EFFECT OF WEATHER PARAMETERS ON THE PRODUCTION OF MANGO AND CITRUS IN UNA DISTRICT OF HIMACHAL PRADESH

Thesis

by

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(NH-2018-17-M)

Submitted to

Dr. YASHWANT SINGH PARMAR UNIVERSITY OF HORTICULTURE AND FORESTRY, NAUNI, SOLAN (HP) - 173 230 INDIA

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CERTIFICATE-I

This is to certify that the thesis entitled, **“Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh”** submitted in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) FRUIT SCIENCE** in the discipline of **HORTICULTURAL SCIENCES** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 India is a bonafide research work carried out by **Mr. Karan Kumar (NH-2018-17-M)** son of Sh. Banarsi Dass under my guidance and supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

Place: Neri, Hamirpur
Date:

Dr Som Dev Sharma
Chairperson
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled, **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh"**, submitted by **Mr. Karan Kumar (NH-2018-17-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) – 173 230 India in partial fulfillment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) FRUIT SCIENCE** in the discipline of **HORTICULTURAL SCIENCE** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an Internal Examiner.

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This is to certify that all the mistakes and errors pointed out by external examiner have been incorporated in the thesis entitled **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh"** submitted by **Mr. Karan Kumar (NH-2018-17-M)** son of Shri Banarsi Dass to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP)-173 230 in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE, FRUIT SCIENCE** in the discipline of **HORTICULTURE SCIENCES.**

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Place: Hamirpur **Karan Kumar**
Date:

CONTENTS

ABBREVIATIONS

%	:	Per cent
&	:	And
HP	:	Himachal Pradesh
UHF	:	University of Horticulture and Forestry
COH&F	:	College of Horticulture and Forestry
ha	:	hectare
et. al	:	Co-workers
˚ C	:	Degree Celsius
@	:	At the rate of
etc	:	Etcetera
m	:	Meter
viz.,	:	Namely
cv	:	Cultivar
i.e.	:	That is
cm	:	Centimeter
T max	:	Maximum Temperature
T min	:	Minimum Temperature
mm	:	Millimeter
MT	:	Million tons
g	:	Gram
/	:	Per
GIS	:	Geographic Information System
kg	:	Kilogram
DEM	:	Digital Elevation Model
KVK	:	Krishi Vigyan Kendra
BBMB	:	Bhakra Beas Management Board
LULC	:	Land Use Land Cover
ml	:	Milliliter

ANOVA	:	Analysis of variance
ICMR	:	Indian Council of Medical Research
GDP	:	Gross domestic product
MAT	:	Mean annual temperature
TAR	:	Total annual rainfall
CO_2	:	Corban dioxide
R^2	:	R- square (variation in regression model)
sq.km	:	Square kilometer
SRTM	:	Shuttle Radar Topographic Mission
LISS	:	Linear Imaging Self scanning System
NASA	:	National Aeronautics Space Administration
SPSS	:	Statistical Package for Social Science

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Chapter-1

INTRODUCTION

Horticulture is an important sector in India which contributes 30.4 per cent GDP to agriculture. Due to different agroecological zones, India becomes a home for different types of horticultural crops such as fruits, vegetables, flowers, plantation and aromatic crops. Globally, India is the second largest producer of fruits and vegetables crops after China in the world. In this sector, fruit crops have also played major role in employment generation, economy, expanding export and ensuring nutrient security (Singh *et al.* 2015)

Nutritional security becomes a primary issue in national and international level and can be achieved by providing fruits 83 g and 185 g vegetables per head per day in addition to meals as suggested by ICMR. It is possible only when we grow more productive crops under suitable climatic conditions. The fruit crops planted in different agroclimatic zones are not give optimum output due to changes in climate and weather. The best example is global warming that causes variation in rainfall, temperature, relative humidity which are closely linked with crop production (Hoogenboom *et al.* 2000).

The horticulture sector is the main driver of economic growth in Himachal Pradesh (HP). The state has favorable agroclimatic regions varying from temperate to subtropical where numerous fruit crops are cultivated in upper and lower regions of the state. The mountainous tract and undulating topography plays an important role in complicating these crops due to changes in the microclimate. Agro-climatically, Himachal Pradesh is divided into four zones with respect to altitude, rainfall, temperature, humidity and topography. In this state, Una district experienced Sub-Montane and Low Hills Subtropical Zone (Zone-I). The main fruit crops cultivated in this region are citrus, mango and litchi.

Una is a district of Himachal Pradesh, covering an area of 1549 square kilometer. It shares boundaries with Punjab state i.e., Hoshiarpur and Rupnagar districts of Punjab and Kangra, Hamirpur and Bilaspur districts of HP. The district is situated between 31°17′52″ - 31°52′00″ north latitude to 75°58'2″- 76°28′25″ east longitude. The temperature ranges from 0^{o}C in winter to 48^{o}C peak in summer. It is mostly low hill and sub-tropical region and has rich diversity of agro-climate topography in the region. The elevational differences along with healthy and well fertile soils in the district are good for fruit production. Fruit crops occupied an area of 6097.06 hectare with production of 22237.38 MT (Anonymous, 2018). Citrus and mango are the major cultivated fruit crops of the district, covering an area of 2047.09 hectare and 2203.22 hectare with production 7858.12 MT and 12260 MT, respectively (Anonymous. 2019).

The key determinants for plants are temperature, humidity, rainfall and seasonal pattern through which plant growth can be influenced directly or indirectly. Although mango is well adapted to high summer heat (Makhmale *et al.* 2016). Weather and climate play a key role in success or failure of fruit production. The phenological stages of fruit crops along with changes in air temperature and rainfall are the most important factors for their production. Different fruit species are influenced differently due to varying levels of adaptability with varying climate change.

Rainfall is the weather variable that is more associated with plant growth and production. It affects the intensity and quality of other weather variables. Heavy rainfall opens the doors for soil borne diseases and it favors plant pest and disease attack. However, the shortage of rainfall causes the impact on vegetative growth of the plant and stops the transpiration process and another impact is on soil fertility and productivity (Abhinav *et al.* 2018). High temperature and polluted air also impact on fruit yield and increase the intensity of physiological disorders such as black tip of mango due to changes in the environmental system.

Physical planning maps not only play an important role in the realization of land use plans, but also in the communication of information about what is and what is not allowed in geographical space or on specific land parcels (Van Elzakker, 2010). The climate aspects of regional geography involve the relationships between natural and cultural features of the region and its climate. The local climatic features, related to the topography, occur on too small a scale to be shown on a regional map.

The above information indicates that changes in weather and climate have pronouncing impact on crop production. Therefore, it is significant to study the impact of climate change on productivity of mango and citrus fruit crops in Una district of HP, being the major fruit crop of the district. Keeping in view the above factors, the present study **"Effect of weather parameters on**

the production of mango and citrus in Una district of Himachal Pradesh" was undertaken with the following objectives:-

1) To study the effect of weather parameters on mango and citrus crop by using time series model.
2) To compute trend value of important weather parameter.
3) To prepare the physiographic map.

Chapter-2

REVIEW OF LITERATURE

Diverse agro-ecological regions in India are bestowed with the opportunity to grow different horticultural crops. The changes in environmental factors like erratic rainfall, snowfall, droughts, increase in temperature, hail storms etc. play a significant role in variation of the fruit production. Climate changes significantly affect the fruit quality and production at global and national level. The changes in climate cause both positive and negative impacts on fruits in temperate, subtropical, and tropical regions. In regions where the prevailing temperatures are already high, further increase in temperature will adversely affect the yield and quality of fruits.

Atmospheric changes can impact plant growth and production of fruit crops. There is a need of sound knowledge of different climatic zones and their transfer methods with regard to climate change for excellent fruit quality and production (Subedi *et al*. 2019).

The present study entitled, **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh"** was carried out with an objective to update and accurately describe the existing crop production database needed for systematic planning and decision-making. The literature-reviews have been discussed in this chapter under the following heads:

2.1 Effect of weather parameters on mango and citrus crop production

2.2 Trend values of weather parameter

2.3 To prepare the physiographic map

2.1 EFFECT OF WEATHER PARAMETER ON MANGO AND CITRUS CROP PRODUCTION

Weather variations refer to any deviation in the climatic behavior over a period of time which occurs naturally or due to intervention of human activities. Weather changes are highly related to agriculture growth and production.

Aguilera and Ruiz-Valenzuela (2014) studied the weather parameters especially as rainfall and temperature for predicting olive crop production for the period of 16 years (1994-2009).

Rainfall recorded before flowering months had been considered the most significant parameter for providing reasonable description of variation in fruit production. The temperature recorded during the two months before budburst was another important variable which showed positive effects on final yield.

Swati *et al.* (2019) studied the impact of temperature and rainfall changes at regional level on productivity of major tropical fruit crops. The study showed that the production and productivity of banana, mango, sapota and papaya had moderate negative correlation with mean annual temperature i.e., more than 50 % except the productivity of land under banana. Whereas, it showed very weak negative and non-significant relation with total annual rainfall. Correlation of all four fruit production ranged between -34 to 53 % and -0.7 to -62 % for productivity with both MAT and TAR, respectively

Reddy *et al.* (2017) reported that an increase in the average temperature and climate change are the major issues presently for the humankind. The change in weather parameters such as temperature, unseasonal rainfall on flowering trend, relative humidity, fruit set and yield of mango. Increase in temperature with 0.7 ℃ to 1.0 ℃ have drastically reduced the quality of mango as a result of climate change and temperature of less than 15 ℃ during the young fruiting that reduce the size and growth of mango fruit but even temperature range higher that have an inverse effect on growth and final size of the mango fruit.

