS}
40	1.1	0.354	0.952 ^{NS}	1.0	0.240	1.216 ^{NS}	2.1	0.074	1.899*
41	0.3	0.767	0.301 ^{NS}	0.8	0.395	0.871 ^{NS}	1.2	0.264	1.153 ^{NS}
42	0.4	0.776	0.288 ^{NS}	2.8	0.037	2.256**	3.2	0.020	2.560**
43	-0.4	0.767	0.301 ^{NS}	2.8	0.005	3.168 ^{NS}	2.3	0.087	1.813*
44	-0.2	0.863	0.175 ^{NS}	1.4	0.315	1.033 ^{NS}	1.2	0.358	0.944 ^{NS}
45	-1.3	0.281	1.112 ^{NS}	-0.2	0.883	0.149 ^{NS}	-1.5	0.211	1.296 ^{NS}
46	-1.2	0.217	1.279 ^{NS}	0.7	0.614	0.513 ^{NS}	-0.5	0.704	0.386 ^{NS}
47	-2.8	0.082	1.845 ^{NS}	3.5	0.021	2.530**	0.6	0.468	0.742 ^{NS}
48	-0.9	0.380	0.899 ^{NS}	3.2	0.011	2.821**	2.3	0.013	2.741**
49	-2.7	0.017	2.629**	4.1	0.001	4.206***	1.4	0.014	2.733**
50	-2.0	0.071	1.918*	1.2	0.354	0.951 ^{NS}	-0.8	0.508	0.675 ^{NS}
51	-0.2	0.843	0.201 ^{NS}	-0.1	0.974	0.033 ^{NS}	-0.2	0.914	0.110 ^{NS}
52	-0.9	0.079	1.861*	1.7	0.350	0.959 ^{NS}	0.8	0.654	0.456 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

The deviation of average maximum temperature during Period-II over base Period-I depicted maximum deviation of -2.7°C during 49th week which was significant at five per cent level and mean difference of 2.4, -2.0 and -0.9°C was significant at ten per cent level during 3rd, 50th and 52nd week. During Period-III over Period-II, periodical deviation was significant at one per cent level during 49th week (4.1°C) and at five per cent level of significance in case of difference of 2.7, 2.8, 3.5 and 3.2°C during the 37th, 42nd, 47th and 48th week and -1.3°C at ten per cent level of significance during 29th SMW. The deviation of average maximum temperature during Period-III over base Period-I depicted maximum deviation of -3.3°C during 15th week which was significant at one per cent level of significance and mean difference of 3.2, 2.3 and 1.4°C which was significant at five per cent level of significance during 42nd, 48th and 49th week, respectively. The mean difference of 1.7, -2.5 , -2.5 , 2.1 and 2.3°C at ten per cent level of significance during 5th, 19th, 33rd, 40th and 43rd week, respectively

4.1.2.1.2 Monthly

Monthly average maximum temperature data for 17 years (2001-2017) was analyzed and the same has been set out as Table 4.27. During Period-I the lowest average maximum temperature was observed during the month of January (16.4°C) and highest average maximum temperature was recorded during the month of May which was 40.2°C (Fig 4.8). It was analysed that from Period-II to Period-IV, lowest maximum temperature was recorded during January month and highest maximum temperature was analysed during the month of May. The highest maximum temperature of 39.5, 39.1 and 39.6°C was observed during Period-II, Period-III and overall Period-IV respectively, whereas, lowest maximum temperature of 17.8°C (Period-II), 17.0°C (Period-III) and 17.1°C (Period-IV) was observed during the month of January. Analysis of coefficient of variation (Table 4.27) on monthly basis depicted that during Period-I, maximum coefficient of variation of 17.4 per cent was in January and minimum of 4.4 per cent was during August month. It was observed that maximum and minimum CV of 16.3 and 5.5 per cent was during the month of February and August, respectively for Period-II. During Period-III, maximum coefficient of variation of 20.5 per cent was during February, while 5.2 per cent was during September, which was minimum. During the overall Period-IV, it was observed that during the month of January, coefficient of variation was maximum (17.7%) whereas, least coefficient of variation of 5.5 was observed during the month of August. Periodical deviation of average maximum temperature of Faridkot was analysed and represented in Table 4.28. The average deviation of maximum temperature during Period-II over base Period-I depicted maximum deviation of -1.3°C observed during December which was significant at five per cent level of significance. During Period-III over base Period-II, periodical deviation was non-significant. The deviation of average maximum temperature during Period-III over base Period-I depicted maximum deviation of -1.4°C was during August which was significant at five per cent level of significance and mean difference of 0.5°C was observed during March which was significant at one per cent level of significance.

Table 4.27: Periodic average and coefficient of variations (%) of monthly maximum temperature at Faridkot (2001-2017)

Months	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-2017	2001-17	2001-05	2006-10	2011-2017	2001-17
January	16.4	17.8	17.0	17.1	17.4	15.7	20.5	17.7
February	21.4	21.5	21.4	21.4	12.2	16.3	9.3	12.2
March	26.7	25.0	27.2	26.4	12.2	16.1	13.9	13.8
April	36.3	36.5	34.5	35.7	8.3	10.0	10.1	9.5
May	40.2	39.5	39.1	39.6	7.4	7.5	8.0	7.6
June	38.0	38.2	37.7	37.9	8.1	7.9	10.2	8.9
July	35.0	34.8	34.7	34.8	5.2	7.4	6.6	6.4
August	35.0	33.4	33.6	34.0	4.4	5.4	6.5	5.5
September	33.7	32.0	33.3	33.0	5.0	7.4	5.2	5.7
October	30.9	31.1	33.1	31.8	8.2	8.7	5.5	7.1
November	27.3	25.8	27.5	26.9	8.9	11.5	7.0	8.8
December	21.6	20.2	21.9	21.3	12.5	12.5	15.2	13.3

Table 4.28: Periodical deviation in average monthly maximum temperature at Faridkot (2001-2017)

Months	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
January	1.4	0.113	1.777 ^{NS}	-0.8	0.391	0.896 ^{NS}	0.6	0.497	0.705 ^{NS}
February	0.1	0.891	0.142 ^{NS}	-0.1	0.919	0.104 ^{NS}	0.0	0.998	0.002 ^{NS}
March	-1.7	0.539	0.641 ^{NS}	2.1	0.360	0.959 ^{NS}	0.5	0.557	0.607 ^{***}
April	0.2	0.828	0.225 ^{NS}	-1.9	0.072	2.013 ^{NS}	-1.8	0.083	1.924 ^{NS}
May	-0.7	0.196	1.412 ^{NS}	-0.4	0.686	0.416 ^{NS}	-1.1	0.270	1.167 ^{NS}
June	0.2	0.808	0.252 ^{NS}	-0.5	0.594	0.550 ^{NS}	-0.2	0.771	0.299 ^{NS}
July	-0.2	0.706	0.391 ^{NS}	-0.1	0.817	0.238 ^{NS}	-0.3	0.386	0.906 ^{NS}
August	-1.6	0.182	1.462 ^{NS}	0.2	0.822	0.231 ^{NS}	-1.4	0.024	2.648 ^{**}
September	-1.8	0.163	1.536 ^{NS}	1.3	0.229	1.281 ^{NS}	-0.5	0.386	0.906 ^{NS}
October	0.3	0.837	0.212 ^{NS}	1.9	0.041	2.342 ^{NS}	2.2	0.053	2.194 ^{NS}
November	-1.5	0.143	1.623 ^{NS}	1.6	0.151	1.553 ^{NS}	0.1	0.867	0.172 ^{NS}
December	-1.3	0.026	2.730 ^{**}	1.7	0.163	1.505 ^{NS}	0.4	0.732	0.353 ^{NS}

^{**}, ^{***} indicates 1 and 5 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

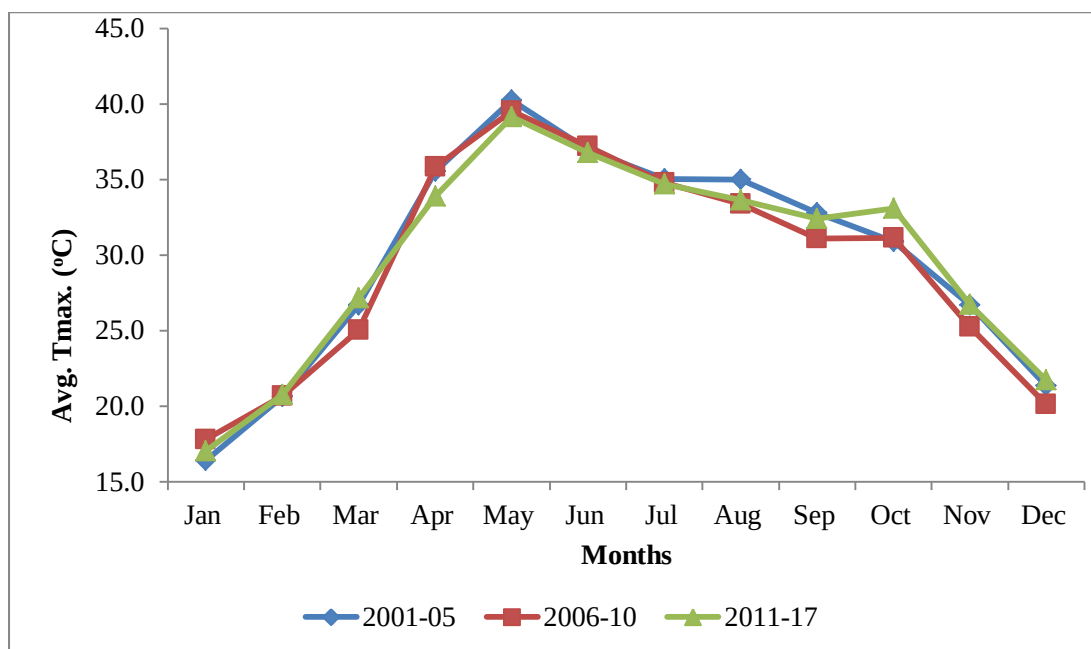


Fig. 4.8: Average monthly maximum temperature at Faridkot (2001-2017) during different periods

4.1.2.1.3 Seasonal

The change in seasonal average maximum temperature for *kharif* and *rabi* season during the period of 17 years (2001-2017) was carried out to comprehend the change in average maximum temperature in Faridkot district of Punjab (Table 4.29). The average maximum temperature was recorded as 36.1, 35.4, 35.5 and 35.6°C during Period-I, Period-II, Period-III and overall Period-IV, respectively during *kharif* season. During *rabi* season the average maximum temperature of 25.4, 24.9, 25.5 and 25.3°C was during Period-I, Period-II, Period-III and overall Period-IV, respectively. The coefficient of variation (Table 4.29) during *kharif* season was 9.8 per cent (Period-I), 11.1 per cent (Period-II), 10.2 per cent (Period-III) and 10.3 per cent (overall Period-IV). During *rabi* season coefficient of variation was 26.8, 28.3, 26.1 and 26.9 per cent during Period-I, Period-II, Period-III and overall Period-IV, respectively. Periodical deviation in average seasonal maximum temperature at Faridkot was analysed and represented as Table 4.30. The periodical deviation over the periods came out to be statistically non-significant during *kharif* and *rabi* season.

4.1.2.1.4 Meteorological seasons during the year

The change in seasons average maximum temperature at Faridkot was carried out for the Period of 17 years (2001-2017) and represented in Table 4.31. It was observed that highest average maximum temperature during monsoon season was recorded as 35.4, 34.6, 34.8 and 34.9°C and lowest average maximum temperature during winter season was recorded as 19.8, 19.8, 20.0 and 19.9°C during Period-I, Period-II, Period-III and overall Period-IV, respectively.

Table 4.29: Periodic average and coefficient of variations (%) of seasonal maximum temperature at Faridkot (2001-2017)

Seasonal	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-17	2001-17	2001-05	2006-10	2011-17	2001-17
<i>Kharif</i>	36.1	35.4	35.5	35.6	9.8	11.1	10.2	10.3
<i>Rabi</i>	25.4	24.9	25.5	25.3	26.8	28.3	26.1	26.9

Table 4.30: Periodical deviation in average maximum seasonal temperature at Faridkot (2001-2017)

Seasonal	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
<i>Kharif</i>	-0.7	0.262	1.206 ^{NS}	0.2	0.757	0.318 ^{NS}	-0.5	0.177	1.451 ^{NS}
<i>Rabi</i>	-0.4	0.597	0.551 ^{NS}	0.6	0.422	0.838 ^{NS}	0.2	0.717	0.373 ^{NS}

NS: Non-significant, P-Probability, t-Test.

Table 4.31: Periodic average and coefficient of variations (%) of maximum temperature during different meteorological seasons at Faridkot (2001-2017)

Seasons	Maximum temperature (°C)				Variation in maximum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
Summer	34.4	33.6	33.7	33.9	19.1	22.1	18.2	19.5
Monsoon	35.4	34.6	34.8	34.9	7.7	10.2	9.2	9.0
Post-monsoon	29.1	28.5	30.3	29.4	11.0	14.0	11.4	12.0
Winter	19.8	19.8	20.0	19.9	18.6	17.7	19.8	18.7

Table 4.32: Periodical deviation in average maximum temperature during different meteorological seasons at Faridkot (2001-2017)

Seasons	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
Summer	-0.8	0.478	0.744 ^{NS}	0.1	0.974	0.034 ^{NS}	-0.7	0.316	1.070 ^{NS}
Monsoon	-0.8	0.246	1.251 ^{NS}	0.2	0.732	0.354 ^{NS}	-0.6	0.128	1.695 ^{NS}
Post-monsoon	-0.6	0.560	0.609 ^{NS}	1.8	0.121	1.732 ^{NS}	1.2	0.485	0.733 ^{NS}
Winter	0.0	0.907	0.120 ^{NS}	0.2	0.814	0.244 ^{NS}	0.2	0.741	0.342 ^{NS}

NS: Non-significant, P-Probability, t-Test.

Coefficient of variation was highest during summer season and was recorded as 19.1, 22.1, 18.2 and 19.5 per cent and lowest CV was during monsoon season and was 7.7, 10.2, 9.2 and 9.0 per cent during Period-I, Period-II, Period-III and overall Period-IV, respectively. Periodical deviation of maximum temperature at Faridkot during different seasons were analysed and represented as Table 4.32. All the deviations of different seasons while comparing different periods were statistically non-significant.

4.1.2.2 Minimum temperature

4.1.2.2.1 Weekly

The change in weekly average minimum temperature at Faridkot district of Punjab was analysed for the Period of 17 years (2001-2017). The seventeen year minimum temperature data have been grouped into four periods (Period-I, Period-II, Period-III and overall Period-IV) and summarized as Table 4.33. During the Period-I the lowest average minimum temperature was observed during the 2nd week (6.9°C) and highest average minimum temperature was recorded during the 20th week which was 31.4°C (Fig 4.9). The highest minimum temperature of 30.1°C was recorded during 26th week of Period-II, while 5.8°C lowest temperature was observed during 2nd week. During Period-III the lowest average minimum temperature was observed during the 52nd week (5.3°C) and highest average minimum temperature was recorded during the 28th week which was 28.2°C. The highest minimum temperature of 29.0°C was recorded during 25th and 27th week of Period-IV, while 6.0°C lowest temperature was observed during 2nd week. The coefficient of variation (CV) of weekly average minimum temperature (Table 4.33) depicted that during Period-I minimum CV of 3.0 per cent observed during 35th SMW, while maximum coefficient of variation of 24.8 per cent was during 3rd SMW.