Salau *et al.* (2016) studied the impact of weather parameters such as temperature below 15 ℃ on chilling injury and poor fruit production in banana fruit crops. Extreme or less rainfall and humidity have also a direct impact on banana productivity. Rajatiya *et al.* (2018) revealed that changes in temperature range 33 ℃ to 36 ℃ during the flowering stage had reduced 65 to 70 % in flowering.

Kunz *et al.* (2016) studied that the effect of changes in climate during 1958 to 2013 with respect to flowering and yield of golden delicious apples, the rise in the late summer temperature with less summer precipitation may induce the stress conditions. The study indicated that an increase in temperature and decreases in precipitation would result in small size and colour of fruits.

Haribar *et al.* (2015) studied on the influence of temperature change on the vegetative and fruiting period of temperate fruits have extreme, higher temperature stop the ripening processes of fruits, decrease mineral and protein, starch and soluble sugar accumulation by low CO_2 level and increase more bioactive compounds owing to lower concentration of CO_2.

Bindi *et al.* (1996) studied variation in weather conditions and influence on the production of grapevine (*Vitis vinifera*) in Italy. They found that the direct relationship between weather and yield variability of grapevine. Increased temperature subsequently decreases the fruit production but shows no effect on quality of the grapevine with rise in temperature. The extreme temperature early in the season improved the vegetative growth with positive impact on biomass of the vine. Solar radiation has a small impact on production and yield variability of grapevine but other parameters such as temperature and CO_2 concentration were found more sensitive to variation in growth and yield of grapevine.

Kumar *et al.* (2014) conducted an experiment in Southern part of India during 2010- 2012 reported that the effect of climatic change on flowering inflorescence and production of the mango cultivar. They explained that in order to count the weather parameter such as rainfall (130 mm), maximum temperature (32 °C), minimum temperature (20.30 ℃) and relative humidity (84.50 %) was the most important. These parameters have a positive impact on both off and main flowering and fruiting period of mango. The climatic variation was positively correlated with yield of the mango and had a direct positive influence on inflorescence, percentage of hermaphrodite flowers and percentage of fruit set per plant.

Abobatta (2019) carried out the study on impacts of climatic variation on citrus cultivation. Citrus plants grow at higher temperatures ranging (13 ℃ to 37 ℃) but temperature rises beyond this range affects the growth of citrus. On the other side, lower temperature can also generate adverse impacts on citrus such as chilling injury and metabolic processes while the CO_2 concentration improves growth and quality of the citrus plant. Low temperature delay the growth of citrus tree and extreme temperature affect fruit quality or increase the fruit cracking, fruit color and fruit drop occur in citrus cultivar *viz.,* Washington Navel orange and hybrid of mandarin “Murcott” increases the fruit abscission layer and also probable impact on citrus yield.

Ahmad *et al.* (2008) examined the capability of temperate fruits to weather variation at Central Institute of Temperate Horticulture, Srinagar India. They reported that temperature and level of CO_2 are the major factors of temperate fruit cultivation. The weather variables have opposite impacts on fruit plant growth and production of temperate fruits. They also revealed that both range of temperature and concentration of CO_2 can cause early flowering initiation and size of fruits is too big or soft.

Zabihi *et al.* (2016) conducted an experiment by using statistical analysis and weather data in Ramsar, Iran over a 30 years period from 1980 to 2010, to study the influence of altitude range and minimum temperature on citrus crop production in order to assess the tolerance of citrus crops to cold stress. High range of elevation and temperature can also influence the woody plant and stop the metabolic activity of the plant. Citrus plants can be susceptible to chilling injuries, so this type of plant would be shifted to the warmth place and cultivate the temperate fruit crops which have ability to withstand the low temperature and higher elevation level. Overall the study showed that higher altitude and minimum temperature have an adverse impact on yield, stage of flowering, fruiting and harvesting of cultivated citrus plants.

Normand *et al.* (2015) evaluated the influence of climate on mango tree development and production. The result revealed that the range of temperature more than 45 ℃ could damage the processes of photosynthesis. During the vegetative growth period of mango 20 ℃ to 30 ℃ temperatures have a more significant impact on mango growth and enhance the fruit colour. Since extreme temperatures enhance the fruit quality as well as fruit production.

Lechaudel *et al.* (2013) studied the influence of weather parameters such as temperature and solar radiation on mango. The results showed that fruit canopy of mango trees was influenced by solar radiations and temperature. The light exposure part of mango trees have better results on good quality flower and fruit setting while shaded portions of the tree have less exposure to fruits and affect the fruiting, quality behaviors of mango and create the physiological disorder on the fruits.

Sukhvibul *et al.* (1999) studied the effect of temperature on inflorescence of mango. The results revealed that temperature range 15 ℃ at day and 5 ℃ at night had strongly impact on inflorescence development but the day and night temperature are 20 ℃ to 10 ℃ and the total no. of flower on the inflorescence were increased but the low temperature reduce the flower induction and lose the quality of the fruits.

Greer *et al.* (2013) studied temperatures that influence grapes in many regions of Australia. The results revealed that temperature had substantial effects on ripening; reducing the rate of ripening by 50 % and delaying harvest ripeness while yield was not affected. Higher temperature also affects the rate of transpiration and photosynthesis processes, the rate of transpiration rate increases when the conductance of stomata is also increased but in case of Semillon grapevine where 35 % of photosynthesis was reduced.

Bashir and Mobeen (2018) investigated the impact rainfall and temperature on production of citrus from 1986 to 2015. The analysis showed that the increase in the temperature and rainfall in the monthly average are impacting the production of citrus (*Citrus reticulata*). The yield of citrus plants was found to be highest during 2014 to 2015 and the lowest during 2010 to 2011 owing to high temperature impact on citrus yield during the spring season. It has been found that yield was also positively correlated with rainfall while negatively correlated with temperature.

Doving *et al.* (2001) collected data from commercial production in two districts of Norway and compared with meteorological data. Reliable data for Trondelag (1973 to 2000) and Valldal (1975 to 2000) were used to find out correlation between weather parameters and production. The result indicated that yields for both districts were negatively correlated with temperature in August previous to the fruiting year. In district Valldal, yield was positively correlated with temperature in April.

Kumar *et al.* (2007) observed that annual rainfall had reduced the production of coconut in different regions by dry spell during the 10 to 15 years period. Impact of variation in dry spell on nut yield was discernible from the study. They also found that long duration forty four months from inflorescence initiation to nut maturation had been affected by dry spell on the yield subsequently three-four years. Regardless of total rainfall, it can be concluded that the prolonged dry conditions affected nut yield for the next four years due to the powerful impact of the fourth year.

Snelgar *et al.* (1991) studied the influence of shading on kiwifruit fruit yield. The results indicated that shaded areas of kiwi vines reduce flowering and resulted in a large decrease in the number of fruit per vine. Shaded portions resulted in low concentration of soluble solid and more fruit softening during the storage at 0 ℃. It is significant to understand that statistical analysis of weather variables and yield of fruit crops owing to impairment to them.

Makhmale *et al.* (2016) reported that climate changes have brought widespread changes in flowering and fruiting patterns of mango. This is adversely affecting fruit production in some areas where previously found too cold for mango cultivations. The effect of temperature above 30

°C during the vegetative phase revealed the influence on growth rate of mango tree and yield rate also, while the range of temperature less than 6 °C during the winter season are not suitable for commercial production of mango. This showed that low temperatures have a negative influence on plant germination and growth of plants. Other climatic variable is rainfall is decisive for growth and development of mango but rainfall is dangerous throughout the blooming period of mango trees and very harmful to mango yield. Ahmad et *al.* (2001) reported that the temperature ranges from 14 °C to 18 °C have more influence on ripening and quality behavior of bananas than range of temperature is 20 °C. Temperature less than 20 °C of temperature are more probable for quality and ripening of banana due to internal ethylene formed at low temperature. As a result, banana ripening and quality were increasing at a higher temperature than low temperature ranged from 14°C to 16°C.

Turner *et al*. (1983) studied the growth of bananas in relation to temperature. This fruit crop was grown for twelve weeks in sunlit chambers to maintain day and night temperature varied from 17/10, 21/14, 25/18, 29/22, 33/26 or 37/30 ºC. In this study temperature was the dominant weather parameter that affects the growth and yield of bananas. The temperature 14°C - 21°C was supreme for banana leaf growth while least at 30°C - 37°C and had a strong negative association with whole plant leaf resistance.

2.2 TREND VALUES OF WEATHER PARAMETERS

Weather variations and global warming caused by anthropogenic emissions and the changing trend of weather parameters merit immediate and systemic consideration; because agricultural crops are affected.

Choudhury *et al.* (2012) reported that analysis of the rainfall events indicated that the increases rainfall trend with the rate of 3.72 mm per year, but during monsoon season decrease the rate of rainfall with the rate of 1.70 mm while post and pre-post increase the rate of rainfall with 3.18 mm and 1.16 mm, respectively. At the end, the rainfall has increased by 3.72 mm during 1983 to 2010 with the help of non-parametric tests and rainfall was more in monsoon season, sunshine and wind speed is directly correlated with each other, trend was revised after monsoon season or winter season while annual evaporations were significantly reduced.

Mandal *et al.* (2019) conducted a study on weather trend analysis of variation in rainfall data of Sundarbans, India from 1966 to 2015. The results revealed that average annual rainfall was

1821 mm and total annual rainfall decreased at six years but eight years rainfall trend more, resulting in less variability of rainfall data during the last fifty years. From the last 10 years, 2006 – 2015 the rainy days were decreased at 79.7 days per year. They were not important variations in rainfall, sunshine, minimum and maximum temperature of the zone.

Vidya *et al.* (2015) conducted a study in Kullu (Western Himalayan zone), Himachal Pradesh to analyze the trend value of maximum temperature, minimum temperature and relative humidity. The variability analysis showed significant variation in weather parameters *viz.*, rainfall, wind speed, relative humidity and minimum temperature while the maximum temperature has no any significant variability. These trends were examined with linear and non-linear models, among which the cubic model is best fit for trend analysis on the basis of R^2 values. The parameters are maximum temperature, minimum temperature and relative humidity values of R^2 are 0.57, 0.67 and 0.62 respectively. At the end, these minute variations in trend of weather parameters influence the productivity of cereal and horticultural crops in different ranges.

Panda and Sahu (2019) reported the fluctuation of weather parameters of thirty seven years of climatic data with other weather parameters in three districts of Odisha from 1980 to 2017. The annual maximum and minimum temperature reduced trend values temperature and the overall range of rainfall trend are distinguished during study period from 1980 to 2017. However, the rainfall statistical trend values are increased during monsoon season. The trend was analyzed through Sen's estimate. These estimates had given different values of trends such as rainfall and maximum temperature showing positive trend value (4.034 and 0.29 respectively) but in case of minimum temperature revealed negative trend (-0.006).

Gumus *et al.* (2017) analyzed the meteorological data for determination of weather variation trends annually as well as seasonal by the use of time series data of different weather variables. In study forty years data were examined from 1975 – 2015 and observed that the data shows both negative and positive trends of each variable. Initially all variables showed no significant trend but during spring season and summer season temperature ranges where changes in mean temperature is 0.053 ℃ per year in spring season and variation occurring in minimum temperature was 0.08 ℃ per year in summer season. At the end, the trend of temperature is variable during the period of 1990 to 2000.

Kumar *et al.* (2010) in Kashmir valley conducted a survey on five station rainfall data for the period of 1903–1982. They found that three weather stations observed a declining pattern in annual rainfall. The declining trend in water was statistically significant at 95 percent confidence level whereas none of the increasing trends was significant in the pre-monsoon and past-monsoon.

Asfaw *et al.* (2018) analyzed the temperature and rainfall data of the North central region of Ethiopia for 114 years between 1901– 2014 to study the analysis of trends to change in temperature and rainfall. The data of temperature examine that the average range of temperature was decreased (0.046 ℃) and notify the maximum and minimum range of temperature is reduced (0.026 ℃ and 0.067 ℃), respectively. The trend of maximum temperature was not significant but in case of minimum temperature trend analysis was significant. The data on rainfall analyzed indicates the range of rainfall was declined annually (15.03 mm) while belg and kiremt range of rainfall decreased 1.93 mm and 13.12 mm, respectively. In this study, maximum temperature showed non-significant trend while the minimum temperature positive trend value and significant.

Mahmood *et al.* (2019) studied climatic variables such as temperature and precipitation from 1951 -2015. The results showed that the time series data of temperature trend increased 84 % during the period and the trend of precipitation is 25 % - 38 % decreased during the study period. Results revealed that precipitation showed extremely decreased or non-significant trends but temperature showed strongly significant and increased trends. The trend of temperature and rainfall were analyzed by Mann-Kendal non-parametric test. The analysis of trends indicated the conditions of climate variations in weather variables.

Worku *et al.* (2018) studied the variation in annual and seasonal temperature and rainfall from 1980 to 2014. They reported that the relationship between crop yield data and weather variable of 35 years. The trend of different weather parameters were analyzed by Mann-Kendall non parametric test, based on these study maximum and minimum temperature show significant highly increased trend by 1.1 ℃ per year and 0.8 ℃ per year, respectively. The trend analyses of seasonal rainfall (spring and summer) were more dispersed than annual rainfall. The result revealed that rainfall trend was significantly decreased by 0.28 mm per year and variations but in temperature data trend was increased or significant.

Akinbile *et al.* (2015) used weather parameters data of 31 years (1980 – 2010) on solar radiation, rainfall, relative humidity and temperature, the data were acquired from IITA

(International Institute for Tropical Agriculture). The trend analysis of various weather parameters revealed that the rainfall and solar radiation indicated non-significant trend and increasing trends in periods but rainfall trend also showed decreasing trend by 3 % per year while temperature and relative humidity were negative decreased significant trend and temperature showed 0.03 % per period decreased during annual season during the study period. Results of weather variables revealed that the temperature and relative humidity show significant reduced trend while solar radiation and rainfall revealed non-significant increased trend of the Nigeria region on the basis of 31 years old time series data.

Kumar *et al.* (2014) observed the weather data of different locations of the India region, the weather data used weekly, monthly, seasonal and taken from IASRI, New Delhi for 41 years (1970-2010) and the data were examined by using Sen's slope estimate and Mann-Kendall test. Both maximum and minimum temperature data presented an increasing trend in North regions of India but some regions showed a decreasing trend of temperature. The region situated at southern, western and central observed an increasing trend but the zone located at the Northern and Eastern site showed a decreasing trend of annual temperature. The result revealed that the trend of both maximum and minimum temperature had increased as well as decreased trend of pigeon pea growing regions of India.

Anurag *et al.* (2017) studied the variation in trends of different weather variables. The fluctuation in temperature, rainfall, wind speed and relative humidity trend of the Hisar, Haryana, and Northwest India. The rainfall trend had been raised during (1980-2014) with monthly rate 2.15 mm per year over the decade and the rate of rainfall trend was increased during 1995 to 2014 by 5.14 mm per year. In case of monthly maximum temperature trends were falling by the -0.07 ℃ and -0.05 ℃ during January and September months, respectively. While the wind speed trend indicated more reducing trend than normal trend to -0.04 kmph per annum. Later, the trend of temperature, rainfall and wind speed showed a decreasing annual trend but during the monthly trend of these weather parameters showed increasing as well as decreasing trend with significant variation in climatic variables.

AL-Ataby *et al.* (2019) reported that the temporal fluctuations in weather parameters of 16 years decades (1984-1999) with trend analysis methods. The weather variables *viz.*, relative humidity, rainfall and temperature indicate the significant annual trend of various locations of the Iraq region. The result revealed that the relative humidity trend was rising in each location by

0.344 while rainfall trend was falling of all research stations by -1.606 mm per year and the temperature trend also showed rising of each location of the country. Finally, these weather variables indicated the variations and fluctuations of meteorological data.

Gedefaw *et al.* (2019) investigated the variation of different weather parameters and trends of temperature and precipitation on two stations of Ethiopia region. This study used time series weather data from 1980-2016 for investigations of trends. Both temperature and precipitation trend analyzed with different trend analysis methods such as Sen's, Mann-kendal and innovative trend analysis methods. The precipitations and temperature revealed significant rising trend of different stations and the trend was highly positive during kiremt while, falling in bega seasons of each stations. Results of this study also showed that the trend fluctuated during different seasons but temperature trend exhibited negative rate and precipitation trend revealed positive trend rate.

Kuri *et al.* (2014) studied different weather parameters of Mymensingh district, Bangladesh by 38 years (1975-2012) past climatic data. Both rainfall and temperature were the chief variables of climate variables, so its trend is utmost valuable for future forecasting related to weather variables. The result of this study showed that maximum temperature and rainfall trend falling and negative over the decades but annual minimum temperature and average temperature trend had been raised and trend of climatic parameters had more variations.

Laddimath *et al.* (2019) studied the trend analysis of climatic parameters from 1901 to 2016 of the Bhima basin, Karnataka, India. They reported that the maximum and minimum temperature trend increased during 1969 to 2005 by 0.4 percent and 0.9 percent, respectively, while rainfall showed a falling and negative trend during 1901 to 2016 decades that is about 0.024 percent of the research region. Whereas, western region had more variation in temperature range and the maximum temperature indicates a rising trend.

Pal *et al.* (2017) studied monthly, seasonal and annual variation from different times in Dadeldhura district of Nepal. The results revealed that increase in maximum and positive temperature trend while rainfall trends had maximum fluctuations and showed decrease trend of rainfall but under monsoon and after monsoon decades revealed positive trend of rainfall, however winter season showed falling and negative trend of rainfall. At the end, both variables average temperature and average rainfall indicated that more variations under significant and non-significant values.

Patle *et al.* (2014) assessed the trend in average rainfall and variations in the climatic parameter, studied daily time series data from 1971 to 2007 of four districts of Arunachal Pradesh. This trend showed the decreasing average rainfall in three districts and had no trend values of western region of the state. The results revealed that three districts of East Siang, upper Siang and lower Dibang trend were falling negative (3.01 mm $year^{-1}$), (3.32 mm $year^{-1}$) and (3.95 mm $year^{-1}$) respectively. However, the trend was not observed in Siang district during the research decade.

Radhakrishna *et al.* (2017) investigated annual temperature showed rising and positive trend at 5 percent level of significance while rainfall parameters initiate the falling as well as negative at the same degree of significance during the period of 1901 to 2014. Long term time series data on rainfall and temperature indicated that negative and mean temperature manifested a significant rising and positive trend owing to less variation in temperature but in case rainfall shows vast fluctuations during the study period.