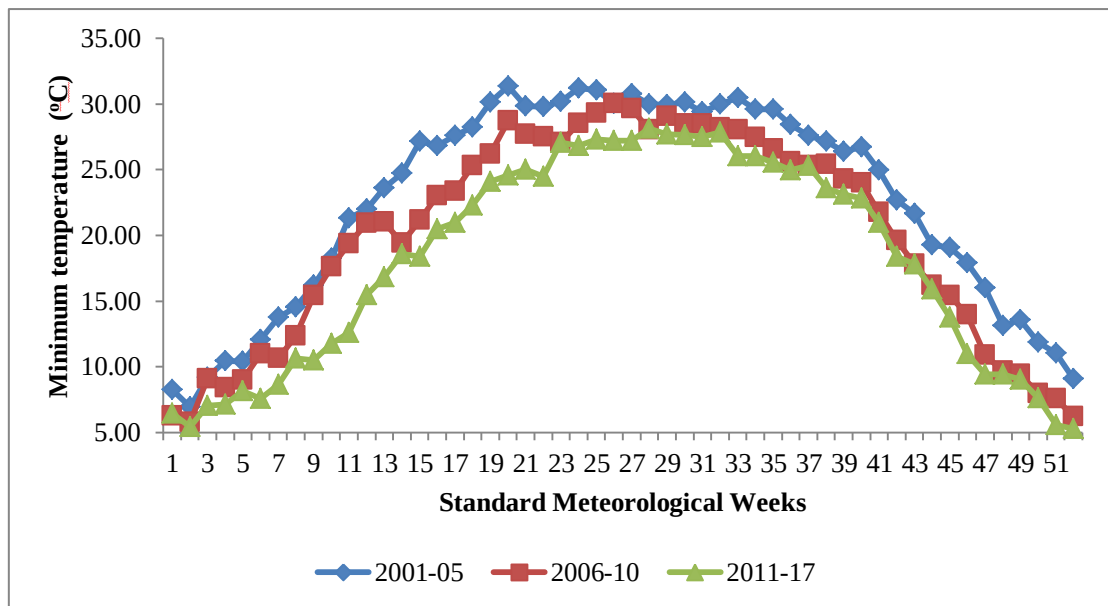


Fig. 4.9: Average weekly minimum temperature at Faridkot (2001-2017) during different periods

Table 4.33: Periodic average and coefficient of variations (%) of weekly minimum temperature at Faridkot (2001-2017)

Weeks	Minimum temperature (°C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
1	8.3	6.3	6.5	6.9	18.4	42.2	24.5	24.1
2	6.9	5.8	5.4	6.0	13.8	30.3	40.7	26.2
3	9.2	9.1	7.0	8.3	24.8	30.4	29.1	27.2
4	10.4	8.4	7.1	8.5	21.9	44.6	24.8	26.8
5	10.4	9.0	8.2	9.1	11.6	27.9	30.0	21.5
6	12.0	11.0	7.6	9.9	11.5	25.6	33.9	21.4
7	13.8	10.6	8.6	10.8	13.4	29.1	25.7	21.5
8	14.5	12.3	10.6	12.3	11.1	18.8	20.3	16.4
9	16.2	15.4	10.5	13.7	10.9	25.2	14.2	17.0
10	18.2	17.6	11.7	15.5	7.3	13.6	14.1	10.8
11	21.3	19.4	12.6	17.2	7.2	15.3	17.7	12.3
12	22.0	20.9	15.5	19.1	7.6	12.8	13.1	10.8
13	23.6	21.0	16.8	20.1	6.3	15.6	8.0	9.7
14	24.7	19.4	18.6	20.7	7.9	15.6	8.7	10.3
15	27.2	21.2	18.4	21.9	10.4	15.8	10.4	11.9
16	26.8	23.0	20.5	23.1	10.7	12.9	9.7	10.8
17	27.6	23.4	21.0	23.7	7.8	10.5	8.6	8.9

Weeks	Minimum temperature (°C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
18	28.2	25.3	22.3	25.0	8.8	8.3	9.3	8.7
19	30.1	26.2	24.1	26.5	6.4	8.2	7.4	7.3
20	31.4	28.7	24.6	27.9	7.8	10.7	6.7	8.3
21	29.8	27.7	25.0	27.3	7.7	8.7	8.0	8.2
22	29.8	27.5	24.5	27.0	8.3	8.5	8.8	8.5
23	30.2	27.1	27.1	28.0	8.8	6.4	6.3	7.1
24	31.2	28.5	26.8	28.7	4.6	5.9	8.7	6.5
25	31.0	29.3	27.3	29.0	6.4	7.3	10.1	8.0
26	30.1	30.1	27.2	28.9	5.5	7.0	8.1	6.9
27	30.8	29.7	27.2	29.0	5.2	5.8	7.4	6.2
28	30.0	28.0	28.2	28.7	4.8	7.6	4.9	5.7
29	30.0	29.1	27.7	28.8	4.1	4.6	4.9	4.5
30	30.1	28.5	27.7	28.7	3.3	4.4	3.7	3.8
31	29.4	28.5	27.5	28.4	4.5	3.7	2.9	3.6
32	30.0	28.2	27.8	28.6	7.6	5.9	4.5	5.8
33	30.5	28.0	26.0	28.0	4.1	4.4	6.6	5.1
34	29.6	27.5	26.0	27.5	4.5	3.4	5.9	4.7
35	29.6	26.6	25.6	27.1	3.0	5.4	5.4	4.6
36	28.4	25.6	24.9	26.2	4.7	5.2	4.2	4.6

Weeks	Minimum temperature (°C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
37	27.6	25.3	25.3	26.0	7.9	7.3	3.8	6.1
38	27.2	25.4	23.6	25.2	4.4	5.1	4.7	4.6
39	26.4	24.3	23.1	24.5	5.7	6.5	3.7	5.1
40	26.7	24.0	22.8	24.3	4.2	9.2	3.9	5.5
41	25.0	21.7	21.0	22.4	8.0	9.8	9.0	8.7
42	22.7	19.6	18.4	20.0	6.6	9.9	7.8	8.0
43	21.7	17.8	17.8	19.0	9.1	10.9	7.7	8.9
44	19.3	16.2	15.9	17.0	9.9	8.4	10.8	9.7
45	19.1	15.4	13.8	15.9	6.8	10.4	14.1	10.5
46	17.9	14.0	11.0	13.9	12.9	13.3	15.2	13.8
47	16.0	10.9	9.4	11.8	13.6	15.3	11.7	13.4
48	13.1	9.7	9.4	10.6	12.5	19.8	15.3	15.7
49	13.5	9.4	9.0	10.5	11.2	25.6	16.7	17.0
50	11.9	8.0	7.6	9.0	17.2	21.0	47.1	26.4
51	11.1	7.6	5.6	7.8	16.0	31.9	31.1	24.0
52	9.1	6.2	5.3	6.7	23.9	39.4	24.4	26.7

Table 4.34: Periodical deviation in average weekly minimum temperature at Faridkot (2001-2017)

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
1	-2.0	0.075	2.045 ^{NS}	0.2	0.878	0.158 ^{NS}	-1.8	0.141	1.597 ^{NS}
2	-1.2	0.230	1.299 ^{NS}	-0.3	0.776	0.292 ^{NS}	-1.5	0.106	1.779 ^{NS}
3	-0.1	0.952	0.062 ^{NS}	-2.0	0.048	2.256**	-2.1	0.043	2.311**
4	-2.0	0.157	1.561 ^{NS}	-1.3	0.277	1.151 ^{NS}	-3.3	0.000	5.217***
5	-1.4	0.228	1.304 ^{NS}	-0.8	0.434	0.816 ^{NS}	-2.2	0.002	4.124***
6	-1.1	0.320	1.061 ^{NS}	-3.4	0.018	2.830**	-4.5	0.001	4.640***
7	-3.1	0.075	2.043 ^{NS}	-2.0	0.218	1.315 ^{NS}	-5.1	0.000	5.585***
8	-2.2	0.065	2.141 ^{NS}	-1.7	0.188	1.413 ^{NS}	-3.9	0.003	3.809***
9	-0.8	0.568	0.595 ^{NS}	-4.9	0.001	4.370***	-5.7	0.000	9.668***
10	-0.6	0.828	0.225 ^{NS}	-5.9	0.031	2.517**	-6.5	0.000	6.692***
11	-1.9	0.505	0.698 ^{NS}	-6.8	0.019	2.784**	-8.7	0.000	9.546***
12	-1.1	0.634	0.494 ^{NS}	-5.4	0.016	2.892**	-6.5	0.000	9.144***
13	-2.6	0.043	2.407**	-4.2	0.003	3.846***	-6.7	0.000	9.897***
14	-5.3	0.000	7.648***	-0.8	0.447	0.791 ^{NS}	-6.1	0.000	6.359***
15	-6.0	0.000	6.758***	-2.8	0.025	2.623**	-8.8	0.000	10.214***
16	-3.8	0.053	2.273**	-2.6	0.095	1.842*	-6.4	0.002	4.324***
17	-4.2	0.009	3.453***	-2.4	0.038	2.395**	-6.7	0.000	7.597***
18	-2.9	0.011	3.294***	-3.0	0.007	3.403***	-6.0	0.000	6.360***

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
19	-3.9	0.005	3.901***	-2.1	0.037	2.397**	-6.0	0.000	7.074***
20	-2.6	0.055	2.246**	-4.1	0.002	4.197***	-6.8	0.000	7.906***
21	-2.2	0.046	2.356***	-2.7	0.069	2.038 ^{NS}	-4.8	0.002	4.264***
22	-2.3	0.083	1.981*	-3.0	0.057	2.150 ^{NS}	-5.3	0.002	4.043***
23	-3.1	0.003	4.259***	0.0	0.997	0.004 ^{NS}	-3.1	0.006	3.509***
24	-2.6	0.003	4.330***	-1.7	0.036	2.415**	-4.4	0.000	7.838***
25	-1.8	0.189	1.435 ^{NS}	-2.0	0.049	2.245**	-3.8	0.001	4.575***
26	0.0	0.998	0.003 ^{NS}	-2.8	0.026	2.609 ^{NS}	-2.8	0.007	3.358***
27	-1.1	0.262	1.208 ^{NS}	-2.5	0.007	3.364***	-3.6	0.000	6.100***
28	-2.0	0.001	5.064***	0.1	0.818	0.236 ^{NS}	-1.9	0.005	3.559***
29	-0.9	0.146	1.610 ^{NS}	-1.4	0.002	4.010***	-2.3	0.000	5.087***
30	-1.6	0.004	4.068***	-0.8	0.034	2.462**	-2.5	0.000	6.526***
31	-0.9	0.038	2.481**	-1.0	0.009	3.255***	-1.9	0.000	5.482***
32	-1.8	0.111	1.792*	-0.4	0.574	0.581 ^{NS}	-2.2	0.014	2.981**
33	-2.5	0.003	4.162***	-2.0	0.028	2.568**	-4.5	0.000	6.280***
34	-2.1	0.002	4.520***	-1.4	0.068	2.043 ^{NS}	-3.6	0.000	5.469***
35	-3.1	0.002	4.446***	-1.0	0.075	1.985*	-4.1	0.000	8.403***
36	-2.8	0.013	3.196***	-0.7	0.372	0.935 ^{NS}	-3.5	0.000	8.269***
37	-2.3	0.010	3.337***	0.0	0.971	0.037 ^{NS}	-2.3	0.004	3.652***

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
38	-1.8	0.121	1.735 ^{NS}	-1.8	0.110	1.756 ^{NS}	-3.6	0.000	5.719***
39	-2.1	0.079	2.010 ^{NS}	-1.2	0.256	1.204 ^{NS}	-3.3	0.000	6.634***
40	-2.7	0.007	3.586***	-1.2	0.253	1.213 ^{NS}	-3.9	0.001	4.654***
41	-3.3	0.005	3.827***	-0.8	0.462	0.765 ^{NS}	-4.0	0.000	5.341***
42	-3.1	0.009	3.430***	-1.2	0.403	0.873 ^{NS}	-4.3	0.008	3.338***
43	-3.9	0.000	6.931***	0.0	0.989	0.014 ^{NS}	-3.9	0.010	3.185***
44	-3.0	0.020	2.894**	-0.3	0.837	0.211 ^{NS}	-3.4	0.027	2.595**
45	-3.6	0.002	4.529***	-1.7	0.144	1.586 ^{NS}	-5.3	0.000	6.147***
46	-3.9	0.000	6.747***	-3.0	0.039	2.367**	-6.9	0.000	5.304***
47	-5.1	0.003	4.177***	-1.5	0.315	1.059 ^{NS}	-6.6	0.001	4.826***
48	-3.4	0.006	3.658***	-0.3	0.777	0.291 ^{NS}	-3.7	0.001	4.432***
49	-4.1	0.009	3.402***	-0.4	0.781	0.285 ^{NS}	-4.5	0.005	3.524***
50	-3.9	0.007	3.608***	-0.4	0.783	0.283 ^{NS}	-4.2	0.003	3.915***
51	-3.5	0.019	2.937***	-2.0	0.084	1.918*	-5.5	0.000	6.373***
52	-2.9	0.002	4.434***	-0.9	0.574	0.582 ^{NS}	-3.8	0.028	2.559**

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

During period-II, maximum and minimum coefficient of variation of 44.6 and 3.4 per cent was during 4th and 34th SMW, respectively. During Period-III, maximum CV of 47.1 per cent was during 50th SMW and minimum of 2.9 per cent was during 31st SMW. Analysis of overall period-IV indicated maximum CV of 27.2 per cent was during 3rd SMW, while minimum CV (3.6 per cent) was during 31st SMW. Periodical deviation of average minimum temperature at Faridkot was analysed and represented as in Table 4.34. The deviation of average minimum temperature during Period-II over base Period-I depicted mean difference of -6.0°C which was significant at one per cent level of significance, was during 15th SMW and mean difference during SMW 13th (-2.6), 16th (-3.8), 20th (-2.6), 31st (-0.9) and 44th (-3.0°C) was significant at five per cent level of significance and mean difference of -2.3 and -1.8°C was significant at ten per cent level of significance during week 22nd and 32nd, respectively. During Period-III over Period-II, deviation (-4.9°C) was significant at one per cent level of significance during week 9th and mean difference of -5.9°C was significant at five per cent level of significance during week 10th and -2.6, -1.0 and -2.0°C at ten per cent level of significance during week 16th, 35th and 51st, respectively. It was observed that average minimum temperature in SMW 4th to 51st was significant at one per cent level of significance, while SMW 3rd, 32th and 52nd (significant at one per cent level of significance) by 2.1, 2.2 and 3.8°C during Period-III over Period-I.

4.1.2.2.2 Monthly

Monthly average minimum temperature data for 17 years (2001-2017) was analyzed and the same has been set out as Table 4.35. During Period-I the lowest average minimum temperature was observed during the month of January (8.9°C) and highest average minimum temperature was recorded during the month of June (30.7°C). It was analysed that from Period-II to Period-V, lowest minimum temperature was recorded during January month and highest minimum temperature was analysed during the month of July. The highest minimum temperature of 28.8, 27.7 and 28.7°C was observed during Period-II, Period-III and overall Period-IV respectively, whereas, lowest minimum temperature of 7.5°C (Period-II), 6.6°C (Period-III) and 7.5°C (Period-IV) was observed during the month of January. Analysis of coefficient of variation (Table 4.35) on monthly basis depicted that during Period-I, maximum coefficient of variation of 27.6 per cent was during January and minimum of 5.0 per cent was during July month. It was observed that maximum and minimum CV of 43.7 and 5.9 per cent was recorded during the month of January and August, respectively for Period-II. During Period-III, maximum coefficient of variation of 44.9 per cent during December, while 5.6 per

cent was during July, which was minimum. Analysis of overall Period-IV indicated maximum coefficient of variation of 34.4 per cent (January) and minimum coefficient of variation of 5.7 per cent (July). Periodical deviation of average minimum temperature at Faridkot was analysed and presented as Table 4.36. The average deviation of minimum temperature during Period-II over base Period-I depicted mean difference of -4.7, -2.7, -2.0, -1.3, -2.2, -2.2, -3.3, -4.0 and -3.6°C during April, May, July, August, September, October, November and December which was significant at one per cent level of significance, respectively. The Periodical deviation was calculated as -5.8, -2.9, -1.9 and -1.1°C during the month March, May, June and July and was one per cent level of significance and mean difference of -2.2°C (February), -2.2°C (April), and -1.2°C (August) was significant at five per cent level of significance and -1.6°C (November) was significant at ten per cent level of significance during the Period-III over base Period-II. During Period-III over base Period-I, periodical deviation was observed during January (-2.3°C), February (-3.7°C), March (-7.0°C), April (-6.4°C), May (-5.6°C), June (-3.7°C), July (-2.4°C), August (-3.0°C), September (-3.5°C), October (-3.5°C), November (-4.8°C) and December (-4.0°C) which was significant at one per cent level of significance, respectively.