2.3 TO PREPARE THE PHYSIOGRAPHIC MAP

Physiographic maps refer to the natural or physical features of the earth surface. It determines the distribution of hills, plain and other terrain of the area. All these maps were prepared in ArcGIS. The key aim of physiographic map preparation is to provide framework and agroecological zones. GIS (Geographical Information System) are composed of several apparatuses, beginning by integrating spatial data taken by remote sensing sources and physiographic maps, and then a computer-readable shape. Modified and reliable data is necessary for strategic planning of the horticulture field, through extending the region, growing production or maintaining amenities for processing purposes.

Bhandari *et al.* (2014) carried out a study on suitability of land for crop establishment using spatial data and preparations of physiographic maps such as slope map, DEM, land capability and other land physiographic units for superiority land classification. Under this study spatial data and GIS technology was used in physiographic units for land suitability analysis. The result indicated that the slope map presented the suitability of slope created along with field qualities and parameters of adaptability to develop the maps of mango for crop suitability.

According to Kannan *et al.* (2018), Geo spatial technology and remote sensing techniques were used for morphometric investigation of the study area. In this investigation, under-used SRTM (Shuttle radar topographic mission) data for preparation of drainage, watershed and aspect map, the data used in this study include a 30 meter resolution of digital elevation model. The overlay analyses showed that the ratio of watersheds ranges between (0.13 to 0.43) refers to watersheds coming beneath elongated form. The analysis will assist the nearby residents use these tools to prepare the irrigation of rainwater and the maintenance of the watershed.

Punithavathi *et al.* (2011) carried out the study on mapping of physiographic units and mapping of soil for proper utilization of land. Using GIS and remote sensing techniques in IRS satellite imagery for physiographic mapping, land zoning, soil mapping and shows different types of landform. This study evaluated soil and physiographic units in Thanjavur district of Tamil Nadu, India to value the land use planning and land resources. Their study revealed that the various classifications of soil and landforms were identified containing upland (6.58 sq. km), pediplen (56.01 sq. km), coastal plain (60%), mud flat (1.38 sq. km) and salt flat (15 sq. km).

Ayalew *et al.* (2014) used geospatial technology to generate the land suitability for appropriate utilization of watershed in surface or sprinkler systems of irrigation and 30 meter resolution of spatial data used for preparation of land suitability map, slope map and also prepared the DEM (Digital Elevation Model) with the help of surface analyst tools of ArcMap. These maps are useful for land planning such as DEM showed elevation of land, slope map showed slope percentage of area and suitability map represents soil factors and irrigation demand. The results of this research work revealed that surface irrigation map was more appropriate than sprinkler irrigation methods and 94.8% land was unsuitable for this system or 3.2% land suitable for sprinkler method. So, the surface suitability map displayed that surface irrigation is better than the sprinkler system in the watershed.

According to Panhalkar (2011), land use and watershed resources through GIS and Remote sensing techniques in topography, hydrology, geology and land use land cover studies. The capabilities of land determination on the basis of slope map of the study region, land use land cover (LULC) map and classifications of land capabilities. The preparation of the slope map was generated with the help of SRTM data from remote sensing and GIS software. The analysis showed that land capabilities were classified in to four different classes and area under these classes expressed such classes are Class II under agriculture sector (16.30 %), Class III (21.04 %), Class IV (34.05 %) and Class VI (28.61%) and watershed generate on the basis of area ability. The land suitability maps of the study region were more effective for land use planning and suitability classification can be evaluated through physiographic maps and attribute data with the help of GIS techniques.

Al-Mashreki *et al.* (2010) to determine the suitability of land with the support of Remote sensing data (Landsat data) and GIS techniques used. For physiographic map preparations such maps are Digital elevation model, thematic map, soil type map, slope map and land use land cover map. These maps are most useful for land use planning or suitability of land and screening land degradation difficulties. The terrain study evaluation of the spatial data at 100 meter taken from the Landsat satellite and generate various thematic as well as physiographic maps for proper utilization of land resources. At the end, the research experiment that the land can be classified in to different classes or suitability of crop cultivation land on the basis of physiographic study, classification of DEM (Lowland, midland, highland and very high land) and features of soils have also valuable for land suitability.

Das *et al.* (2014) revealed that the area can be classified on the basis of physiographic maps and soil characteristics of the research region. Under this research work, GIS and remote sensing data were more helpful for land use planning and consumption of natural resources. IRS-P6, LISS-III and LISS- IV spatial remote sensing data were used to prepare LULC map, slope map, soils classification map, fertility map and other physiographic maps. The result of the study showed that Geospatial technique was useful for map making and suitability of research region for cultivation area and waste area. Soil map and fertility map showed the utilization of the study area, and classification of land for fruit cultivation suitability.

Simmi *et al.* (2018) used geoinformatics technology for monitoring the physical appearance of the study area with the help of physiographic maps and land use land cover mapping. This study was conducted at north western parts of Bhiwani district of Haryana by using a toposheet for investigating area mapping and spatial data used for physiographic map preparation by ArcMap 10.5.1 software. The research revealed that the physiographic map and LULC maps were classified the study region in the form of plain land (86%) for agriculture, sandy dune (6%), wasteland (3%) and valley land (5%). These land use land cover (LULC) maps were very facilitating for land classification and suitability of land.

Sharma *et al.* (2015) found that the apple growing data to be generated with the support of remote sensing data and GIS software. The spatial data was used in accordance with Indian remote sensing satellite *viz.*, IRS-P6 and other sensors create apple field map and physiographic maps such as slope map, aspect map, DEM (Digital elevation model), elevation map etc. The physiographic map showed the apple orchard appearances were situated inside the range of elevation of 2000 to 3000 meters. Such sites will also be used as comparison sites to standardize the suitability of the field and management strategy for apple sites.

Chapter-3

MATERIALS AND METHODS

The current study analysis entitled **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh"** was carried out in the Department of Fruit Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P.) during the year 2019-2020. The materials used and procedures followed during the investigations are listed as below.

3.1 General overview of the study area

3.2 Data Collection

3.3 Statistical analysis tools and techniques

3.4 Physiography of study area

3.1 GENERAL OVERVIEW OF THE STUDY AREA

3.1.1 Study area

The current study was focused on Una district of Himachal Pradesh. This area is situated in low hills of Himachal Pradesh and district is bordered by boundaries of Kangra, Hamirpur and Bilaspur beside boundary with Punjab state i.e. Rupnagar and Hoshiarpur district. The major fruit crops grown in the district are mango and citrus, these fruit crops are covering an area of 6097.06 hectare with production 22237.38 metric tones. This subtropical district covers total geographical area of 1549 Sq. Km.

3.1.2 Geographical situation

The district is located between 31°17'52" - 31°52'0" north latitude to 75°58'2" - 76°28'25" east longitude. The altitude of the district ranges from 350 to 1200 meters above sea level. The climate of the district is sub-tropical with semi-hilly tract. The temperature ranges from 0˚C in the winters to 48˚C in the summers and the average annual precipitation is 1253 mm.

The analysis of study area was first characterized by clipping from the toposheets of the study area. Initially, a 1:50000 – scale toposheet was geo-referenced in GIS software ArcMap 10.5.1.

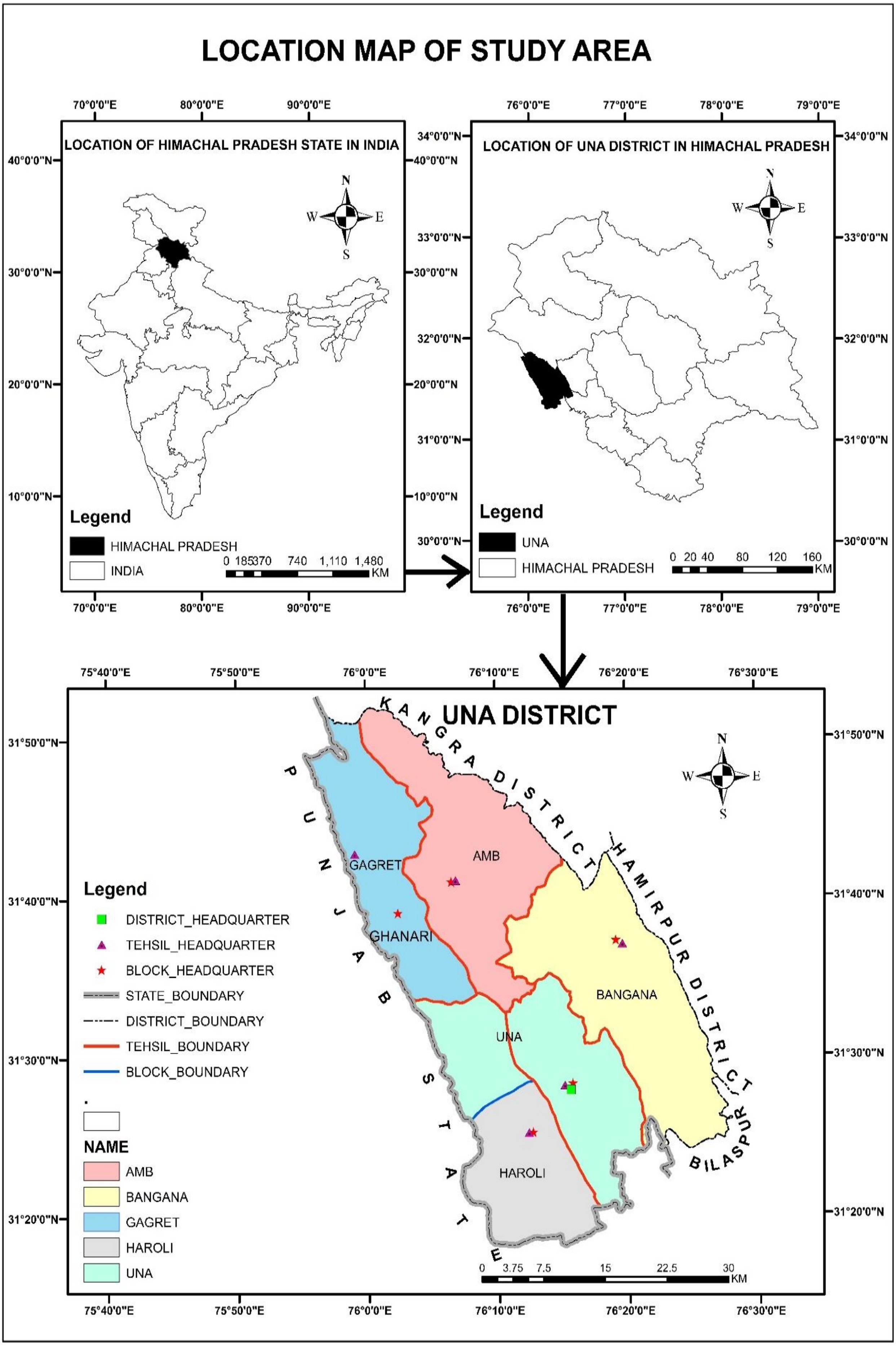

Fig. 1: Location map of the study area.