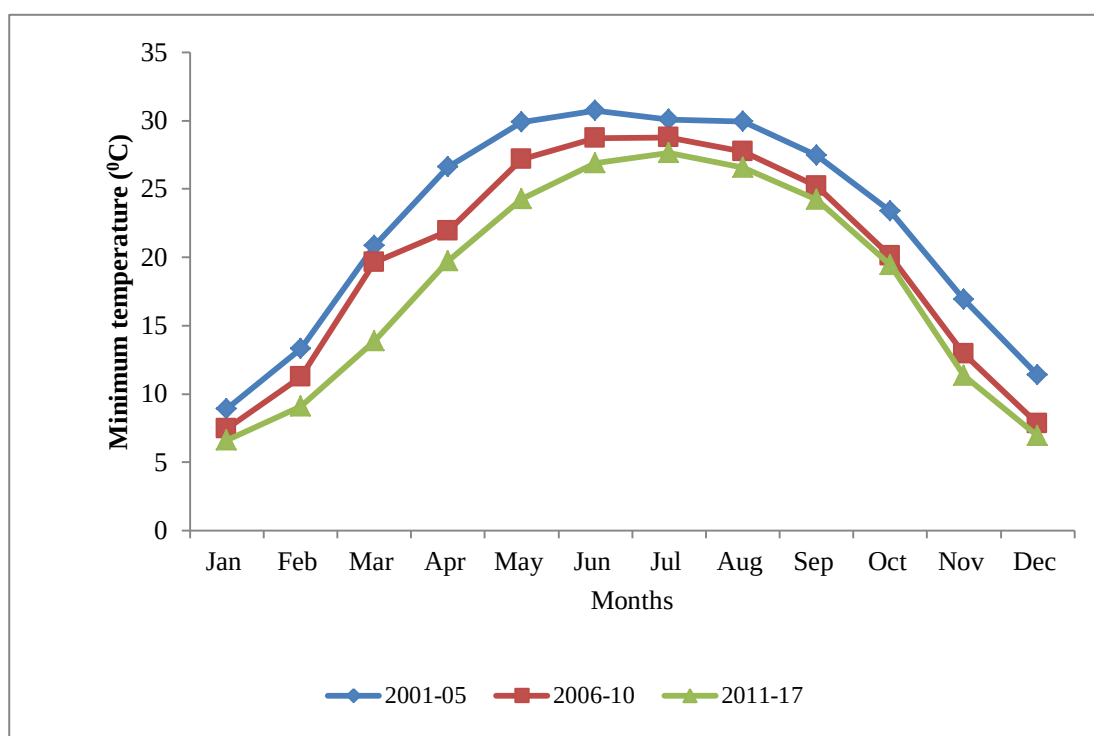


Fig. 4.10: Average monthly minimum temperature at Faridkot (2001-2017) during different periods

Table 4.35: Periodic average and coefficient of variations (%) of monthly minimum temperature at Faridkot (2001-2017)

Months	Minimum temperature (°C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	2001-05	2006-10	2011-2017	2001-17	2001-05	2006-10	2011-2017	2001-17
January	8.9	7.5	6.6	7.5	27.6	43.7	35.9	34.4
February	13.3	11.2	9.1	11.0	18.0	28.4	29.3	24.4
March	20.9	19.6	13.9	17.7	13.3	17.7	21.8	17.1
April	26.6	21.9	19.7	22.5	11.2	16.0	13.2	13.2
May	29.9	27.2	24.3	26.8	8.4	10.5	10.2	9.7
June	30.7	28.7	26.9	28.6	7.4	8.7	9.5	8.5
July	30.1	28.8	27.7	28.7	5.0	6.5	5.6	5.7
August	29.9	27.7	26.6	27.9	5.7	5.9	6.6	6.1
September	27.4	25.2	24.2	25.5	7.0	8.7	6.4	7.3
October	23.4	20.1	19.5	20.8	13.0	17.3	15.4	14.9
November	16.9	12.9	11.4	13.5	17.9	24.3	26.6	22.5
December	11.4	7.8	6.9	8.5	22.9	35.1	44.8	32.4

Table 4.36: Periodical deviation in average minimum monthly temperature at Faridkot (2001-2017)

Months	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
January	-1.4	0.123	1.726 ^{NS}	-0.9	0.245	1.236 ^{NS}	-2.3	0.000	5.749***
February	-2.1	0.060	2.194 ^{NS}	-2.2	0.045	2.286**	-4.2	0.000	7.302***
March	-1.2	0.577	0.582 ^{NS}	-5.8	0.009	3.201***	-7.0	0.000	14.803***
April	-4.7	0.000	6.143***	-2.2	0.018	2.830**	-6.9	0.000	11.962***
May	-2.7	0.002	4.464***	-2.9	0.004	3.787***	-5.6	0.000	8.577***
June	-2.0	0.008	3.470***	-1.9	0.013	3.021***	-3.9	0.000	6.865***
July	-1.3	0.002	4.368***	-1.1	0.002	4.095***	-2.4	0.000	7.915***
August	-2.2	0.001	5.407***	-1.2	0.024	2.647**	-3.4	0.000	7.135***
September	-2.2	0.003	4.210***	-1.0	0.069	2.039 ^{NS}	-3.2	0.000	9.917***
October	-3.3	0.001	5.349***	-0.7	0.506	0.690 ^{NS}	-3.9	0.001	4.563***
November	-4.0	0.000	5.763***	-1.6	0.098	1.827*	-5.5	0.000	7.044***
December	-3.6	0.000	5.680***	-0.9	0.317	1.053 ^{NS}	-4.5	0.000	5.620***

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.2.2.3 Seasonal

The change in seasonal minimum temperature for *kharif* and *rabi* season during the period of 17 years (2001-2017) was carried out to comprehend the change in average minimum temperature in Faridkot district of Punjab (Table 4.37). The average minimum temperature recorded was 29.3, 27.1, 25.6 and 27.1°C during Period-I, Period-II, Period-III and overall Period-IV, respectively during *kharif* season. During *rabi* season the average minimum temperature of 16.9, 14.2, 11.8 and 14.1°C was during Period-I, Period-II, Period-III and overall Period-IV, respectively. Coefficient of variation during *kharif* season was 8.8 per cent (Period-I), 11.2 per cent (Period-II), 11.1 per cent (Period-III), 10.4 per cent (overall Period-IV), whereas, during *rabi* season coefficient of variation was 38.7, 45.4, 47.1 and 43.5 per cent during Period-I, Period-II, Period-III and overall Period-IV, respectively. Periodical deviation in average seasonal minimum temperature of Faridkot was analysed and represented as Table 4.38. Analysis showed the change in *kharif* season mean difference (-2.2°C) during Period-II over base Period-I and Period-III over base Period-II (-1.6°C) and Period-III over base Period-I (-3.7°C) which was significant at one per cent level of significance. It is clearly seen in Table 4.2 that during *rabi* season, the mean difference of Period-II over base Period-I (-2.7°C), Period-III over base Period-II (-2.4°C) and Period-III over base Period-I (-5.0°C) which was significant at one per cent level, respectively.

4.1.2.2.4 Meteorological seasons during the year

The change in season wise average minimum temperature at Faridkot was studied for the period of 17 years (2001-2017) and presented as in Table 4.39. It was observed that highest average minimum temperature was during monsoon season and was recorded as 29.5, 27.6, 26.3 and 27.7°C and lowest average minimum temperature was during winter season was recorded as 11.2, 9.1, 7.5 and 9.1°C during Period-I, Period-II, Period-III and overall Period-IV, respectively. The average minimum temperature was recorded as 25.8, 22.9, 19.3 and 22.3°C during Period-I, Period-II, Period-III and overall Period-IV, respectively, during summer season. During post-monsoon season the average minimum temperature of 20.2, 16.6, 15.5 and 17.2°C was during Period-I, Period-II, Period-III and Period-IV, respectively.

Table 4.37: Periodic average and coefficient of variations (%) of seasonal minimum temperature at Faridkot (2001-2017)

Seasonal	Minimum temperature (°C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
<i>Kharif</i>	29.3	27.1	25.6	27.1	8.8	11.2	11.1	10.4
<i>Rabi</i>	16.9	14.2	11.8	14.1	38.7	45.4	47.1	43.5

Table 4.38: Periodical deviation in average seasonal minimum temperature at Faridkot (2001-2017)

Seasonal	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
<i>Kharif</i>	-2.2	0.000	12.574***	-1.6	0.000	6.961***	-3.7	0.000	16.218***
<i>Rabi</i>	-2.7	0.000	5.675***	-2.4	0.000	5.672***	-5.0	0.000	25.671***

*** indicates 1 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

Table 4.39: Periodic average and coefficient of variations (%) of minimum temperature during different meteorological seasons at Faridkot (2001-2017)

Seasons	Minimum temperature ($^{\circ}$ C)				Variation in minimum temperature (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
Summer	25.8	22.9	19.3	22.3	18.2	22.6	26.5	22.4
Monsoon	29.5	27.6	26.3	27.7	7.8	9.3	9.0	8.7
Post-monsoon	20.2	16.6	15.5	17.2	22.1	29.9	33.4	28.2
Winter	11.2	9.1	7.5	9.1	27.7	38.6	41.3	35.0

Table 4.40: Periodical deviation in average minimum temperature during different meteorological seasons at Faridkot (2001-2017)

Seasons	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
Summer	-2.9	0.001	5.608***	-3.6	0.000	6.367***	-6.5	0.000	14.252***
Monsoon	-1.9	0.000	12.057***	-1.3	0.000	6.222***	-3.2	0.000	15.197***
Post-monsoon	-3.6	0.000	7.209***	-1.1	0.200	1.345 ^{NS}	-4.7	0.000	6.045***
Winter	-2.2	0.055	2.244 ^{NS}	-1.6	0.000	4.765***	-3.8	0.001	4.765***

*** indicates 1 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

Analysis of coefficient of variation (Table 4.39) on seasons basis depicted that the coefficient of variation was highest during winter season and was 27.7, 38.6, 41.3 and 35.0 per cent and lowest coefficient of variation was during monsoon season and was 7.8, 9.3, 9.0 and 8.7 per cent during Period-I, Period-II, Period-III and overall Period-V, respectively. Coefficient of variation during summer season was 18.2 per cent during Period-I, 22.6 per cent during Period-II, 26.5 per cent during Period-III and 22.4 during overall Period-IV. During post-monsoon season coefficient of variation was 22.1, 29.9, 33.4 and 28.2 per cent during Period-I, Period-II, Period-III and overall Period-V, respectively. Periodical deviation of seasons minimum temperature at Faridkot was analysed and represented as Table 4.40. The periodical deviation of -6.5°C was statistically significant at one per cent level of significance during the summer season. During monsoon season the mean difference of -1.9°C during Period-II over base Period-I, -1.3°C during Period-III over base Period-II and -3.2°C during Period-III over base Period-I, was significant at one per cent level of significance, respectively. During post-monsoon season deviation in minimum temperature was observed as -3.6°C during Period-II over base Period-I was significant at one per cent level of significance and -4.7°C during Period-III over base Period-I which was significant at one per cent level of significance. During post-monsoon season the mean difference of -1.6°C during Period-III over base Period-II, -3.8°C during Period-III over base Period-I, which was significant at one per cent level of significance.

4.1.2.3 Rainfall

4.1.2.3.1 Weekly

The change in average weekly rainfall, during the period of 2001-2017, was studied and the results were shown in Table 4.41. During the Period-I the lowest average rainfall was observed during the 1st and 49th week which was 0.0 mm and highest average rainfall was recorded during the 31st week which was 46.0 mm. The highest rainfall of 48.7 mm was recorded during 31st week of Period-II, while 0.0 mm lowest rainfall was observed during 4th and 46th week. It was observed that in Period-III lowest rainfall was recorded during 15th, 40th, 47th, 48th and 49th week (0.0 mm) and highest rainfall was during 36th week (41.6 mm). During overall Period-IV the lowest average rainfall was observed during the 48th week (0.0 mm) and highest average rainfall was recorded during the 26th week which was 37.9 mm. The coefficient of variation (CV) of weekly average rainfall (Table 4.41) depicted that during Period-I minimum variation of 0.0 per cent observed during 1st and 2nd SMW, while maximum coefficient of variation of 192.9 per cent was during 28th SMW. During period-II,

maximum and minimum coefficient of variation of 231.0 and 0.0 per cent was during 26th and 4th SMW, respectively. During Period-III, maximum CV of 187.0 per cent was during 25th SMW and minimum of 0.0 per cent was during 15th SMW. Analysis of overall period-IV indicated maximum CV of 700.0 per cent during 49th SMW, while minimum CV (98.6 per cent) was during 17th SMW. Periodical deviation of average rainfall of Faridkot was analysed and represented as Table 4.42. The periodical deviation of 15.9 and -11.3 mm was statistically significance at five per cent level of significance during week 38th and 39th and 2.0 mm at one per cent level of significance during 1st week during Period-II over base Period-I. The deviation of average rainfall -1.9 mm during 1st week was statistically significant at one per cent level of significance and 15.0 mm at ten per cent level of significance during week 25th during Period-III over base Period-II. During, Period-III over base Period-I periodic deviation was significant at five per cent level of significance during the week of 21st and 39th by -7.3 and -10.5 mm, respectively. The mean difference of -1.0 and 23.3 mm was statistically significant at ten per cent level of significance during 15th and 38th SMW.

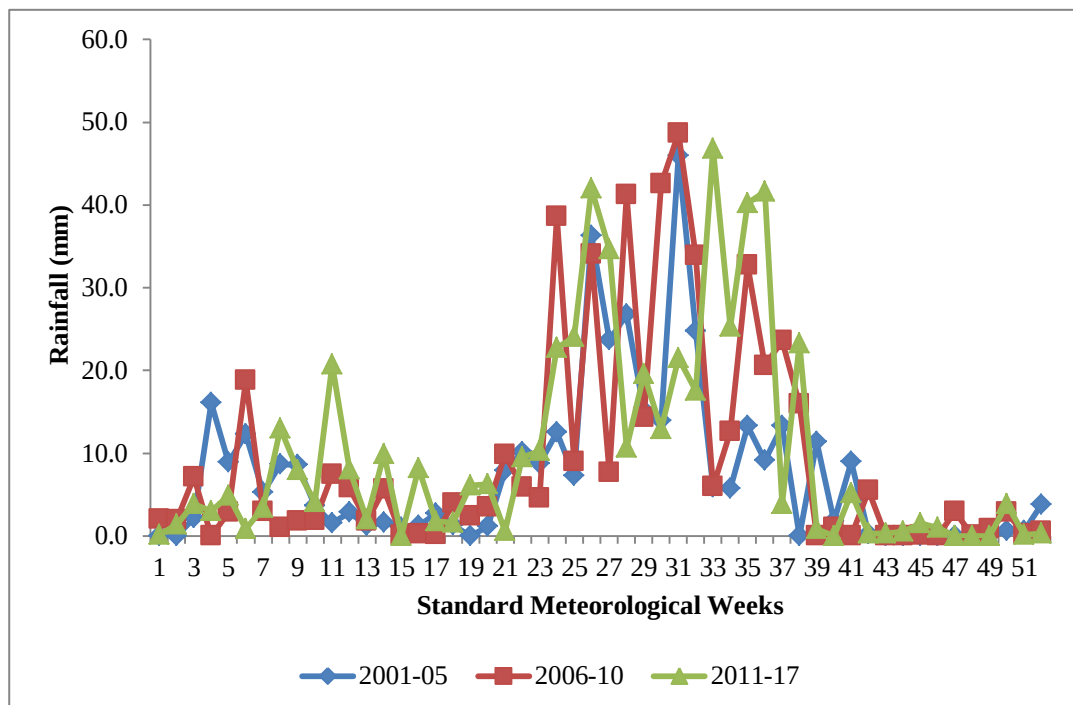


Fig. 4.11: Average weekly rainfall at Faridkot (2001-2017) during different periods

Table 4.41: Periodic average and coefficient of variations (%) of weekly rainfall at Faridkot (2001-2017)

Weeks	Rainfall (mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
1	0.0	2.0	0.1	0.6	0.0	193.0	5.4	169.9
2	0.0	1.9	1.4	1.1	0.0	49.2	113.4	254.9
3	2.1	7.1	3.9	4.3	52.9	136.6	118.8	195.4
4	16.1	0.0	3.0	6.0	88.3	0.0	73.4	153.1
5	8.9	2.9	4.8	5.5	80.7	158.7	145.3	129.9
6	12.3	18.8	0.8	9.7	84.4	185.9	62.2	186.4
7	5.3	3.0	3.4	3.8	79.6	38.4	71.8	212.1
8	8.7	1.0	13.0	8.1	146.7	37.6	149.1	205.3
9	8.6	1.7	7.9	6.3	87.1	29.9	141.1	242.6
10	3.6	1.9	4.1	3.3	33.5	120.8	130.5	103.6
11	1.5	7.4	20.7	11.0	52.9	99.5	65.6	243.1
12	2.9	5.8	8.0	5.8	92.4	125.4	90.5	195.2
13	1.2	1.8	2.0	1.7	52.9	129.1	75.6	254.7
14	1.6	5.6	9.9	6.1	37.7	107.6	34.8	120.3
15	1.0	0.0	0.0	0.3	105.8	52.9	0.0	205.8
16	1.2	0.2	8.2	3.7	105.6	52.9	82.9	173.8
17	2.7	0.2	1.8	1.6	160.5	52.9	81.0	98.6

Weeks	Rainfall (mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
18	1.3	3.9	1.6	2.2	94.8	122.8	113.4	219.9
19	0.0	2.4	6.1	3.1	0.0	95.2	151.2	254.5
20	1.2	3.4	6.3	3.9	36.4	81.8	117.6	176.7
21	7.9	9.8	0.6	5.6	140.9	173.6	37.8	205.3
22	10.2	5.9	9.5	8.6	133.2	66.0	102.2	209.6
23	8.7	4.6	10.3	8.1	146.7	71.1	81.0	102.6
24	12.5	38.6	22.8	24.4	125.8	132.1	126.8	149.6
25	7.2	9.0	24.0	14.5	79.8	90.6	187.0	173.7
26	36.2	34.0	42.0	37.9	143.5	231.0	182.7	177.0
27	23.6	7.7	34.6	23.2	142.5	194.2	132.4	224.7
28	26.7	41.2	10.7	24.7	192.9	180.0	97.2	178.0
29	15.2	14.3	19.6	16.7	144.9	40.5	137.3	224.9
30	13.9	42.5	12.9	22.1	144.1	158.7	172.5	228.3
31	46.0	48.7	21.5	37.0	147.1	123.7	159.6	187.0
32	24.8	33.8	17.5	24.6	156.8	127.2	175.3	218.3
33	5.9	5.9	46.8	22.2	98.3	196.1	115.4	151.4
34	5.7	12.6	25.3	15.6	63.7	196.0	178.4	201.9
35	13.3	32.7	40.3	29.9	119.7	116.9	141.5	156.4

Weeks	Rainfall (mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
36	9.1	20.6	41.6	25.6	105.8	137.0	104.2	185.1
37	13.3	23.6	3.8	12.6	125.3	142.5	118.8	169.3
38	0.0	15.9	23.3	14.1	0.0	161.9	162.8	210.5
39	11.3	0.0	0.9	3.7	195.5	0.0	31.1	238.4
40	1.8	1.0	0.0	0.8	105.8	52.9	0.0	264.6
41	9.0	0.0	5.1	4.7	105.8	0.0	37.8	264.6
42	0.2	5.5	0.3	1.8	52.9	105.8	37.8	264.6
43	0.0	0.0	0.3	0.1	0.0	0.0	33.4	233.7
44	0.0	0.0	0.5	0.2	0.0	0.0	75.6	264.6
45	0.0	0.0	1.6	0.6	0.0	52.9	37.8	264.6
46	0.0	0.0	1.0	0.4	0.0	0.0	5.4	37.8
47	0.0	3.0	0.0	0.9	0.0	52.9	0.0	264.6
48	0.0	0.1	0.0	0.0	0.0	52.9	0.0	264.6
49	0.0	0.8	0.0	0.3	0.0	52.9	0.0	700.0
50	0.6	2.8	3.9	2.6	52.9	52.9	82.9	154.2
51	0.6	0.2	0.1	0.3	52.9	52.9	37.8	264.6
52	3.8	0.5	0.3	1.4	101.9	49.0	24.4	252.9

Table 4.42: Periodical deviation in average weekly rainfall at Faridkot (2001-2017)

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
1	2.0	0.006	3.727***	-1.9	0.002	4.055***	0.1	0.424	0.833 ^{NS}
2	1.9	0.347	1.000 ^{NS}	-0.6	0.767	0.304 ^{NS}	1.4	0.181	1.437 ^{NS}
3	5.0	0.415	0.861 ^{NS}	-3.3	0.531	0.649 ^{NS}	1.7	0.560	0.603 ^{NS}
4	-16.1	0.332	1.033 ^{NS}	3.0	0.227	1.287 ^{NS}	-13.0	0.342	0.997 ^{NS}
5	-6.0	0.350	0.993 ^{NS}	2.0	0.613	0.523 ^{NS}	-4.1	0.511	0.682 ^{NS}
6	6.5	0.673	0.438 ^{NS}	-18.0	0.077	1.971*	-11.5	0.191	1.401 ^{NS}
7	-2.3	0.611	0.529 ^{NS}	0.4	0.931	0.089 ^{NS}	-1.9	0.685	0.418 ^{NS}
8	-7.7	0.346	1.002 ^{NS}	11.9	0.056	2.164 ^{NS}	4.3	0.618	0.515 ^{NS}
9	-6.8	0.369	0.951 ^{NS}	6.2	0.278	1.148 ^{NS}	-0.6	0.936	0.082 ^{NS}
10	-1.7	0.656	0.462 ^{NS}	2.2	0.311	1.066 ^{NS}	0.5	0.897	0.133 ^{NS}
11	5.9	0.271	1.184 ^{NS}	13.3	0.471	0.749 ^{NS}	19.2	0.294	1.107 ^{NS}
12	2.9	0.482	0.738 ^{NS}	2.2	0.713	0.378 ^{NS}	5.1	0.388	0.903 ^{NS}
13	0.5	0.743	0.340 ^{NS}	0.2	0.924	0.098 ^{NS}	0.7	0.754	0.322 ^{NS}
14	4.0	0.230	1.299 ^{NS}	4.2	0.628	0.500 ^{NS}	8.2	0.338	1.007 ^{NS}
15	-0.9	0.186	1.445 ^{NS}	0.0	0.255	1.208 ^{NS}	-1.0	0.098	1.823*
16	-1.0	0.294	1.124 ^{NS}	7.9	0.203	1.361 ^{NS}	7.0	0.262	1.189 ^{NS}
17	-2.5	0.131	1.684 ^{NS}	1.6	0.201	1.369 ^{NS}	-0.9	0.593	0.552 ^{NS}
18	2.6	0.425	0.840 ^{NS}	-2.3	0.408	0.864 ^{NS}	0.3	0.832	0.218 ^{NS}

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
19	2.4	0.250	1.240 ^{NS}	3.7	0.366	0.946 ^{NS}	6.1	0.120	1.700 ^{NS}
20	2.3	0.473	0.754 ^{NS}	2.8	0.601	0.539 ^{NS}	5.1	0.313	1.063 ^{NS}
21	1.9	0.790	0.276 ^{NS}	-9.2	0.099	1.817*	-7.3	0.038	2.392**
22	-4.3	0.538	0.644 ^{NS}	3.6	0.620	0.512 ^{NS}	-0.7	0.934	0.085 ^{NS}
23	-4.2	0.426	0.838 ^{NS}	5.7	0.460	0.769 ^{NS}	1.5	0.846	0.199 ^{NS}
24	26.1	0.203	1.388 ^{NS}	-15.8	0.527	0.655 ^{NS}	10.3	0.635	0.490 ^{NS}
25	1.7	0.865	0.175 ^{NS}	15.0	0.098	1.823*	16.8	0.061	2.113 ^{NS}
26	-2.2	0.915	0.110 ^{NS}	8.0	0.655	0.460 ^{NS}	5.7	0.799	0.262 ^{NS}
27	-16.0	0.253	1.231 ^{NS}	27.0	0.189	1.408 ^{NS}	11.0	0.624	0.506 ^{NS}
28	14.5	0.474	0.751 ^{NS}	-30.5	0.049	2.245 ^{NS}	-16.0	0.170	1.477 ^{NS}
29	-0.9	0.960	0.051 ^{NS}	5.3	0.774	0.295 ^{NS}	4.4	0.783	0.283 ^{NS}
30	28.6	0.203	1.387 ^{NS}	-29.6	0.099	1.819*	-1.0	0.907	0.120 ^{NS}
31	2.7	0.951	0.063 ^{NS}	-27.2	0.438	0.808 ^{NS}	-24.5	0.228	1.284 ^{NS}
32	9.1	0.691	0.412 ^{NS}	-16.3	0.401	0.877 ^{NS}	-7.3	0.532	0.647 ^{NS}
33	0.1	0.986	0.018 ^{NS}	40.8	0.365	0.950 ^{NS}	40.9	0.363	0.952 ^{NS}
34	6.9	0.313	1.077 ^{NS}	12.6	0.337	1.008 ^{NS}	19.6	0.135	1.624 ^{NS}
35	19.4	0.403	0.884 ^{NS}	7.6	0.789	0.276 ^{NS}	26.9	0.261	1.191 ^{NS}
36	11.5	0.374	0.941 ^{NS}	21.0	0.570	0.588 ^{NS}	32.5	0.378	0.923 ^{NS}
37	10.3	0.556	0.614 ^{NS}	-19.8	0.148	1.568 ^{NS}	-9.5	0.200	1.373 ^{NS}

Weeks	2006-10 over 2001-05			2011-17 over 2006-10			2011-17over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
38	15.9	0.032	2.600**	7.4	0.587	0.562 ^{NS}	23.3	0.083	1.929*
39	-11.3	0.035	2.532**	0.9	0.424	0.833 ^{NS}	-10.5	0.021	2.724**
40	-0.8	0.678	0.431 ^{NS}	-1.0	0.255	1.208 ^{NS}	-1.8	0.194	1.392 ^{NS}
41	-9.0	0.318	1.064 ^{NS}	5.1	0.424	0.833 ^{NS}	-3.8	0.691	0.410 ^{NS}
42	5.3	0.155	1.569 ^{NS}	-5.2	0.097	1.833*	0.1	0.770	0.301 ^{NS}
43	0.0	0.000	0.000 ^{NS}	0.3	0.424	0.833 ^{NS}	0.3	0.424	0.833 ^{NS}
44	0.0	0.000	0.000 ^{NS}	0.5	0.232	1.273 ^{NS}	0.5	0.232	1.273 ^{NS}
45	0.0	0.347	1.000 ^{NS}	1.5	0.436	0.812 ^{NS}	1.6	0.424	0.833 ^{NS}
46	0.0	0.000	0.000 ^{NS}	1.0	0.424	0.833 ^{NS}	1.0	0.424	0.833 ^{NS}
47	3.0	0.347	1.000 ^{NS}	-3.0	0.255	1.208 ^{NS}	0.0	0.000	0.000 ^{NS}
48	0.1	0.347	1.000 ^{NS}	-0.1	0.255	1.208 ^{NS}	0.0	0.000	0.000 ^{NS}
49	0.8	0.347	1.000 ^{NS}	-0.8	0.255	1.208 ^{NS}	0.0	0.000	0.000 ^{NS}
50	2.2	0.471	0.756 ^{NS}	1.0	0.785	0.280 ^{NS}	3.2	0.289	1.120 ^{NS}
51	-0.4	0.545	0.632 ^{NS}	-0.1	0.815	0.240 ^{NS}	-0.5	0.405	0.870 ^{NS}
52	-3.3	0.358	0.975 ^{NS}	-0.2	0.679	0.426 ^{NS}	-3.5	0.234	1.267 ^{NS}

***, ** and * indicates 1, 5 and 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.1.2.3.1 Monthly

The change in monthly average rainfall over the Periods has been depicted in Table 4.43. During Period-I the lowest average rainfall was observed during the month of November (0.0 mm) and highest average rainfall was recorded during the month of July which was 98.2 mm. It was analysed that from Period-II to Period-IV, lowest rainfall was recorded during November and December month and highest rainfall was during the month of July (Period-I, II) and August (Period-III, IV). The highest rainfall of 98.2 mm (Period I) and 120.9 mm (Period II) was in the month of July, whereas, it was 127.4 and 106.9 mm in August during Period-III and overall Period-IV, respectively. Lowest rainfall of 3.1 mm (Period-II), 2.0 mm (Period-III) and 2.0 mm (Period-IV) was observed during the month of November. Analysis of coefficient of variation (Table 4.43) on monthly basis depicted that during Period-I, highest coefficient of variation of 430.9 per cent was during May and lowest 0.0 per cent was during November month. It was observed that highest and lowest CV of 400.5 and 258.3 per cent was recorded during the month of May and July, respectively for Period-II. During Period-III, highest coefficient of variation of 376.0 per cent was during April, while 159.1 per cent was during November, which was lowest. Analysis of Period-IV indicated maximum coefficient of variation of 511.2 per cent (October) and minimum coefficient of variation of 80.1 per cent (November). Periodical deviation of average rainfall at Faridkot was analysed and represented as Table 4.44.

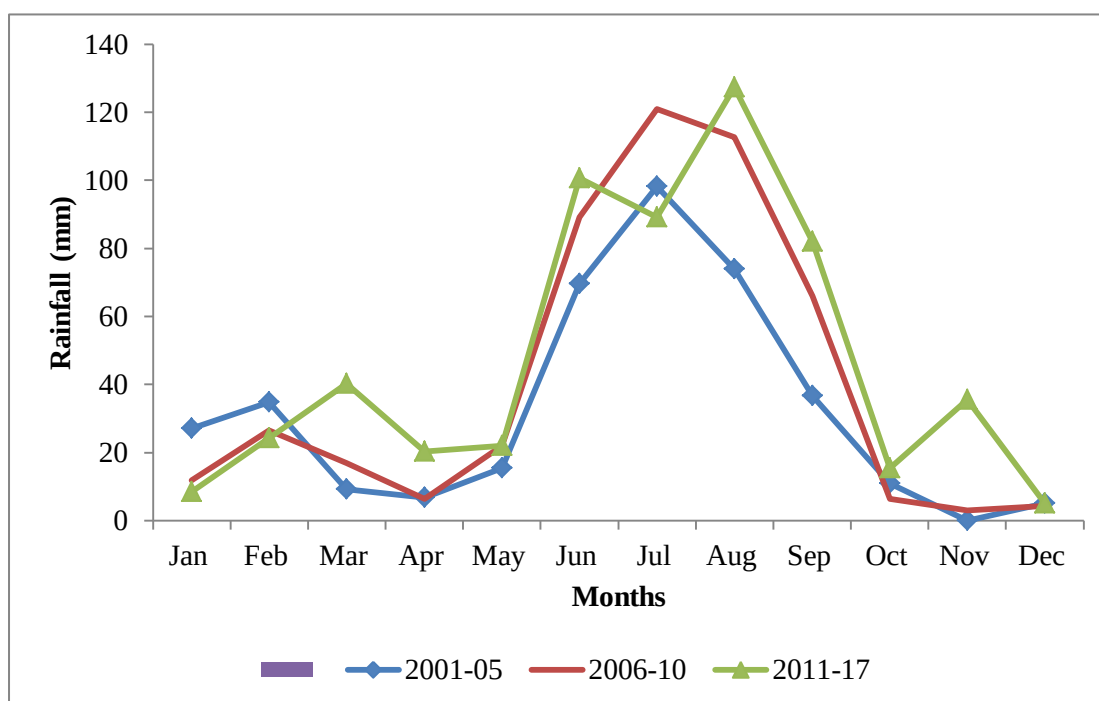


Fig. 4.12: Average monthly rainfall at Faridkot (2001-2017) during different periods

Table 4.43: Periodic average and coefficient of variations (%) of monthly rainfall at Faridkot (2001-2017)

Months	Rainfall (mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
January	27.1	11.8	8.4	15.1	232.6	337.2	332.6	297.4
February	34.9	26.6	24.3	28.2	278.7	354.5	221.1	301.1
March	9.2	16.9	40.3	23.9	145.0	313.6	301.3	210.2
April	6.7	6.5	20.2	12.0	292.5	325.9	376.0	162.8
May	15.4	22.1	22.1	20.1	430.9	400.5	307.0	259.3
June	69.6	89.1	100.6	87.9	271.1	330.7	320.6	225.1
July	98.2	120.9	89.2	101.4	339.4	258.3	243.9	284.4
August	73.9	112.7	127.4	106.9	351.4	344.9	283.7	275.2
September	36.8	66.0	82.1	63.6	395.9	368.2	256.3	237.8
October	11.0	6.5	6.0	7.6	289.2	334.1	253.5	511.2
November	0.0	3.1	2.0	2.0	0.0	328.6	159.1	80.1
December	5.0	4.4	5.0	4.6	293.6	294.2	267.5	171.1

Table 4.44: Periodical deviation in average monthly rainfall at Faridkot (2001-2017)

Months	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
January	-15.3	0.356	0.979 ^{NS}	-3.4	0.568	0.590 ^{NS}	-18.7	0.154	1.541 ^{NS}
February	-8.2	0.745	0.336 ^{NS}	-2.3	0.900	0.129 ^{NS}	-10.6	0.598	0.545 ^{NS}
March	7.6	0.492	0.720 ^{NS}	23.4	0.361	0.958 ^{NS}	-31.0	0.233	1.269 ^{NS}
April	-0.2	0.938	0.081 ^{NS}	13.8	0.109	1.761 ^{NS}	13.5	0.101	1.805 ^{NS}
May	6.6	0.533	0.652 ^{NS}	0.0	1.000	0.000 ^{NS}	6.6	0.565	0.595 ^{NS}
June	19.5	0.603	0.542 ^{NS}	11.5	0.759	0.316 ^{NS}	31.0	0.281	1.140 ^{NS}
July	22.7	0.581	0.575 ^{NS}	-31.7	0.438	0.808 ^{NS}	-8.9	0.766	0.306 ^{NS}
August	38.9	0.314	1.075 ^{NS}	14.7	0.815	0.240 ^{NS}	53.5	0.402	0.876 ^{NS}
September	29.2	0.092	1.916*	16.1	0.645	0.475 ^{NS}	45.3	0.213	1.330 ^{NS}
October	-4.5	0.678	0.431 ^{NS}	-0.5	0.949	0.065 ^{NS}	-4.9	0.046	0.473 ^{NS}
November	3.1	0.328	1.042 ^{NS}	-0.2	0.940	0.078 ^{NS}	2.8	0.195	1.389 ^{NS}
December	-0.6	0.882	0.153 ^{NS}	-0.1	0.980	0.026 ^{NS}	-0.7	0.858	0.473 ^{NS}

* indicates 10 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

The highest deviation of average rainfall during Period-II over base Period-I depicted mean difference of 29.2 and was observed during September and was statistically significant at ten per cent level of significance. The deviation of average rainfall during Period-III over base Period-II depicted maximum deviation of 23.4 mm during March, which was statistically non-significant. The Periodical deviation in average rainfall was statistically non-significant during the Period-III over base Period-I.