The analysis of study area was first characterized by clipping from the toposheets of the study area. Initially, a 1:50000 – scale toposheet was geo-referenced in GIS software ArcMap 10.5.1. This software and toposheet of study area was provided by Geoinformatics lab, Department of Fruit Science, College of Horticulture and Forestry, Neri Hamirpur, Himachal Pradesh.

3.1.3 Crops

Among the various fruit crops cultivated in Una district of HP are mango, citrus, guava and pear. Mango and citrus cover areas of 2203 hectare and 2048 hectare with production 12261 metric tonnes, 7859 metric tonnes, respectively during the 2018-2019.

3.2 DATA COLLECTION

The secondary data from (1996 – 2018) and (2004 - 2018) for the weather parameters and the citrus and mango crop production data same as 23 years was acquired.

3.2.1 Crop yield data

Yearly crop production (kg/hectare) data of mango and citrus were acquired from past 23 years (1996 to 2018). It was collected from Directorate of Horticulture, Shimla, Himachal Pradesh.

3.2.2 Weather data

Data on weather parameters *viz.*, maximum temperature, minimum temperature and rainfall for past 23 years (1996 to 2018), was acquired from BBMB weather station and for 15 years from 2004 to 2018 was acquired from KVK Berthin.

3.2.3 Terrain data

Terrain parameters were derived using the Digital Elevation Model (DEM). The NASA Shuttle Radar Topographic Mission (SRTM) has been used for this purpose, offering digital services elevation data (DEM) for more than 80 per cent of the world. Data has been downloaded from earth explorer browser. Terrain data are used for physiography analysis of the study area and to prepare various types of maps linked with physiography examination such maps are: elevation map, contour map, hill-shade map, aspect map and slope map.

3.2.4 Effect of weather parameter on yield of fruit crops

An analysis was conducted to investigate the probable linkage between the fruit crop production and selected weather parameters *viz.,* maximum temperature, minimum temperature and rainfall so that the impact on fruit production can be showed. Under this analysis, firstly taken the annual weather parameter and the annual crop production data were calculated. To find out the impact of weather parameter on fruit production using regression study and correlated to single weather variable and all the weather parameters were combined with fruit production.

3.2.5 Computing trends of weather parameters

The analysis of weather parameters was carried out for identification of the current variation trend for all weather parameter (maximum temperature, minimum temperature and rainfall) and to consider the climatic variability and changes in the climatic situation over the period 1996 to 2018. The computation of trend of certain weather parameter were analyzed on the basis of R^2 of the regression model such as linear and non-linear (logarithmic, inverse, quadratic , cubic, compound, power, S , growth and exponential).

3.3 STATISTICAL ANALYSIS TOOLS AND TECHNIQUES

3.3.1 Regression analysis

3.3.1.1 Fitting of linear and non-linear models on the basis of R^2 value.

3.3.1.2 Fitting of multiple linear regression models.

3.3.2 Correlation analysis

3.3.3 Variability analysis

The statistical analysis was done using SPSS (Statistical Package for Social Science) software.

3.3.1 Regression analysis

The regression analysis was based on different regression models such as linear and non-linear functions *viz.,* logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential. These regression analysis were carried out to find the effect of weather parameters on crop yield and checking the model adequacy on the basis of R^2 and standard error of estimation. The regression analysis is also used for trend analysis on the basis of R^2 values of regression model.

These models have different trend values but the trend was computed through the value of R^2 and Standard error. Following the subsequent models were used:

Table 3.1: Equations of regression models.

Regression models		Equations of models
I.	Linear	$Y = \alpha + \beta x + \varepsilon$
II.	Logarithmic	$Y = \alpha + \beta \text{ in } (X) + \varepsilon$
III.	Inverse	$Y = \alpha + \frac{\beta}{x} + \varepsilon$
IV.	Quadratic	$Y = \alpha + \beta_1 X + \beta_2 X^2 + \varepsilon$
V.	Cubic	$Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon$
VI.	Compound	$Y = \alpha \beta^X + \varepsilon$
VII.	Power	$Y = \alpha X^\beta + \varepsilon$
VIII.	S curve	$Y = e(^{\alpha + \frac{\beta}{x}}) + \varepsilon$
IX.	Growth	$Y = e^{(\alpha + \beta X)} + \varepsilon$
X.	Exponential	$Y = \alpha \text{ x } e^{\beta X} + \varepsilon$

3.3.1.1 Fitting of linear and non-linear models on the basis of R^2 value.

The analysis of regression was done through fitting two types of models such as linear and non-linear models, the adequacy of the models was determined by standard error and R^2 values. These models are described as below:

3.3.1.1 – (i) Linear model:

The effect on citrus and mango yield by the weather parameters was analyzed by the linear regression model. In which the models have two type of variable viz., dependent and independent variables. The production of citrus and mango fruit is dependent and weather parameters were independent variables.

The models equation is given below,

$$\{\mathbf{Y = \alpha + \beta x + \varepsilon}\}$$

Where,

Y denote a dependent variable

α denote the intercept

β denote the regression line slope

ε denote the random error, independently and normally distribute with standard deviation σ^2 and mean 0.

Here, the task has to obtain the estimates of ($\hat{\alpha}$ = α = â) and ($\hat{\beta}$ = β = $\hat{b}$). They were counted as x^2

$$\hat{\boldsymbol{\beta}} = \boldsymbol{\beta} = \hat{\boldsymbol{b}} = \frac{\mathbf{n(\Sigma XY - \Sigma X\, \Sigma Y)}}{\boldsymbol{n}\, \boldsymbol{\Sigma}\, \boldsymbol{x^2} - (\Sigma \mathrm{x})^2}$$

$$\hat{\boldsymbol{\alpha}} = \boldsymbol{\alpha} = \hat{\mathbf{a}} = \overline{\boldsymbol{Y}} - \boldsymbol{\beta}\overline{\boldsymbol{X}}$$

3.3.1.1 – (ii) Nonlinear models:

The analysis of the effect of weather parameters on the yield of the citrus and mango by the nonlinear models such as logarithmic, inverse, quadratic, cubic, compound, power, S curve, growth, exponential. These nonlinear models were tried to fit the equation in the data. In this models fruit production were taken dependent variable and weather parameters were independent variables.

3.3.1.1.(ii).1. Logarithmic model

The logarithmic model represents the trend analysis between fruit production data (dependent variable, Y) and weather parameters (independent variables, X). The equations of logarithmic model is

$$\mathbf{Y = \boldsymbol{\alpha} + \boldsymbol{\beta}\ In\ (X) + \boldsymbol{\varepsilon}}$$

Where,

Y and X denotes the fruit yield and weather variables respectively.

α , β and ε are constant values.

(In) denotes the log.

3.3.1.1.(ii).2. Inverse model

The inverse model of regression analysis was applied to study the effect of independent variable (X) on dependent variable (Y). The equation of model is described below:

$$\mathbf{Y} = \boldsymbol{\alpha} + \frac{\boldsymbol{\beta}}{\boldsymbol{X}} + \boldsymbol{\varepsilon}$$

Where,

X and Y also denote the independent and dependent variables respectively.

α , β and ε are the constant values.

3.3.1.1.(ii).3. Quadratic model

The impact of climatic variability on the fruit production was carried out by the non-linear quadratic model and analysing the trend between the independent and dependent variables. The model equation is given below:

$$\mathbf{Y = \alpha + \beta_1 X + \beta_2 X^2 + \varepsilon}$$

Where,

X and Y are denotes the weather parameter and yield respectively.

α , β_1 , β_2 and ε denote the constants.

3.3.1.1.(ii).4. Cubic model

The equation of cubic model is described below,

$$\mathbf{Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3 + \varepsilon}$$

Where,

X and Y denote the weather parameters and the fruit productions respectively.

α , ε and β denotes the constant estimation.

3.3.1.1.(ii).5. Compound model

The compound model represents the trend between dependent and independent variables. The equation of compound model described below:

$$\mathbf{Y = \alpha\ \beta^X + \varepsilon}$$

Where,

X and Y denotes to independent and dependent variables, respectively.

α , β and ε denotes the constant values.

3.3.1.1.(ii).6. Power model

The power model equations are described below:

$$\mathbf{Y = \alpha\ X^\beta + \varepsilon}$$

Where,

Y and X are the dependent and independent variables respectively.