4.1.2.3.3 Seasonal

The change in seasonal (*kharif* and *rabi*) rainfall for the period of 17 years (2001-2017) was studied. Regarding crop growing seasons. During *kharif* season, the recorded average rainfall in period-I, Period-II, Period-III and Period-IV as well as Period-V was 304.6 mm, 411.8 mm, 426.8 mm and 385.6 mm, respectively (Table 4.45). During *rabi* season, the recorded average rainfall in period-I, Period-II, Period-III, Period-IV and Period-V was 86.3 mm, 74.7 mm, 98.4 mm and 87.1 mm, respectively. It has been observed from the Table 47 that coefficient of variation during *kharif* season was 368.7 per cent during Period-I, 430.2 per cent during Period-II, 355.9 per cent during Period-III and 296.4 per cent during overall Period-IV. Similarly, during *rabi* season the coefficient of variation was 580.5 per cent during Period-I, 644.3 per cent during Period-II, 590.0 per cent during Period-III and 525.8 per cent during overall period-IV. Periodical deviation in average seasonal rainfall at Faridkot was analysed and represented as Table 4.46. Analysis showed the change in *kharif* season rainfall during Period-II over base Period-I (107.2 mm) was significant at five per cent level of significance and Period-III over base Period-II (15.0 mm) and Period-III over base Period-I (-41.2 mm) was statistically non-significant, respectively. It is clear in Table 4.46 that during *rabi* season, the mean difference of Period-II over base Period-I (-11.6), Period-III over base Period-II (24.0) and Period-III over base Period-I (-10.9) was statistically non-significant.

4.1.2.3.4 Meteorological seasons during the year

The change in seasons wise average rainfall for the period of 17 years (2001-2017) was taken and grouped as summer, monsoon, post-monsoon and winter season. During summer season, the recorded average rainfall in period-I, Period-II, Period-III and as well as Period-IV was 31.4 mm, 45.4 mm, 82.6 mm and 56.1 mm, respectively (Table 4.47). During Monsoon season, the recorded highest average rainfall during period-I, Period-II, Period-III, and Period-IV was 278.4 mm, 388.7 mm, 399.3 mm and 359.8 mm, respectively.

Table 4.45: Periodic average and coefficient of variations (%) of seasonal rainfall at Faridkot (2001-2017)

Seasonal	Rainfall (mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
<i>Kharif</i>	304.6	411.8	426.8	385.6	368.7	430.2	355.9	296.4
<i>Rabi</i>	86.3	74.7	98.4	87.1	580.5	644.3	590.0	525.8

Table 4.46: Periodical deviation in average seasonal rainfall at Faridkot (2001-2017)

Seasonal	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
<i>Kharif</i>	107.2	0.022	2.837**	15.0	0.851	0.193 ^{NS}	-41.2	0.132	1.642 ^{NS}
<i>Rabi</i>	-11.6	0.806	0.253 ^{NS}	24.0	0.573	0.583 ^{NS}	-10.9	0.781	0.285 ^{NS}

** indicate 5 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

In the post-monsoon season, the lowest average rainfall was 11.0 mm, 9.5 mm, 8.8mm and 9.7 mm during Period-I, Period-II, Period-III and overall Period-IV, respectively. During winter season, the average rainfall was recorded as 70.2 mm, 42.8 mm, 35.5 mm and 48.1 mm during period-I, Period-II, Period-III as well as Period-IV, respectively. It has been observed from the Table 4.47 that coefficient of variation during summer season was 460.9 per cent (Period-I), 452.4 per cent (Period-II), 445.8 per cent (Period-III), 241.0 Per cent (Period-IV). Similarly, during monsoon season the coefficient of variation was recorded lowest 330.8 per cent during Period-I, 383.7 per cent during Period-II, 318.7 per cent during Period-III, 280.8 per cent during Period-IV. During post-monsoon season the CV was 406.8, 572.2, 267.5 and 180.3 per cent during period-I, Period-II, Period-III, and over all Period-IV, respectively. It was observed highest coefficient of variation of 521.2 per cent during Period-I, 563.0 per cent during Period-II, 507.5 per cent during Period-III, 443.0 Per cent during Period-IV during winter season. Periodical deviation of season wise rainfall of Faridkot was analysed and presented in Table 4.48. The deviation in average season wise rainfall during summer season was observed as 14.0 mm during Period-II over base Period-I, 37.2 mm during Period-III over base Period-II and 51.2 mm during Period-III over base Period-I, which was statistically non-significant. During monsoon season deviation in rainfall was observed as 110.3 mm during Period-II over base Period-I and was statistically significant at five per cent level of significance, 10.5 mm during Period-III over base Period-II and 120.9 mm during Period-III over base Period-I was calculated statistically non-significant. The periodical deviation over the periods came out to be statistically non-significant during post-monsoon season. The deviation in average season wise rainfall during winter season was observed as -27.4 during Period-II over base Period-I, -7.3 during Period-III over base Period-II and -34.7 during Period-III over base Period-I, which was statistically non-significant.

Table 4.47: Periodic average and coefficient of variations (%) of rainfall during different meteorological seasons at Faridkot (2001-2017)

Seasons	Rainfall(mm)				Variation in rainfall (Coefficient of Variation %)			
	Period I	Period II	Period III	Period IV	Period I	Period II	Period III	Period IV
	(2001-05)	(2006-10)	(2011-17)	(2001-17)	(2001-05)	(2006-10)	(2011-17)	(2001-17)
Summer	31.4	45.4	82.6	56.1	460.9	452.4	445.8	241.0
Monsoon	278.4	388.7	399.3	359.8	330.8	383.7	318.7	280.8
Post-monsoon	11.0	9.5	8.8	9.7	406.8	572.2	267.5	180.3
Winter	70.2	42.8	35.5	48.1	521.2	563.0	507.5	443.0

Table 4.48: Periodical deviation in average rainfall during different meteorological seasons at Faridkot (2001-2017)

Seasons	2006-10 over 2001-05			2011-17 over 2006-10			2011-17 over 2001-05		
	Mean difference	P Value	t Value	Mean difference	P Value	t Value	Mean difference	P Value	t Value
Summer	14.0	0.287	1.141 ^{NS}	37.2	0.299	1.112 ^{NS}	51.2	0.152	1.584 ^{NS}
Monsoon	110.3	0.043	2.399**	10.5	0.886	0.147 ^{NS}	120.9	0.161	1.547 ^{NS}
Post-monsoon	-1.4	0.903	0.126 ^{NS}	-0.7	0.942	0.076 ^{NS}	-2.1	0.858	0.184 ^{NS}
Winter	-27.4	0.457	0.782 ^{NS}	-7.3	0.712	0.382 ^{NS}	-34.7	0.268	1.189 ^{NS}

** indicate 5 % level of significance respectively, NS: Non-significant, P-Probability, t-Test.

4.2 To analyze the impact of climate change on productivity of wheat and cotton crops in south west Punjab.

4.2.1 Impact of climatic parameters on wheat productivity in Punjab

For assessing the impact of climatic parameters on wheat productivity in Punjab, two districts Bathinda and Faridkot were selected and within each districts effect of climatic parameters was described. For these two different districts, three different yield forecast equations has been developed with three different models by using weekly data of weather variables, as discussed below:-

4.2.1.1 Impact of climatic factors on wheat productivity at Bathinda

4.2.1.1.1 Basic model (model 1)

Weather data correlated with yield during critical periods were used for regression analysis. Initially, weeks were selected having high degree of correlation with wheat yield and were taken for further climate change impact analysis. The selected weeks, were clumped to form variables as X_1 (Tmax2nd-3rd weeks), X_2 (Tmax6th-7th weeks), X_3 (Tmin48th week), X_4 (Tmin4th week), X_5 (Rain2nd week), X_6 (Rain11th week) which were similar in nature and have regular relationship. After selecting these variables, basic model: multiple linear regression model was used for determining the effect of climatic parameters on wheat yield.

The regression equation for Bathinda district is as follows:

$$Y = 5992.12 - 130.281 * T_{\max}(2-3) + 45.907 * T_{\max}(6-7) - 144.369 * T_{\min}(48) + 24.114 * T_{\min}(4) - 33.071 * RF(2) - 66.901 * RF(11)$$

Table 4.49: Regression relationship of wheat yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	5992.12	0.00 ^{NS}
2	X_1 (Tmax2 nd -3 rd weeks)	-130.28	0.01*
3	X_2 (Tmax6 th -7 th weeks)	45.91	0.45 ^{NS}
4	X_3 (Tmin48 th week)	-144.37	0.06 ^{NS}
5	X_4 (Tmin4 th week)	24.11	0.50 ^{NS}
6	X_5 (Rain2 nd week)	-33.07	0.80 ^{NS}
7	X_6 (Rain11 th week)	-66.90	0.19 ^{NS}
R²=0.48			

*level of significance at five per cent level, NS-non-significant, P-probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 6th-7th weeks and minimum temperature during 4th week, which were depicted as Table 4.49. Maximum temperature was significant at 5 per cent probability level during 2nd-3rd weeks and dependent variable (wheat yield) showed 48 per cent variations as explained by variables in the functions (weather parameters) for the Bathinda region.

4.2.1.1.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables were used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation derived using modified model for wheat yield analysis for Bathinda region is as follows:

$$Y=4809.83-154.837*T_{\max}(2-3)+47.071*T_{\max}(6-7)-95.010*T_{\min}(48)+12.53*T_{\min}(4)-34.433*RF(2)-64.042*RF(11)+8.143*CI$$

Table 4.50: Regression relationship of wheat yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	4809.83	0.00 ^{NS}
2	X ₁ (T _{max} 2 nd -3 rd weeks)	-154.84	0.00 ^{NS}
3	X ₂ (T _{max} 6 th -7 th weeks)	47.07	0.35 ^{NS}
4	X ₃ (T _{min} 48 th week)	-95.01	0.14 ^{NS}
5	X ₄ (T _{min} 4 th week)	12.53	0.67 ^{NS}
6	X ₅ (Rain2 nd week)	-34.43	0.75 ^{NS}
7	X ₆ (Rain11 th week)	-64.04	0.13 ^{NS}
8	X ₇ (Composite index)	8.14	0.00 ^{NS}
R²=0.67			

NS-non-significant, P-probability

Note:- T_{max}- maximum temperature, T_{min}- minimum temperature

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 6th-7th weeks, minimum temperature during 4th week and composite index, which was depicted in Table 4.50. Coefficient of almost all the variables were non-significant. Variation in wheat yield for Bathinda region is 67 per cent explainable using weather variables and CI together.

4.2.1.1.3 (SPSS software) Model 3

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Bathinda, weather data was selected for the period 1981-2007 while weeks were taken into account in accordance with the growing period of wheat i.e. from 43rd week to 12th week for wheat yield analysis.

The following regression equation was obtained for analysis in Bathinda district of Punjab:

$$Y=3202.55+69.05*Time+20.92*Z11+38.30*Z21+5.60*Z231$$

$$R^2 = 0.93$$

Where,

Z11 is the sum product of maximum temperature,

Z21 is the sum product of minimum temperature,

Z131 is sum product of maximum temperature and rainfall.

The above equation clearly explained the relationship between time, maximum temperature and minimum temperature and its combination with rainfall which played an important role in determining the wheat yield for Bathinda region. The R^2 value of 93 per cent indicated that the variation of wheat yield in Bathinda region was 93 per cent explained by the weather variables. Gill *et al* (2015) also explained 90% variation in wheat yield due to weather.

4.2.1.2 Impact of climatic parameters on Wheat productivity at Faridkot

4.2.1.2.1 Basic model (model 1)

Weather data correlated with yield during critical periods were used for regression analysis. Initially, weeks were selected having high degree of correlation with wheat yield and were taken for further climate change impact analysis. The selected weeks, were clumped to form variables as X_1 (Tmax52nd week), X_2 (Tmax9th-10th week), X_3 (Tmin2nd week), X_4 (Tmin10th-12th weeks), X_5 (Rain51st) and X_6 (Rain3rd) which were similar in nature and have regular relationship. After selecting these variables, basic model: multiple linear regression model was used for determining the effect of climatic parameters on wheat yield. This regression equation for Faridkot district is as follows:

$$Y=1834.2-38.644*Tmax(52)+121.081*Tmax(9-10)-111.276*Tmin(2)+51.168*Tmin(10-12)+10.431*RF(51)+9.783*RF(3)$$

Table 4.51: Regression relationship of wheat yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	1834.20	0.09 ^{NS}
2	X ₁ (Tmax52 nd week)	-38.64	0.34 ^{NS}
3	X ₂ (Tmax9 th -10 th week)	121.08	0.03*
4	X ₃ (Tmin2 nd week)	-111.28	0.03*
5	X ₄ (Tmin10 th -12 th weeks)	51.17	0.09 ^{NS}
6	X ₅ (Rain51 st week)	10.43	0.90 ^{NS}
7	X ₆ (Rain3 rd week)	9.78	0.31 ^{NS}
R²=0.90			

*Indicate level of significant at five per cent level, NS-non-significant, P-probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature

Most of the climatic parameters reflected positive regression coefficient except for maximum temperature during 52nd week and minimum temperature during 2nd week, which were depicted in Table 4.51. Maximum temperature was significant at 5 per cent probability level during 9th-10th weeks and minimum temperature during 2nd week. The dependent variable (wheat yield) showed 90 per cent variations as explained by variables in the functions (weather parameters) for the Faridkot region.

4.2.1.2.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables were used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation derived using modified model for wheat yield analysis for Faridkot region is as follows:

$$y=12953.2-333.753*Tmax(52)+237.203*Tmax(9-10)-108.595*Tmin(2)-18.536*Tmin(10-12)-224.676*RF(51)+94.973*RF(3)-59.191*CI$$

Table 4.52: Regression relationship of wheat yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	12953.20	0.21 ^{NS}
2	X ₁ (Tmax52 nd week)	-333.75	0.22 ^{NS}
3	X ₂ (Tmax9 th -10 th weeks)	237.20	0.09 ^{NS}
4	X ₃ (Tmin2 nd week)	-108.60	0.04*
5	X ₄ (Tmin10 th -12 th weeks)	-18.54	0.73 ^{NS}
6	X ₅ (Rain51 st week)	-224.68	0.30 ^{NS}
7	X ₆ (Rain3 rd week)	94.97	0.23 ^{NS}
8	X ₇ (Composite index)	-59.19	0.26 ^{NS}
R²=0.95			

*Indicate level of significant at five per cent level, NS- non-significant, P- Probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 9th-10th weeks, rainfall during 3rd week and composite index, which was depicted in Table 4.52. Coefficient of almost all the variables was non-significant except for minimum temperature during 2nd week which were significant at 5 per cent probability level. Variation in wheat yield for Faridkot region is 95 per cent explainable using weather variables and CI together.

4.2.1.2.3 SPSS software (Model 3)

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Faridkot, weather data was selected for the period 2001-2010 while weeks were taken into account in accordance with the growing period of wheat i.e. from 43rd week to 12th week for wheat yield analysis.

The following regression equation is obtained for analysis in Faridkot district of Punjab:
 $Y = 3828.66 + 1.37 * Z_{121}$

$$R^2 = 0.49$$

Where,

Z₁₂₁ is sum product of maximum temperature and minimum temperature.

The above equation clearly explained the relationship between time, and its combination with maximum temperature and minimum temperature which played an

important role in determining the wheat yield at Faridkot region. The R^2 value of 49 per cent indicated that the variation of wheat yield at Faridkot region was 49 per cent explainable by the weather variables.

4.2.2 Impact of climatic parameters on cotton productivity in Punjab

For assessing the impact of climatic parameters on cotton productivity in Punjab, two districts Faridkot and Bathinda were selected and within each district effect of climatic parameters were described. For these two different districts, two different yield forecast equations were developed with three different models by using weekly data of weather variables, as discussed bellow:-

4.2.2.1 Impact of climatic parameters on American cotton productivity at Bathinda

4.2.2.1.1 Basic model (model 1)

Weather data correlated with yield during critical periods were used for regression analysis. Initially, weeks were selected having high degree of correlation with American cotton yield and were taken for further climate change impact analysis. The selected weeks, were clumped to form variables as X_1 (Tmax42nd week), X_2 (Tmax44th-45th weeks), X_3 (Tmin17th week), X_4 Tmin(42nd-45th weeks), X_5 (Rain20th-21st weeks) and X_6 (Rain38th week) which were similar in nature and have regular relationship. After selecting these variables, basic model: multiple linear regression model was used for determining the effect of climatic parameters on American cotton yield. This regression equation for Bathinda district is as follows:

$$Y=1400.48+22.837*Tmax(42)-27.198*Tmax(44-45)-53.950*Tmin(17)+17.972*Tmin(42-45)+1.533*RF(20-21)+0.245*RF(38)$$

Table 4.53: Regression relationship of American cotton yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	constant	1400.48	0.10 ^{NS}
2	X_1 (Tmax42 nd week)	22.84	0.17 ^{NS}
3	X_2 (Tmax44 th -45 th weeks)	-27.20	0.13 ^{NS}
4	X_3 (Tmin17 th week)	-53.95	0.04*
5	X_4 Tmin(42 nd -45 th weeks)	17.97	0.56 ^{NS}
6	X_5 (Rain20 th -21 st weeks)	1.53	0.65 ^{NS}
7	X_6 (Rain38 th week)	0.25	0.79 ^{NS}
$R^2=0.42$			

*Indicate level of significant at five per cent level, NS- non-significant, P- Probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature.

Most of the climatic parameters reflected positive regression coefficient except for maximum temperature during 44th-45th weeks and minimum temperature during 17th week, which was depicted in Table 4.53. Minimum temperature was significant at 5 per cent probability level during 17th weeks and dependent variable (American cotton yield) showed 42 per cent variations as explained by variables in the functions (weather parameters) for the Bathinda region.

4.2.2.1.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables were used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation derived using modified model for American cotton yield analysis for Bhatinda region is as follows:

$$Y = 28.857 + 34.866 * T_{\max}(42) - 13.686 * T_{\max}(44-45) - 32.214 * T_{\min}(17) - 0.288 * T_{\min}(42-45) + 0.700 * RF(20-21) - 0.154 * RF(38) + 2.570 * CI$$

Table 4.54: Regression relationship of American cotton yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	constant	28.86	0.97 ^{NS}
2	X ₁ (T _{max} 42 nd week)	34.87	0.02*
3	X ₂ (T _{max} 44 th -45 th weeks)	-13.69	0.38 ^{NS}
4	X ₃ (T _{min} 17 th week)	-32.21	0.16 ^{NS}
5	X ₄ (T _{min} 42 nd -45 th weeks)	-0.29	0.99 ^{NS}
6	X ₅ (Rain20 th -21 st weeks)	0.70	0.81 ^{NS}
7	X ₆ (Rain38 th week)	-0.15	0.85 ^{NS}
8	X ₇ (Composite index)	2.57	0.01*
R²=0.61			

*Indicate level of significant at five per cent level, NS- non-significant, P- Probability

Note:- T_{max}- maximum temperature, T_{min}- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 42nd weeks, minimum temperature during 20th-21st week and composite index, which was depicted in Table 4.54. Maximum temperature during 42nd weeks and composite index was significant at 5 per cent probability level. Variation in American

cotton yield for Bathinda region is 61 per cent explainable using weather variables and CI together.

4.2.2.1.3 (SPSS software) Model 3

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Bathinda, weather data was selected for the period 1981-2014 while weeks were taken into account in accordance with the growing period of American cotton i.e. from 14th week to 47th week for American cotton yield analysis.

The regression equation using SPSS model to analyze the yield of American cotton for Bathinda district is as follows:

$$Y=649.75+7.97*Time+19.05*Z11+0.38*Z131-0.44*Z231$$

$$R^2 = 0.83$$

Where,

Z11 is the sum product of maximum temperature,

Z131 is the sum product of maximum temperature and rainfall,

Z231 is sum product of minimum temperature and rainfall.

The above equation clearly explained the relationship between time, maximum temperature, minimum temperature and its combination with rainfall which played an important role in determining the American cotton yield for Bathinda region. The R^2 value of 83 per cent indicated that the variation of American cotton yield in Bathinda region was 83 per cent explained by the weather variables. Gill and Bhatt (2015) reported similar results which revealed that SPSS model fits better for the selected districts as far as American cotton yield is concerned.

4.2.2.1.2 Impact of climatic parameters on Desi cotton productivity at Bathinda

4.2.2.1.2.1 Basic model (model 1)

Weather data correlated with yield during critical periods were used for regression analysis. Initially, weeks were selected with high degree of correlation with Desi cotton yield and were taken for further climate change analysis. The selected weeks, were clumped to form variables as X_1 (Tmax16th week), X_2 (Tmax33rd week), X_3 (Tmax42nd week), X_4 (Tmax44th -45th weeks), X_5 (Tmin40th -43rd weeks), X_6 X_6 (Rain33rd -34th weeks) and X_7 (Rain38th week) which were similar in nature and have regular relationship. After selecting these variables, basic models multiple linear regression model was used for determining the effect of climatic parameters on Desi cotton yield. The regression equation using basic model to analyze the yield of Desi cotton for Bathinda district is as follows:

$$Y=261.688+7.834*Tmax(16)+20.099*Tmax(33)-14.606*Tmax(42)-9.224*Tmax(44-45)-8.398*Tmin(40-43)-0.521*RF(33-34)-0.781*RF(38)$$

Table 4.55: Regression relationship of desi cotton yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	261.69	0.78 ^{NS}
2	X ₁ (Tmax16 th week)	7.83	0.40 ^{NS}
3	X ₂ (Tmax33 rd week)	20.10	0.28 ^{NS}
4	X ₃ (Tmax42 nd week)	-14.61	0.29 ^{NS}
5	X ₄ (Tmax44 th -45 th weeks)	-9.22	0.51 ^{NS}
6	X ₅ (Tmin40 th -43 rd weeks)	-8.40	0.60 ^{NS}
7	X ₆ (Rain33 rd -34 th weeks)	-0.52	0.65 ^{NS}
8	X ₇ (Rain38 th week)	-0.78	0.21 ^{NS}
R² =0.34			

NS- non-significant, P- Probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 16th and 33rd weeks, which were depicted in Table 4.55. Coefficient of almost all the variables was non-significant and dependent variable (Desi cotton yield) showed 34 per cent variations as explained by variables in the functions (weather parameters) for the Bathinda region.

4.2.2.1.2.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables were used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation using modified to analyze the yield of Desi cotton model for Bathinda district is as follows:

$$Y = -1391.97 + 15.216 * \text{Tmax}(16) + 28.153 * \text{Tmax}(33) - 1.812 * \text{Tmax}(42) - 0.122 * \text{Tmax}(44-45) - 3.741 * \text{Tmin}(40-43) + 0.542 * \text{RF}(33-34) - 1.126 * \text{RF}(38) + 1.986 * \text{CI}$$

Table 4.56: Regression relationship of desi cotton yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	-1391.97	0.10 ^{NS}
2	X ₁ (Tmax16 th week)	15.22	0.04*
3	X ₂ (Tmax33 rd week)	28.15	0.05*
4	X ₃ (Tmax42 nd week)	-1.81	0.87 ^{NS}
5	X ₄ (Tmax44 th -45 th weeks)	-0.12	0.99 ^{NS}
6	X ₅ (Tmin40 th -43 rd weeks)	-3.74	0.75 ^{NS}
7	X ₆ (Rain33 rd -34 th weeks)	0.54	0.55 ^{NS}
8	X ₇ (Rain38 th week)	-1.13	0.02*
9	X ₈ (Composite index)	1.99	0.00 ^{NS}
R² =0.65			

*Indicate level of significant at five per cent level, NS- non-significant, P- Probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for maximum temperature during 16th -33rd weeks, rainfall during 33rd-34th week and composite index, which was depicted in Table 4.56. Maximum temperature during 16th and 33rd weeks and rainfall during 38th week was significant at 5 per cent probability level. Variation in desi cotton yield for Bhatinda region is 65 per cent explainable using weather variables and CI together.

4.2.2.1.2.3 (SPSS software) Model 3

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Bathinda, weather data was selected for the period 1981-2007 while weeks were taken into account in accordance with the growing period of Desi cotton i.e. from 14th week to 47th week for Desi cotton yield analysis.

The regression equation using SPSS software to analyze the yield of Desi cotton for Bathinda district is as follows:

$$Y=358.680+8.322*\text{time}+0.343*Z121+0.028*Z131$$

$$R^2 = 0.82$$

Where,

Z121 is the sum product of maximum temperature and minimum temperature,

Z131 is the sum product of maximum temperature and rainfall,

The above equation clearly explained the relationship between time, maximum temperature, minimum temperature and its combination with rainfall which played an important role in determining the Desi cotton yield for Bathinda region. The R^2 value of 82 per cent indicated that the variation of Desi cotton yield in Bathinda region was 82 per cent explainable by the weather variables.

4.2.2.2.1 Impact of climatic parameters on American cotton productivity at Faridkot

4.2.2.2.1.1 Basic model (model 1)

Weather data correlated with yield at critical periods were used for regression analysis. Initially, weeks were selected which were having high degree of correlation with wheat yield and were taken for further climate change analysis. The selected weeks, were clumped to form variables as X_1 (Tmax18th-19th weeks), X_2 (Tmax30th-37th week), X_3 (Tmax40th-41th week), X_4 (Tmin30th-37th week), X_5 (Tmin41th-47th weeks), X_6 (Rain 22nd-23rd) and X_7 (Rain 28th week), which were similar in nature and have regular relationship. After selection of these variables are done, basic model: multiple linear regression model was selected for determining the effect of climatic parameters on American cotton yield. The regression equation using basic model to analyze the yield of American cotton for Faridkot district is as follows:

$$Y = 4427.85 - 44.370 * \text{Tmax}(18-19) - 33.764 * \text{Tmax}(23-24) + 10.916 * \text{Tmin}(14-19) - 16.196 * \text{Tmin}(27-37) - 32.251 * \text{Tmin}(40-47) - 38.376 * \text{RF}(15-16) + 6.619 * \text{RF}(36-38)$$

Table 4.57: Regression relationship of American cotton yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	4427.85	0.44 ^{NS}
2	X_1 (Tmax18 th -19 th weeks)	-44.37	0.47 ^{NS}
3	X_2 (Tmax23 rd -24 th weeks)	-33.76	0.63 ^{NS}
4	X_3 (Tmin14 th -19 th weeks)	10.92	0.89 ^{NS}
5	X_4 (Tmin27 th -37 th weeks)	-16.20	0.96 ^{NS}
6	X_5 (Tmin40 th -47 th weeks)	-32.25	0.62 ^{NS}
7	X_6 (Rain15 th -16 th weeks)	-38.38	0.68 ^{NS}
8	X_7 (Rain36 th -38 th weeks)	6.62	0.58 ^{NS}
$R^2 = 0.83$			

NS- non-significant, P- Probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for minimum temperature during 14th-19th weeks and rainfall 36th-38th weeks, which is depicted in Table 4.57. Coefficient of almost all the variables was non-significant and dependent variable (American cotton yield) showed 83 per cent variations as explained by variables in the functions (weather parameters) for the Faridkot region

4.2.2.1.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables was used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation using modified model to analyze the yield of American cotton for Faridkot district is as follows:

$$Y = 4147.46 - 39.636 * T_{\max}(18-19) - 39.169 * T_{\max}(23-24) + 14.741 * T_{\min}(14-19) - 36.566 * T_{\min}(27-37) - 19.706 * T_{\min}(40-47) - 69.363 * RF(15-16) + 3.687 * RF(36-38) + 4.378 * CI$$

Table 4.58: Regression relationship of American cotton yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	4147.46	0.43 ^{NS}
2	X ₁ (T _{max} 18 th -19 th weeks)	-39.64	0.47 ^{NS}
3	X ₂ (T _{max} 23 rd -24 th weeks)	-39.17	0.53 ^{NS}
4	X ₃ (T _{min} 14 th -19 th weeks)	14.74	0.82 ^{NS}
5	X ₄ (T _{min} 27 th -37 th weeks)	-36.57	0.88 ^{NS}
6	X ₅ (T _{min} 40 th -47 th weeks)	-19.71	0.71 ^{NS}
7	X ₆ (Rain15 th -16 th weeks)	-69.36	0.45 ^{NS}
8	X ₇ (Rain36 th -38 th weeks)	3.69	0.70 ^{NS}
9	X ₈ (Composite index)	4.38	0.34 ^{NS}
R² = 0.95			

NS- non-significant, P- Probability

Note:- T_{max}- maximum temperature, T_{min}- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient except for minimum temperature during 14th -19th weeks, rainfall during 36th -38th week and composite

index, which was depicted in Table 4.58. Coefficient of almost all the variables were non-significant. Variation in American cotton yield for Faridkot region is 95 per cent explainable using weather variables and CI together.

4.2.2.2.1.3 (SPSS software) Model 3

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Faridkot, weather data was selected for the period 2001-2014 while weeks were taken into account in accordance with the growing period of American cotton i.e. from 14th week to 47th week for American cotton yield analysis.

The regression equation using SPSS model to analyze the yield of American cotton for Faridkot district is as follows:

$$Y=400.39+61.19*Time-0.56*Z30+0.07*Z131$$

$$R^2 = 0.97$$

Where,

Z30 is the sum of rainfall,

Z131 is the sum product of maximum temperature and rainfall.

The above equation clearly explained the relationship between time, maximum temperature, rainfall and its combination with rainfall which played an important role in determining the American cotton yield for Faridkot region. The R^2 value of 97 per cent indicated that 97 per cent variation of American cotton yield in Faridkot region was explained by the weather variables.

4.2.2.2.2 Impact of climatic parameters on Desi cotton productivity at Faridkot

4.2.2.2.2.1 Basic model (model 1)

Weather data correlated with yield at critical periods were used for regression analysis. Initially, weeks were selected which were having high degree of correlation with Desi cotton yield and were taken for further climate change impact analysis. The selected weeks, were clumped to form variables as X_1 (Tmax32nd week), X_2 (Tmax40th week), X_3 (Tmini 28th-33rd weeks), X_4 (Tmini 39th -46th weeks), X_5 (RF15th-16th weeks), X_6 (Rain26th week) which were similar in nature and have regular relationship. After selection of these variables are done, basic model: multiple linear regression model was selected for determining the effect of climatic parameters on Desi cotton yield.

The regression equation using basic model to analyze the yield of Desi cotton for Faridkot district is As follows:

$$Y=6513.06-48.845*T_{\max}(28-33)-23.531*T_{\max}(40-45)-120.776*T_{\min}(31-33)-5.874*RF(21-22)-3.519*RF(33-34)$$

Table 4.59: Regression relationship of desi cotton yield with weather parameters using basic model

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	6513.06	0.29 ^{NS}
2	X ₁ (T _{max} 28 th -33 rd weeks)	-48.85	0.71 ^{NS}
3	X ₂ (T _{max} 40 th -45 th weeks)	-23.53	0.51 ^{NS}
4	X ₃ (T _{min} 31 st -33 rd weeks)	-120.78	0.15 ^{NS}
5	X ₄ (Rain21 st -22 nd weeks)	-5.87	0.63 ^{NS}
6	X ₅ (Rain33 rd -34 th weeks)	-3.52	0.54 ^{NS}
R²=0.91			

NS- non-significant, P- Probability

Note:- T_{max}- maximum temperature, T_{min}- minimum temperature.

Most of the climatic parameters reflected negative regression coefficient, which is depicted in Table 4.59. Coefficient of almost all the variables was non-significant and dependent variable (Desi cotton yield) showed 91 per cent variations as explained by variables in the functions (weather parameters) for the Faridkot region.