α , β and ε are the constant values.

3.3.1.1.(ii).7. S curve model

The effect of weather parameters on the production of mango and citrus was studied by using the S curve regression model. The equation of these model is are given below:

$$\mathbf{Y = e(^{\alpha + \frac{\beta}{X}}) + \varepsilon}$$

Where,
Y and X denotes the dependent and independent variables, respectively.
e denotes natural log.
α , β and ε are constant estimates.

3.3.1.1.(ii).8. Growth model

The growth model equation are given below:

$$\mathbf{Y = e^{(\alpha + \beta X)} + \varepsilon}$$

Where,
Y and X denotes fruit yield and weather parameters respectively.
e denotes natural log.
α , β and ε are constant estimates.

3.3.1.1.(ii).9. Exponential model

The Exponential model were used for working out the trend analysis of selected weather parameter and the equation of this model is given below:

$$\mathbf{Y = \alpha \times e^{\beta X} + \varepsilon}$$

Where,
Y and X denotes the dependent and independent variables, respectively.
e the natural log.
α , β and ε are constant values.

3.3.1.2 Fitting of multiple linear regression models

The multiple linear regression model is used for studying the explanation of more than one independent variables. So, multiple linear regression model was used which is as under:

$$\mathbf{Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + \beta_P X_P + \varepsilon}$$

Where,

X and Y denotes to independent and dependent variable.

B_X denote regression coefficients.

i = 1,2,3 ……….. P.

In this study, Y was taken as dependent variable i.e. fruit production whereas X was considered independent variable i.e. weather parameters such as frost, relative humidity, precipitation, maximum temperature, minimum temperature and rainfall.

Throughout the multiple linear regression determination, the coefficient measurements such as α and β were worked out using least squares method. The equation was:

$$\boldsymbol{\beta = (x' x)^{-1} (x' y)}$$

$$\boldsymbol{\alpha = \bar{Y} - (\beta_1 \bar{X} + \ldots\ldots\ldots + \beta_P \bar{X}_P}$$

3.3.1.2.1 Indicators used for goodness of fit of regression model.

Numerous indices were used to assess the goodness of fit of various regression and time series models. The indices were such as:

a) Standard Error : This approach is also used for goodness of fit and in regression model. It is an approximation of standard deviation of random portion of the data.

$$\mathbf{SE} = \frac{\mathbf{SD}}{\sqrt{\mathbf{n}}}$$

Or

$$\mathbf{SD} = \sqrt{\mathbf{MSE}}$$

Where,

n = denotes the no. of observation

b) R-square (R^2) : The statistics analysis how successful the fit is in explaining the variation of the data. R^2 is the square of correlation between response values and the predicted response values. It is also known as square of multiple correlation coefficient and multi-determination coefficient. R^2 is defined as the ratio of sum of square of deviation and the total sum of square.

$$\mathbf{R^2} = \frac{\mathbf{SSR}}{\mathbf{TSS}} = \frac{\textbf{Sum of square due to regression}}{\textbf{Total sum of square}}$$

Where,

$$\mathbf{SSR} = \sum_{i}^{n}\{ \boldsymbol{\beta i} \sum(\mathbf{X_i - \bar{X}_i}) (\mathbf{Y_i - \bar{Y}_i}) \}$$

$$\textbf{TSS} = \sum_{i}^{n}(Y_i - \overline{Y})^2$$

R^2 can take values between 0 to 1. A value closer to 1, indicates that a greater proportion of variance is accounted for by the model.

3.3.2 Correlation analysis

The analysis of correlation was performed to assess the degree of interaction between two variables. In this analysis, the degree of correlations between weather parameters (i.e., frost, relative humidity, precipitation, maximum temperature, minimum temperature and rainfall) and yield of fruits (i.e., mango and citrus) were calculated using the correlation coefficient of Karl Pearson′s. The analysis are describe as:

$$r_{(X,Y)} = \frac{\mathrm{Cov}(X,Y)}{\sqrt{v(X)}\sqrt{v(Y)}}$$

$$= \frac{\frac{1}{n}\left(\sum XY - \frac{\sum X \sum Y}{n}\right)}{\sqrt{\frac{1}{n}\left[\sum X^2 - \frac{(\sum X)^2}{n}\right]}\sqrt{\frac{1}{n}\left[\sum Y^2 - \frac{(\sum Y)^2}{n}\right]}}$$

Where,

r(x, y) denotes the Karl Pearson′s correlation coefficient.

v(x) denotes the variance of X.

v(y) represent the variance of Y.

3.3.3 Variability analysis

In order to determine the variability in the weather parameter during period of research (1996 to 2018), comprehensive statistical analysis for arithmetic mean of different weather parameters, standard deviation, coefficient of variance, skewness and kurtosis were carried out on the selected annual weather parameters using SPSS software.

a) $\overline{X}$ **(Arithmetic mean)** = $\frac{1}{n}\sum_{i=1}^{n} X_i$

b) **σ (Standard deviation)** = $\sqrt{[\frac{1}{n}\sum_{i=1}^{n}(X_i - \overline{X})^2]}$

c) **CV (Coefficient of variation)** = $\frac{\sigma}{\overline{X}}$ **x 100**

d) **S_k (Skewness) = G_1** = $\frac{\sqrt{N(N-1)}}{N-2}\;\frac{\sum_{i=1}^{N}\frac{(Y_i-\overline{Y})^3}{N}}{s^3}$

e) **Kurtosis** = $\frac{\sum_{i=1}^{N}(Y_i-\overline{Y})^4/N}{s^4}$

3.4 PHYSIOGRAPHY OF STUDY AREA

Physiography of study area was analyzed considering the natural and physical features of the earth surface. It was evaluated with help of digital elevation map (DEM), contour map, aspect map, hill-shade map and slope map. These maps are under the determining factors for the condition of the fruit orchard and its productivity. All maps were prepared by satellite data and Arc Map 10.5.1 software. The methodology of creating the physiographic map are discussed in fig. 3.2.

3.4.1 Digital Elevation Model (DEM)

Digital elevation model (DEM) is a representation of topography of the earth surface. It was prepared from spatial data or terrain elevation data. It was also used for studying physiography of the study area through the different maps prepared related to terrain study of the earth surface.

3.4.2 Hill-shade Map

The Hill-shade map displays the strength of light on the surface of a certain area and also show the area under shadow. The map revealed the frequency of light from the sun on surface area at raster cell from 0 (dark) to 254 (light). The values of hill-shade map relate to the sun position and a value of 0 (dark) represents the area under shadow and the value is 254 (light) implies that the surface pointed straight to the Sun and will gain more energy than shadow area. Hill-shading was the hypothetical illumination of a surface according to a specified altitude of the sun. Hill-shade map also prepared by filling the DEM of the study area with the help of surface analyst tools in the Arc Map 10.5.1 software.

3.4.3 Contour map

Contour displays points having similar elevation in comparison to a particular datum and the map represents height surface feature of contour lines is known as contour map. It provides the elevation of the surface indicated by contour lines. This map was prepared by DEM of the study area with help of surface analyst tools in software Arc Map 10.5.1.

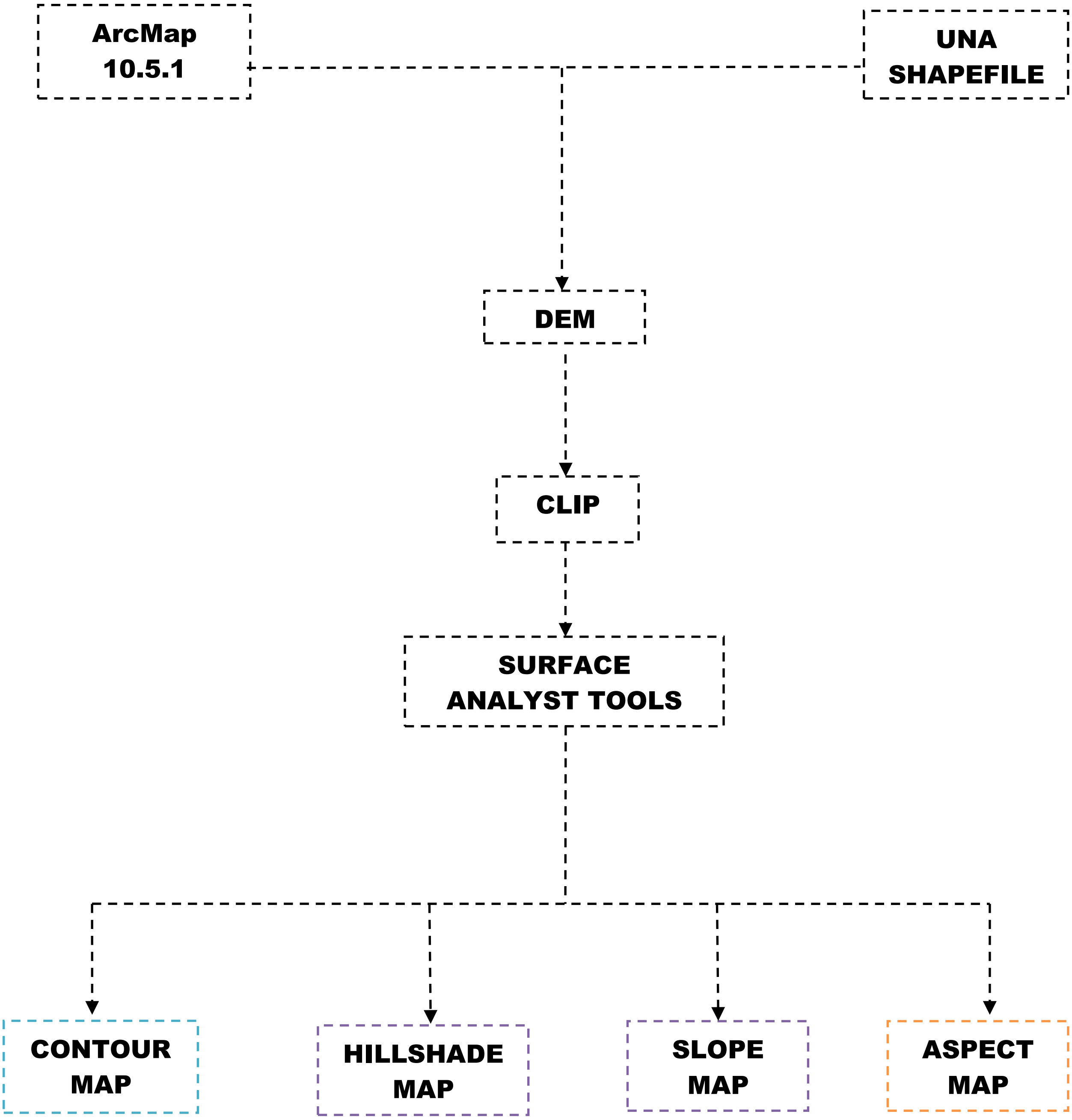

Fig. 3.2 : Methodology of developing Contour, Hill-shade, Aspect and Slope maps.

3.4.4 Slope map

Slope is the indicator of the steepness or inclination of a landscape. Some horizontal plane features *viz.*, incline, grade, pitch and gradient are used as slope interchangeably. Slope was represented as percentage and angle of the surface. On a topo map the average slope of a surface element may be determined easily from contour lines. Slope denotes the calculation of the height change ratio and slope change direction of a particular position on the earth's surface.

Slope map was prepared by filling of the digital elevation model of the study area with the help of surface and hydrology analyst tools of the Arc Map 10.5.1 software.

3.4.5 Aspect map

Aspect map is used to determine the direction of a compass on a topographical slope face, typically calibrated to northerly degrees. Aspect map can be created by surface gradient. The direction face of a slope will influence the physical and biotic slope feature, its called as the effect of slope.

The aspect of the surface often influences the amount of sunshine which it receives e.g. locations with a southerly presence in northern latitude tend to be warm and drier than area with a northern aspect. It also shows the slope direction on surface area. Aspect map was also generated by filling the DEM of the study area with help of surface analyst tools of Arc Map 10.5.1 software.

Chapter 4

RESULTS AND DISCUSSION

The present microclimatic analysis entitled, **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh"** encompasses on the weather parameters and production statistics of Una district during the period of 1996-2018. The study was carried out with objective to analyze the effect of weather parameters on fruit crops, to calculate the trend value of weather parameters and to prepare the physiographic map of district Una (HP) in the GIS lab, Department of Fruit Science , College of Horticulture and Forestry, Neri, Hamirpur (HP). The results have been presented and discussed in this chapter under the following heads and subheads:

4.1 VARIABILITY ANALYSIS OF SELECTED WEATHER PARAMETERS

4.1.1 Descriptive statistics for variability in weather parameters

4.2 ANALYSIS OF CORRELATION COEFFICIENT

4.2.1 Correlation analysis between selected weather parameters and fruit production

4.2.2 Correlation coefficient between temperature and fruit production of mango crop

4.2.3 Correlation coefficient between temperature and fruit production of citrus crop

4.3 EFFECT OF WEATHER PARAMETERS ON PRODUCTION OF FRUIT CROPS

4.3.1 Regression models for citrus production with selected weather parameters

4.3.2 Regression models for mango production with selected weather parameters

4.3.3 The analysis of multiple linear regression of citrus and mango

4.4 COMPUTED TREND VALUE OF IMPORTANT WEATHER PARAMETERS

4.4.1 Regression models for selected weather parameters

4.5 PREPARATION OF PHYSIOGRAPHIC MAP OF UNA DISTRICT

4.5.1 Preparation of Digital elevation model

4.5.2 Preparation of Contour map

4.5.3 Preparation of Aspect map

4.5.4 Preparation of Hill-shade map

4.5.5 Preparation of Slope map

4.1 VARIABILITY ANALYSIS OF SELECTED WEATHER PARAMETERS

4.1.1 Descriptive statistics for variability in weather parameters

The descriptive variability analysis for mean, standard error (SE), standard deviation (SD), coefficient of variation (CV), skewness (Sk) and kurtosis (Kt) of selected weather variables such as maximum temperature (T max), minimum temperature (T min) and rainfall (RF) trend series for the period of twenty three years from 1996 to 2018 is given below:

Table 4.1: Variability analysis of maximum temperature for time period (1996-2018).

Year	Mean	SE	SD	CV (%)	Skewness	Kurtosis
1996	31.81	0.33	6.22	19.55	-0.22	-0.69
1997	28.19	0.43	8.15	28.89	-0.71	0.18
1998	29.88	0.38	7.32	24.49	0.22	-0.72
1999	29.42	0.40	7.65	26.00	-0.91	0.99
2000	28.82	0.36	6.91	23.98	-0.64	0.75
2001	28.84	0.31	5.87	20.36	-0.24	-0.45
2002	29.98	0.36	6.86	22.88	-0.12	-0.80
2003	29.83	0.38	7.27	24.38	-0.42	-0.27
2004	30.93	0.36	6.92	22.37	-0.43	-0.21
2005	30.83	0.37	7.15	23.20	-0.33	-0.49
2006	31.31	0.33	6.23	19.89	-0.37	-0.44
2007	31.11	0.36	6.95	22.35	-0.49	-0.44
2008	30.64	0.34	6.51	21.23	-0.74	0.70
2009	31.79	0.34	6.42	20.19	-0.03	-0.80
2010	29.67	0.33	6.37	21.48	-0.51	-0.03
2011	28.36	0.32	6.17	21.76	-0.53	0.04
2012	29.01	0.38	7.28	25.09	-0.25	-0.63
2013	28.26	0.35	6.69	23.67	-0.29	-0.08
2014	28.61	0.36	6.90	24.13	-0.16	-0.67
2015	28.47	0.34	6.50	22.83	-0.23	-0.82
2016	30.22	0.31	6.01	19.88	-0.50	-0.37
2017	30.02	0.33	6.39	21.30	-0.26	-0.73
2018	29.78	0.32	6.12	20.56	-0.15	-0.64
Range	28.19 – 31.81					
Mean	**(29.81 ± 0.35)**					

T max (℃) = maximum temperature; **SE** = Standard error; **SD** = Standard deviation; **CV** = Coefficient of variation

Table 4.1 reveals the variability analysis of maximum temperature of Una district from the period (1996 – 2018). The annual maximum temperature was 29.81℃ over twenty three years and it ranged from 28.19℃ to 31.81℃. The highest annual maximum temperature (31.81℃) was recorded during the year 1996 whereas, the lowest annual maximum temperature was recorded during the year 1997. The range of standard deviation varied from 5.87 to 8.15 and coefficient of variation ranged from 19.55 to 28.89 %. In the year 1996 maximum temperature was more consistent (19.55 %) and was less consistent (26.89 %) during the year 1997. With reference to estimation of normality assumption (skewness = 0 and kurtosis = 3), the value of skewness was observed far away from zero and the value of kurtosis was also far away from three. Hence, the variability analysis of maximum temperature did not show trend and had no normality assumption.

Table 4.2: Variability analysis of minimum temperature for time period (1996-2018).

Year	Mean	SE	SD	CV (%)	Skewness	Kurtosis
1996	16.84	0.31	5.91	35.10	-0.22	-1.30
1997	17.02	0.33	6.39	37.55	-0.14	-0.93
1998	18.68	0.37	7.00	37.48	-0.27	-1.16
1999	18.62	0.31	5.98	32.15	-0.35	-1.15
2000	18.10	0.32	6.13	33.89	-0.35	-1.16
2001	18.55	0.32	6.12	32.99	-0.44	-0.86
2002	18.55	0.33	6.32	34.07	-0.27	-1.21
2003	18.16	0.37	7.01	38.61	-0.48	-0.76
2004	18.52	0.32	6.17	33.31	-0.35	-1.02
2005	18.24	0.34	6.60	36.18	-0.28	-1.18
2006	18.32	0.29	5.50	30.03	-0.50	-0.81
2007	18.16	0.32	6.16	33.90	-0.35	-1.21
2008	18.11	0.32	6.08	33.54	-0.59	-0.83
2009	18.06	0.31	5.92	32.80	-0.31	-1.20
2010	18.13	0.32	6.17	34.06	-0.60	-0.90
2011	17.18	0.32	6.04	35.14	-0.38	-1.06
2012	18.46	0.40	7.57	41.03	-0.08	-1.01
2013	17.77	0.33	6.24	35.13	-0.41	-0.96
2014	17.40	0.32	6.16	35.38	-0.24	-1.26
2015	17.79	0.31	5.91	33.24	-0.35	-1.18
2016	18.44	0.31	5.92	32.10	-0.43	-1.05
2017	18.34	0.31	6.01	32.76	-0.32	-1.25
2018	17.97	0.32	6.11	34.01	-0.34	-1.12
Range	16.84 – 18.68					
Mean	**(18.06 ± 0.32)**					

T min (℃) = Minimum temperature; **SE** = Standard error; **SD** = Standard deviation; **CV** = Coefficient of variation

The annual variability of minimum temperature over the study period from (1996-2018) is represented in Table 4.2. The annual mean minimum temperature (18.06 ℃) was recorded in the period of twenty three years and its range varied from 16.84 ℃ to 18.68 ℃. The highest average annual minimum temperature (18.68 ℃) was observed in year 1998, whereas in the year 1996 lowest mean was recorded (16.84 ℃). The standard deviation was observed highest (7.57) in the year 2012 and lowest value noticed (5.50) in the year 2006, respectively. With regards to minimum temperature, the coefficient of variation varied from 30.03 to 41.03 %. The range of coefficient of variation implied that minimum temperature was less uniform (41.03 %) in the year 2012 and more uniform (30.03 %) in the year 2016. The values of skewness ranged from -0.06 to -0.08 and these values were distant from zero and were negative. However, all the value of kurtosis were far away from three and the value varied from -0.76 to -1.30, which were negative. Hence, the minimum temperature did not follow normality assumption i.e. skewness = 0 and kurtosis = 3. Which exhibited non-significant trend.