4.2.2.2.2 Modified model (model 2)

In modified model, to obtain forecast equation using multiple regression analysis, the weather parameters during critical periods along with composite index variables were used. An overall composite index (CI) was derived for merged technological parameters (mechanization, seed, irrigation and fertilizer). The technology is advancing and improving with time thus there is a need to introduce CI in the basic model for modifying it and introducing it as a linear time scale dummy variable. Regression equation using modified model to analyze the yield of Desi cotton for Faridkot district is as follows:

$$Y=7846.87-75.795*T_{\max}(28-33)-22.093*T_{\max}(40-45)-123.101*T_{\min}(31-33)-5.670*RF(21-22)-7.493*RF(33-34)-2.452*CI$$

Table 4.60: Regression relationship of desi cotton yield with weather parameters using composite index

S. No.	Variables	Linear	
		Coefficient	P-Value
1	Constant	7846.87	0.49 ^{NS}
2	X ₁ (Tmax28 th -33 rd weeks)	-75.80	0.74 ^{NS}
3	X ₂ (Tmax40 th -45 th weeks)	-22.09	0.68 ^{NS}
4	X ₃ (Tmin31 st -33 rd weeks)	-123.10	0.33 ^{NS}
5	X ₄ (Rain21 st -22 nd weeks)	-5.67	0.75 ^{NS}
6	X ₅ (Rain33 rd -34 th weeks)	-7.49	0.70 ^{NS}
7	X ₆ (Composite index)	-2.45	0.81 ^{NS}
R²=0.92			

NS-non-significant, P-probability

Note:- Tmax- maximum temperature, Tmin- minimum temperature

Most of the climatic parameters reflected negative regression coefficient, which was depicted in Table 4.60. Coefficient of almost all the variables were non-significant. Variation in Desi cotton yield for Faridkot region is 92 per cent explained using weather variables and CI together.

4.2.2.2.3 SPSS software (Model 3)

The impact of climatic parameters (maximum temperature, minimum temperature and rainfall) on wheat productivity was studied by using SPSS software. In Faridkot, weather data was selected for the period 2001-2010 while weeks were taken into account in accordance with the growing period of Desi cotton i.e. from 14th week to 47th week for Desi cotton yield analysis.

The following regression equation is obtained for analysis in Faridkot district of Punjab:

$$Y=213.699+51.872*Time+0.050*Z231$$

Z231 is the sum product of minimum temperature and rainfall

$$R^2=0.96$$

The above equation clearly explained the relationship between time, maximum temperature its combination with rainfall which played an important role in determining the Desi cotton yield for Faridkot region. The R² value of 96 per cent indicated that the variation of Desi cotton yield in Faridkot region was 96 per cent explained by the weather variables.

4.3 Validations of the models

Forecasted yield of crops grown at Bathinda from the year 2008 to 2017 was used for validation of wheat, American cotton and desi cotton against the actual yield and the error percentage was observed for the above crops. At Faridkot these models has been verified with independent dataset for the years from 2011-17 outside sampling series for wheat and American cotton. In case of desi cotton all the models calibrated from 2001 to 2008 and validated for the years 2009 to 2011 and as yield data was not available from 2012 onwards. The figure 4.13 to 4.18 showed the comparison between actual and forecast yield by three different models (Basic model, Modified model and SPSS software) for wheat, American cotton and Desi cotton.

For wheat grown in Bhatinda district, the results depicted (Figure 4.13) that SPSS software (model 3) was best fit when crop sown during the years 2008, 2009, 2011 to 2017, whereas, for the year 2010 modified model (model 2) was best fitted. For the year 2010 all three models (model 1, 2 and 3) showed to be best fit to predict the yield. The forecasted yield of wheat was analysed and represented as Table 4.61. The error per cent was calculated lowest by -3.4 per cent during the year 2011-12 through SPSS software and was recorded 3.2 per cent during the year 2015-16, which was the highest. In case of basic model (model 1) error per cent ranged between -20.7 per cent (2007-08) to -1.7 per cent during the year 2009-10. When modified model was used to forecast the crop yield the error per cent recorded was -26.7 per cent during the year 2014-15 which was recorded lowest. It went up to 2.7 per cent during the year 2009-10 and was recorded highest.

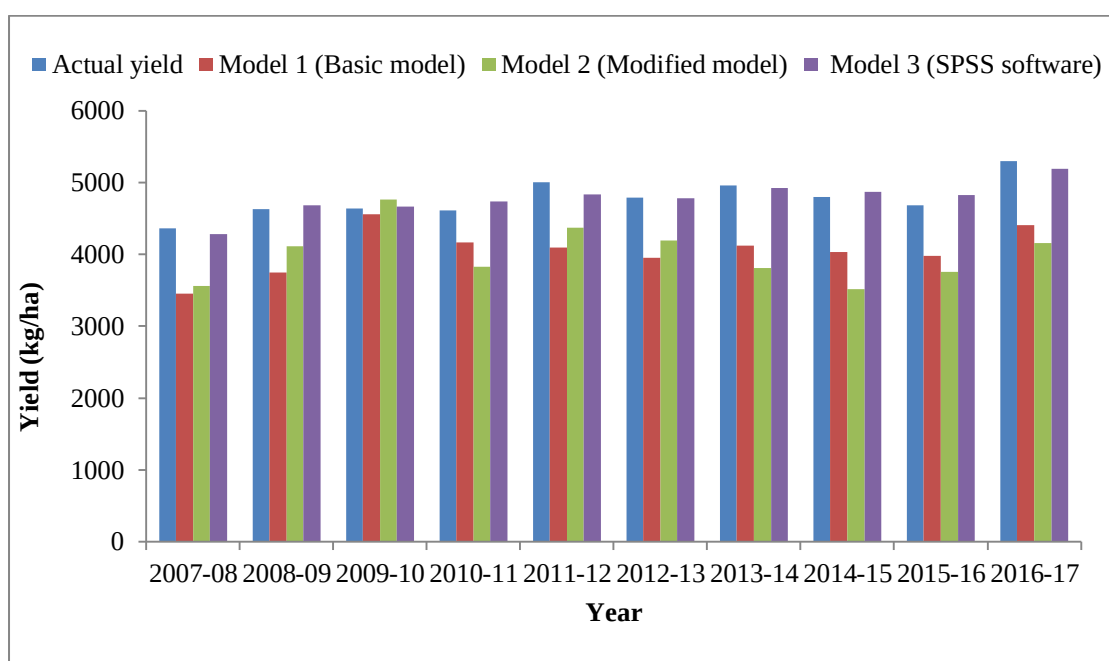


Fig. 4.13: Validation of statistical models in wheat at Bathinda (2008-2017)

For American cotton grown in Bathinda district, the results depicted (Figure 4.14) that modified model (model 2) was best fit when crop sown during the years 2008, 2009, 2010, 2011 and 2012, whereas, for the year 2013 basic model (model 1) was best fitted. For the year 2014, 2015, 2016 and 2017 SPSS software (model 3) showed to be best fit to predict the yield. The forecasted yield of American cotton was analysed and represented as Table 4.63. The error per cent was calculated lowest by -28.6 per cent during the year 2008 through basic model (model 1) and was recorded 17.1 per cent during the year 2014, which was the highest. In case of modified model (model 2) error per cent ranged between -27.5 per cent (2015) to 21.8 per cent during the year 2014. When SPSS software (model 3) was used to forecast the crop yield the error per cent recorded was -26.7 per cent during the year 2011 which was recorded lowest. It went up to 13.5 per cent during the year 2015 and was recorded highest.

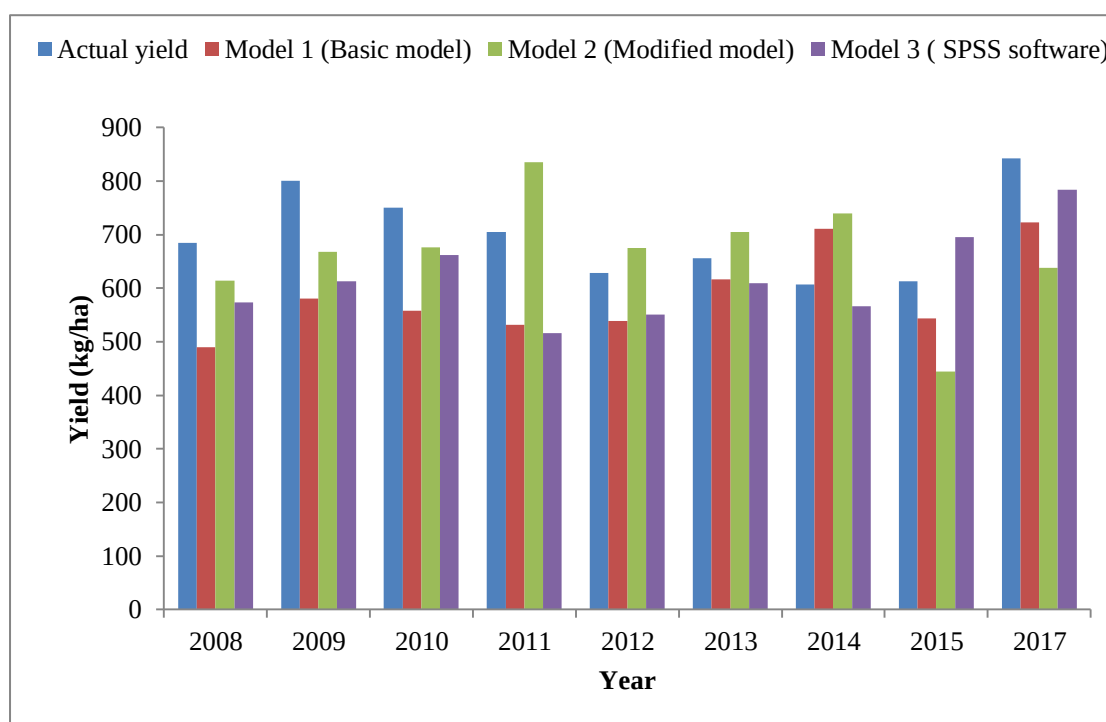


Fig. 4.14: Validation of statistical models in American cotton at Bathinda (2008-2017)

For Desi cotton grown in Bathinda district, the results depicted (Figure 4.15) that modified model (model 2) was best fit when crop sown during the years 2008, 2009, 2010 and 2014, whereas, for the year 2011, 2012, 2015 and 2017 SPSS software (model 3) was best fitted. For the year 2013 basic model (model 1) showed to be best fit to predict the yield. The forecasted yield of American cotton was analysed and represented as Table 4.65. The error per cent was calculated lowest by -27.3 per cent during the year 2009 through basic model (model 1) and was recorded 10.0 per cent during the year 2015, which was the highest. In case of modified model (model 2) error per cent ranged between -29.0 per cent (2017) to

2.9 per cent during the year 2008. When SPSS software (model 3) was used to forecast the crop yield the error per cent recorded was -18.5 per cent during the year 2009 which was recorded lowest. It went up to 12.8 per cent during the year 2014 and was recorded highest.

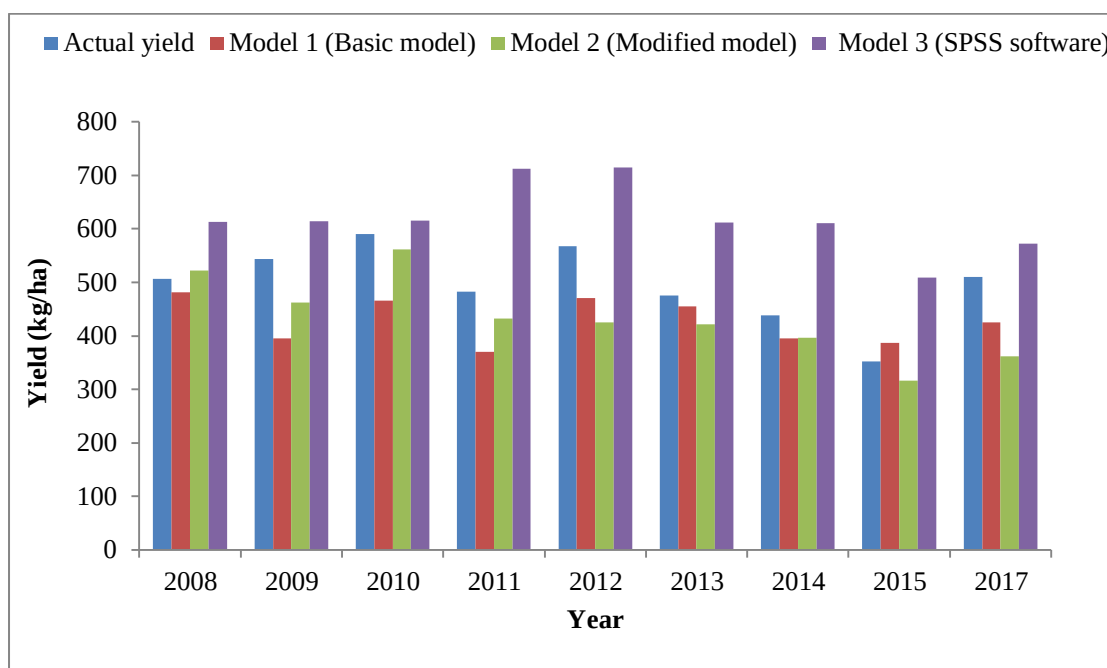


Fig. 4.15: Validation of statistical models in desi cotton at Bathinda (2008-2017)

For wheat grown in Faridkot district, the results depicted (Figure 4.16) that modified model (model 2) was best fit when crop sown during the years 2010-2011, 2011-2012, 2013-2014 and 2016-2017, whereas, for the year 2012-2013 and 2015-2016 basic model (model 1) was best fitted. For the year 2014-2015 SPSS software (model 3) showed to be best fit to predict the yield. The forecasted yield of wheat was analysed and represented as Table 4.62.

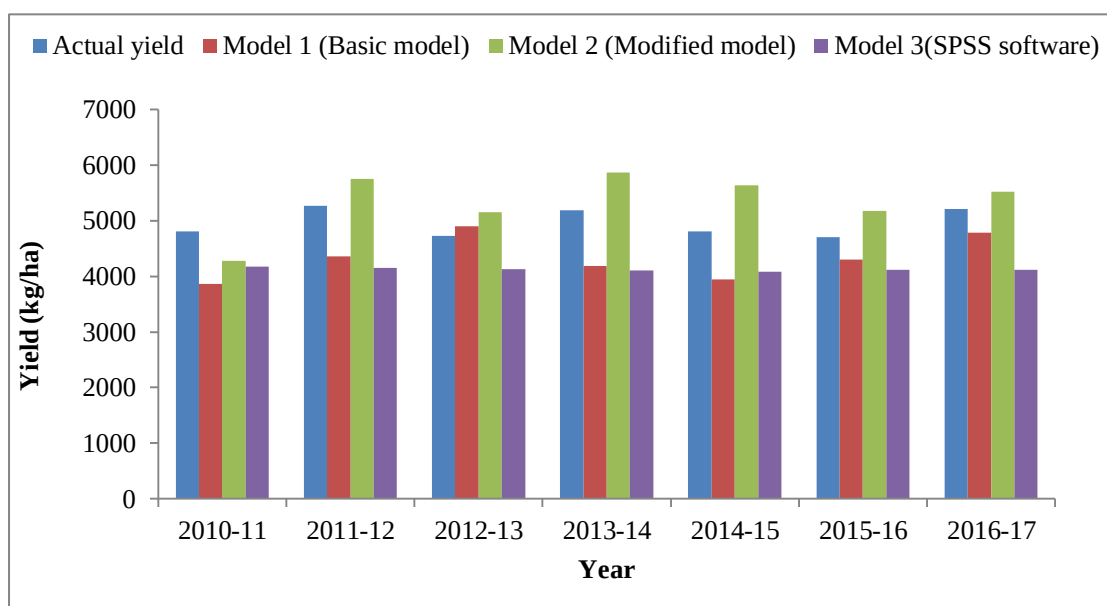


Fig. 4.16: Validation of statistical models in wheat at Faridkot (2011-2017)

The error per cent was calculated lowest by -19.7 per cent during the year 2010-11 through basic model and was recorded 3.6 per cent during the year 2012-13, which was the highest. In case of modified model (model 2) error per cent ranged between -11.1 per cent (2010-11) to 17.1 per cent during the year 2014-15. When SPSS software (model 3) was used to forecast the crop yield the error per cent recorded was -21.2 per cent during the year 2011-12 which was recorded lowest. It went up to -12.7 per cent during the year 2012-13 and was recorded highest.

For American cotton grown in Faridkot district, the results depicted (Figure 4.17) that SPSS software (model 3) was best fit when crop sown during the years 2011, 2012 and 2015 whereas, for the year 2011, 2013 and 2017 basic model (model 1) was best fitted. For the year 2014 modified model (model 2) showed to be best fit to predict the yield. The forecasted yield of American cotton was analysed and represented as Table 4.64. The error per cent was calculated lowest by -18.1 per cent during the year 2015 through basic model (model 1) and was recorded 18.3 per cent during the year 2013, which was the highest. In case of modified model (model 2) error per cent ranged between -28.8 per cent (2012) to 28.2 per cent during the year 2013. When SPSS software (model 3) was used to forecast the crop yield the error per cent recorded was -20.4 per cent during the year 2013 which was recorded lowest. It went up to 19.1 per cent during the year 2017 and was recorded highest.

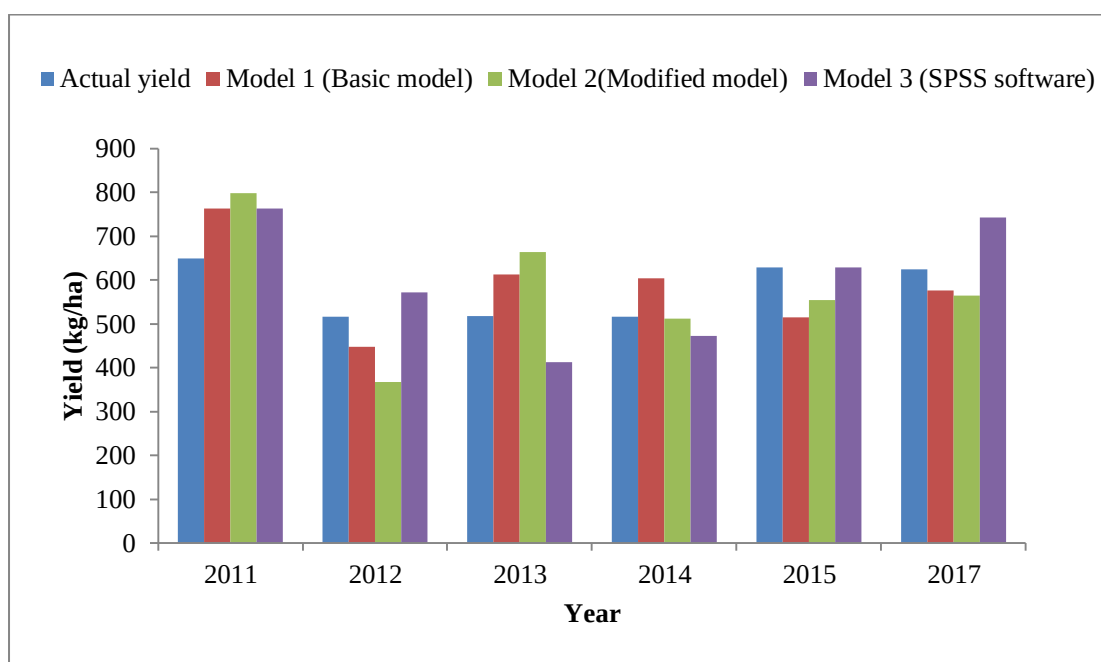


Fig. 4.17: Validation of statistical models in American cotton at Faridkot (2015-2017)

For Desi cotton grown in Faridkot district, the results depicted (Figure 4.18) that SPSS software (model 3) was best fit when crop sown during the years 2009, whereas, for the year 2010 basic model (model 2) was best fitted. For the year 2011 modified model (model 2) showed to be best fit to predict the yield. The forecasted yield of desi cotton was analysed and represented as Table 4.66. The error per cent was calculated lowest by -18.3 per cent during the year 2011 through basic model (model 1) and was recorded 16.4 per cent during the year 2009, which was the highest. In case of modified model (model 2) error per cent ranged between 13.1 per cent (2011) to 22.2 per cent during the year 2010. When SPSS software (model 3) was used to forecast the crop yield the error per cent recorded was 6.4 per cent during the year 2009 which was recorded lowest. It went up to 20.6 per cent during the year 2010 and was recorded highest.

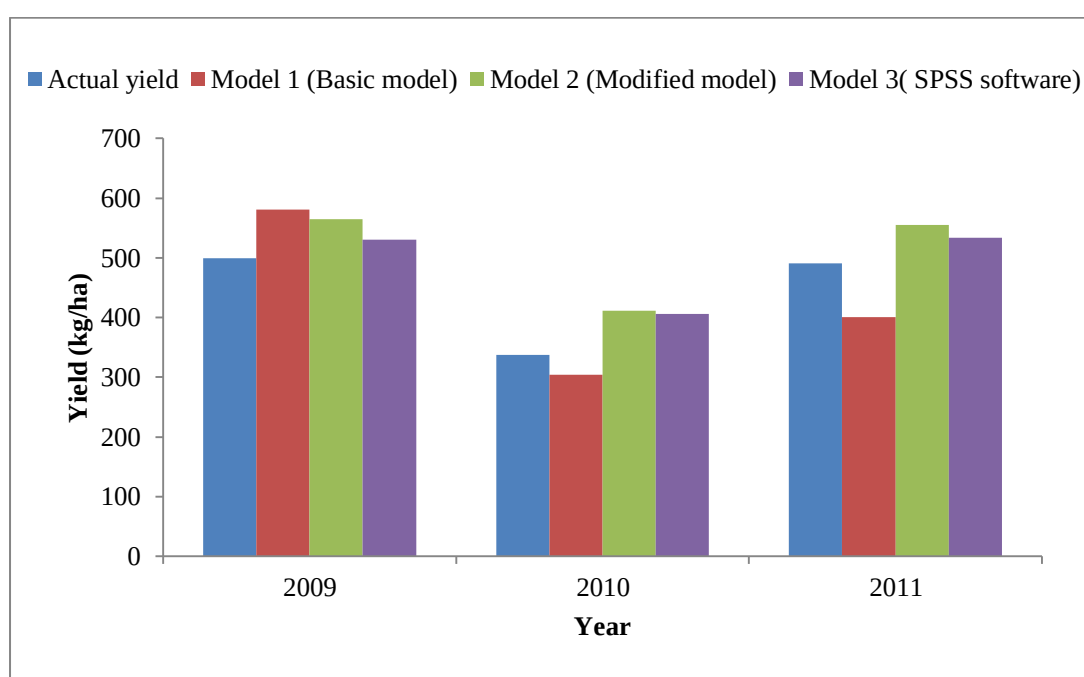


Fig. 4.18: Validation of statistical models in desi cotton at Faridkot (2009-2011)

Table 4.61: Forecast yield and error per cent of different models in wheat at Bathinda (2011 to 2017)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model(model 2)		SPSS Software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Bathinda							
2007-08	4361	3457	-20.7	3561	-18.3	4278	-1.9
2008-09	4628	3746	-19.1	4111	-11.2	4686	1.3
2009-10	4634	4557	-1.7	4761	2.7	4669	0.8
2010-11	4609	4165	-9.6	3827	-17.0	4737	2.8
2011-12	5000	4095	-18.1	4370	-12.6	4832	-3.4
2012-13	4787	3950	-17.5	4191	-12.5	4777	-0.2
2013-14	4958	4118	-16.9	3806	-23.2	4923	-0.7
2014-15	4797	4035	-15.9	3517	-26.7	4870	1.5
2015-16	4679	3983	-14.9	3759	-19.7	4826	3.2
2016-17	5300	4404	-16.9	4162	-21.5	5190	-2.1

Table 4.62: Forecast yield and error per cent of different models in wheat at Faridkot (2011 to 2017)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model(model 2)		SPSS Software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Faridkot							
2010-11	4810	3860	-19.7	4278	-11.1	4178	-13.1
2011-12	5266	4355	-17.3	5751	9.2	4150	-21.2
2012-13	4730	4903	3.6	5148	8.8	4132	-12.7
2013-14	5181	4185	-19.2	5868	13.3	4102	-20.8
2014-15	4807	3940	-18.0	5630	17.1	4087	-15.0
2015-16	4698	4299	-8.5	5171	10.1	4111	-12.5
2016-17	5204	4787	-8.0	5519	6.1	4116	-20.9

Table 4.63: Forecast yield and error per cent of different models in American cotton at Bathinda (2011-2017)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model(model 2)		SPSS software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Bathinda							
2008	685	489	-28.6	615	-10.3	574	-16.2
2009	800	580	-27.4	668	-16.5	613	-23.4
2010	750	557	-25.7	676	-9.9	662	-11.8
2011	705	532	-24.5	835	18.5	516	-26.7
2012	629	538	-14.4	675	7.2	551	-12.4
2013	656	616	-6.1	705	7.5	610	-7.1
2014	607	711	17.1	739	21.8	567	-6.7
2015	613	544	-11.2	444	-27.5	695	13.5
2017	842	723	-14.1	638	-24.2	784	-6.8

Table 4.64: Forecast yield and error per cent of different models in American cotton at Faridkot (2011-2017)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model(model 2)		SPSS software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Faridkot							
2011	649	764	17.7	798	23.0	764	17.7
2012	516	447	-13.3	368	-28.8	572	10.9
2013	518	613	18.3	664	28.2	413	-20.4
2014	517	604	16.8	512	-0.9	472	-8.7
2015	629	515	-18.1	554	-11.9	629	-0.1
2017	624	576	-7.7	565	-9.4	743	19.1

Table 4.65: Forecast yield and error per cent of different models in desi cotton at Bathinda (2008-17)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model (model 2)		SPSS software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Bathinda							
2008	507	481	-5.1	522	2.9	613	-8.5
2009	544	396	-27.3	462	-15.1	614	-18.5
2010	590	466	-21.1	561	-4.8	615	-14.8
2011	483	371	-23.2	432	-10.5	712	-2.9
2012	568	470	-17.2	426	-25.1	715	-9.7
2013	475	456	-4.1	421	-11.3	612	11.1
2014	438	396	-9.6	397	-9.3	611	12.8
2015	352	387	10.0	317	-10.0	509	-2.2
2017	510	425	-16.6	362	-29.0	573	-15.1

Table 4.66: Forecast yield and error per cent of different models in desi cotton at Faridkot (201-2011)

Year	Actual yield(kg/ha)	Basic model(model 1)		Modified model (model 2)		SPSS software (model 3)	
		Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %	Forecast yield (kg/ha)	Error %
Faridkot							
2009	499	581	16.4	565	13.2	531	6.4
2010	337	304	-9.7	412	22.2	406	20.6
2011	491	401	-18.3	555	13.1	534	8.7

CHAPTER V

SUMMARY

Change in climate associated with unabated increase in greenhouse gases, including fluorinated gases, nitrous oxide, carbon dioxide and methane. It can pose threats to agriculture productivity and food security by modifying the spatial and temporal distribution of rainfall, temperature and water availability (Ali *et al* 2017). Wheat (*triticum aestivum* L.) is most staple cereal crop, belongs to Gramineae family. In India, it ranks second in area and production after rice. In Punjab, wheat is a major cereal crop during *rabi* season. In 2016-17 it was grown on area of 34.95 lac hectares with production of 176.36 lac tonnes and average yield of 50.46 quintals per hectare (Anonymous, 2018). Low temperature and dew formation during early phase promotes tillering, whereas, hot and humid condition encourages insects and diseases. Wheat yield reduced by 7.5 per cent for every 10°C increase of temperature (Graciela *et al* 2003).

Cotton (*Gossypium* spp.) known as king of fibers is an important cash crop of India and World. It belongs to the genus *Gossypium* under tribe *Gossypieae* of Malvaceae family. It is also called the backbone of textile industry. For germination of cotton 16°C temperature is required and 21 to 27°C temperature is required for proper crop growth. During 2017-18 total production was 12.71 lakh bales with an average yield of 7.53 quintals lint per hectare. At the time of fruiting phase, the day temperature ranging from 27 to 32°C and cool nights are required. Dry period is good for boll opening. The bright sunshine from mid September to November i.e picking periods assure a best quality of the produce (Anonymous 2019).

In Punjab, sowing period of cotton is recommended from 1st April to 15th May. Very early and too late sowing of cotton is not suitable and associated with the poor crop stand and decreased productivity. Therefore any deviation in mean temperature or heat stress is expected to decrease the cotton yields (Singh *et al* 2007).

The study was carried out with the following specific objectives:

1. To comprehend the changing pattern of the important weather parameters in two districts (Faridkot and Bathinda) of south west Punjab.
2. To analyze the impact of climate change on the productivity of wheat and cotton crops in south west Punjab.

For evaluating the objectives of the study:

Crop Data: To study the change in climatic pattern and its impact on crop productivity (i.e. cotton and wheat) in Punjab. The yearly data on area, production and yield under cotton and wheat crops for the period of 37 years (1981-2017) at Bathinda and 17 years (2001-2017) at Faridkot has been collected from Statistical Abstract of Punjab. The data was tabulated and analyzed using suitable statistical methods.

Climatic or weather Data: The weather data for the period of 37 years (1981-2017) at Bathinda and 17 years (2001-2017) at Faridkot was collected on weekly basis for meteorological factors (maximum and minimum temperature and rainfall). The weather data was collected from Punjab Agricultural University (PAU) Regional Research Station, Faridkot and Regional Research Station, Bathinda.

The salient features of the study are as under:

- In Bathinda district, the lowest maximum temperature was recorded during January and highest during May over the period of 1981-2017
- The minimum temperature of Bathinda district was observed highest during the month of July and lowest during January from the year 1981-2017
- Rainfall was highest during the month of August and lowest during November at Bathinda from the year 1981-2017
- The maximum temperature of Faridkot district was highest during the month of May, while the lowest during January over the period of 2001-2017
- Minimum temperature was highest during the month of July and lowest during January at Faridkot from the year 2001-2017
- The rainfall of Faridkot district was highest during the month of August and lowest during November from the year 2001-2017
- In case of maximum temperature at Bathinda, more variation has been found in fourth decade as compared to others and at Faridkot the variation was observed more during second pentad
- More variation in minimum temperature has been found in fourth decade and third pentad at Bathinda and Faridkot, respectively
- In case of rainfall at Bathinda, more variation has been found in fourth decade as compared to others. Whereas, at Faridkot the variation was more during second pentad

The impact of climatic parameters on crops: The growing period of cotton crop was considered between 14th to 47th weeks and 43rd to 12th weeks for wheat. The degree and nature of the relationship between the productivity of crops was evaluated with correlation techniques and it was also used for obtaining this relationship for weekly climate over their growing periods. For evaluating the results, statistical model was developed from a data series of 27 years from 1981 to 2007 for Bathinda districts and 10 years 2001 to 2010 for Faridkot districts using linear and multiple regression method and verified with independent dataset for the years from 2008 to 2017 for Bathinda and 2011 to 2017 for Faridkot districts outside their sampling series.

- Maximum temperature during 2nd to 3rd weeks and minimum temperature during 48th week of wheat growing season had negative effect on wheat yield at Bathinda.
- At Faridkot district, minimum temperature during 2nd week during booting stage showed negative effect.
- In Bathinda district, maximum temperature during 42nd weeks (at boll development and peak flowering stage) of American cotton and desi cotton had positive effect. In case of desi cotton minimum temperature during 40th to 43rd weeks and rainfall during 33rd to 34th weeks had negative effect on its yield.
- Maximum temperature during 23rd to 24th week (flower bud form) of American cotton in Faridkot district had negative effect on its yield, whereas, rainfall during 15th to 16th week (at germination and emergence stage) had negative impact on American cotton yield.
- Maximum temperature during 28th to 33rd weeks and minimum temperature during 31st - 33rd week of desi cotton growing season had negative effect on desi cotton yield, whereas, rainfall during 33rd to 34th week had negative impact on its yield at Faridkot district.
- The three models (i.e. SPSS software, basic model and modified model) predicted wheat and cotton yield and the error per cent of all these models remained below 30 per cent for two districts (Faridkot and Bathinda) of south west Punjab
- For desi cotton, SPSS software was best fit for Faridkot and Bathinda region.
- In case of wheat, SPSS software fits better for Bathinda region and modified model gave best result for Faridkot.
- For American cotton, SPSS software was best fit for Faridkot and Bathinda region.

In case of maximum temperature at Bathinda, more variation has been found in fourth decade as compared to others. Whereas, at Faridkot the variation was observed more during second pentad. More variation in minimum temperature has been found in fourth decade and third pentad at Bathinda and Faridkot, respectively. In case of rainfall at Bathinda, more variation has been found in fourth decade as compared to others. Whereas, at Faridkot the variation was more during second pentad. The three models SPSS software, basic model as well as modified model predicted wheat and cotton yield and the error per cent of all these models was ranged below 30 % for two districts Bathinda and Faridkot of south west Punjab.

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