The data on variability analysis of monthly and annual are presented in table 4.3 showed. The month of January (2007), March (2004 and 2008) and April (1999) recorded no rainfall. Likewise, lowest amount of rainfall were recorded in the month of October, November and December during the period under study (1996 to 2018). In general, the maximum amount of rainfall was recorded in the month of June, July, August and September. The highest average rainfall (360.60 mm) was recorded in the month August while lowest average rainfall was recorded in November month (7.26 mm). An average annual rainfall (1232.7 mm) was recorded over twenty three year (1996 to 2018) and its range varied from 800.0 to 2027.7 mm. The highest annual rainfall (2027.7 mm) was recorded in the year 1998, whereas the lowest annual rainfall 800 mm was recorded in the year 2009. Coefficient of variation ranges from 306.13 to 408.46 percent, which indicated that annual rainfall was more consistent (306.13 %) in the year 1998 and less consistent (408.46 %) in the year 2011, respectively. On estimating normality assumption (skewness = 0 and kurtosis = 3), the range of skewness was observed 4.00 to 7.84 and these value were far away from zero. Likewise, the range of kurtosis was 17.39 to 80.77 and values noticed were far away from three. So, there was non-significant trend and the data did not follow normality assumption.

The result of variability analysis indicate that weather parameters *viz.,* rainfall, maximum and minimum temperature did not follow normality assumption (skewness = 0 and kurtosis = 3). On the basis of coefficient of variation, the data on weather parameters showed least dispersion, skewness and kurtosis indicating a weak relationship with weather parameters over the time period (1996 to 2018). The relationship between weather parameters and time period revealed that trendline was decreasing partially shown in Fig. 2,3 and 4. Similar study were done by Asfaw *et al.,* (2018) pointing out that non-significant trend of variation by maximum temperature and showed decreasing trend by annual rainfall.

Table 4.3: Monthly as well as annual variability analysis rainfall for time period (1996-2018).

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total RF(mm)	Mean	SD	CV (%)	Skewness	Kurtosis
1996	59.0	122.8	39.0	17.2	30.8	174.3	413.6	435.7	196.6	37.2	0.0	0.0	1526.2	4.17	13.23	317.26	5.47	36.26
1997	52.5	16.2	17.1	115.4	49.5	142.4	545.7	438.0	169.9	22.7	112.4	162.9	1844.7	5.05	16.92	334.76	7.26	74.10
1998	1.7	135.3	143.9	45.4	19.7	263.5	468.0	400.8	437.0	112.4	0.0	0.0	2027.7	5.56	17.01	306.13	4.00	17.39
1999	45.8	9.0	9.3	0.0	121.1	98.7	401.8	276.5	151.1	0.0	0.0	0.0	1113.3	3.05	10.80	354.08	5.24	30.40
2000	86.9	65.9	24.6	2.4	40.5	143.8	422.8	194.2	60.0	0.0	0.0	0.0	1041.1	2.87	8.84	308.24	4.89	29.51
2001	19.8	10.6	34.7	33.2	39.3	77.1	451.2	362.7	43.5	0.0	2.2	11.0	1085.3	2.97	11.37	382.47	6.10	42.48
2002	40.0	44.5	24.5	29.5	22.0	75.7	256.6	329.0	226.0	32.5	0.0	2.0	1082.3	3.01	9.68	321.65	4.81	28.51
2003	46.5	72.0	61.5	32.5	4.2	143.0	292.2	311.6	149.0	20.0	0.0	9.5	1142.0	3.13	9.64	308.25	4.72	27.16
2004	115.3	2.9	0.0	27.9	41.2	75.5	216.1	376.0	42.5	159.9	0.0	43.0	1100.3	3.01	10.85	360.82	5.44	36.01
2005	52.7	163.7	79.9	2.6	8.7	41.8	411.9	190.0	47.5	0.0	0.0	0.0	998.8	2.74	9.06	330.96	5.29	33.62
2006	37.0	1.6	110.0	13.0	81.3	88.5	262.3	344.4	151.6	5.5	7.5	25.0	1127.7	3.11	11.41	366.43	5.82	39.72
2007	0.0	99.0	160.5	25.7	12.7	104.6	377.5	575.7	38.5	3.9	5.5	33.5	1437.1	3.92	13.75	350.69	6.89	67.87
2008	35.0	17.4	0.0	22.1	33.2	262.6	179.2	532.2	125.0	40.5	0.0	0.0	1247.2	3.41	11.16	327.42	4.96	28.52
2009	6.8	23.5	19.6	25.5	7.7	35.2	262.1	209.9	187.5	12.5	9.7	0.0	800.0	2.24	8.80	393.32	5.95	42.51
2010	8.0	23.0	1.5	2.6	56.0	141.4	453.2	288.0	154.5	24.0	8.0	94.5	1254.7	3.44	11.88	345.66	5.18	33.61
2011	34.0	117.0	70.0	63.1	32.5	128.4	159.0	486.5	144.5	0.0	0.0	3.5	1238.5	3.39	13.86	408.46	7.84	80.77
2012	138.5	9.5	2.5	28.4	6.0	11.5	137.6	288.2	167.7	2.5	2.5	9.3	804.2	2.20	8.00	364.30	4.84	24.91
2013	53.5	87.6	48.3	1.3	34.4	335.3	217.8	415.5	83.9	18.7	0.0	29.0	1325.3	3.63	11.90	327.83	5.21	33.25
2014	76.0	75.7	47.9	27.5	49.5	83.3	264.9	350.8	130.1	15.0	0.0	63.5	1184.2	3.25	11.03	339.84	4.88	26.77
2015	63.2	97.6	200.2	40.5	16.0	98.7	574.7	297.2	74.4	13.5	0.2	17.2	1493.4	4.09	14.20	347.15	5.29	32.30
2016	15.5	26.8	49.4	2.5	90.1	118.3	95.8	379.6	77.1	12.9	0.0	5.8	873.8	2.39	8.41	352.23	5.85	43.18
2017	120.7	1.2	27.8	27.8	29.6	146.4	83.8	464.6	189.6	0.0	0.0	42.0	1133.5	3.23	10.76	332.85	4.39	21.90
2018	20.0	33.1	5.0	43.1	5.5	178.2	347.9	346.7	458.2	14.2	19.0	0.4	1471.3	4.03	13.97	346.62	5.38	35.30
Mean RF	49.06	54.60	51.18	27.36	36.15	129.05	317.20	**360.60**	152.42	23.82	**7.26**	24.00	**1232.7**					

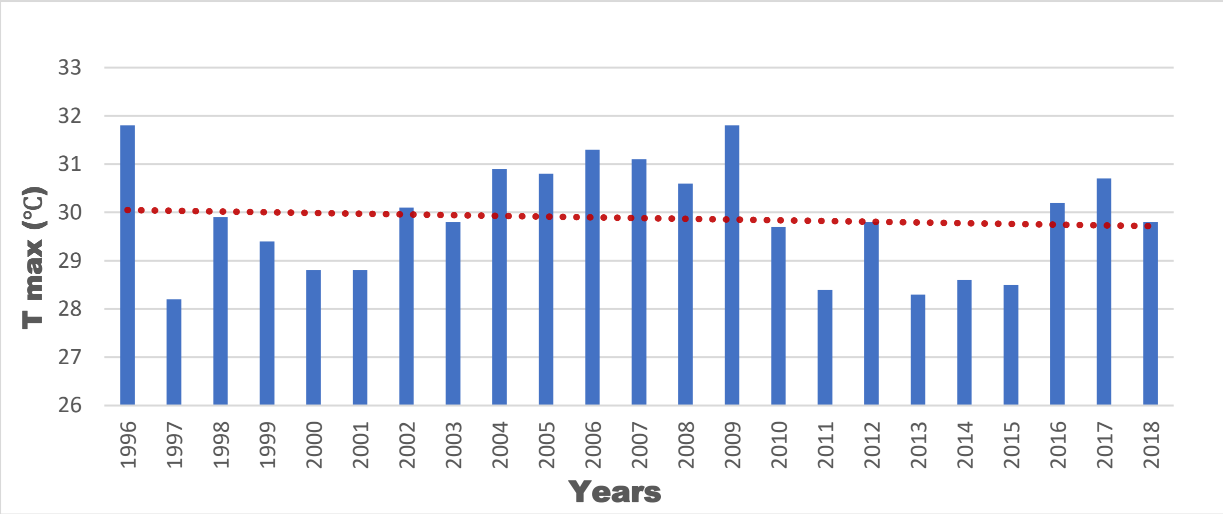

Fig. 2: Relationship between maximum temperature with time period.

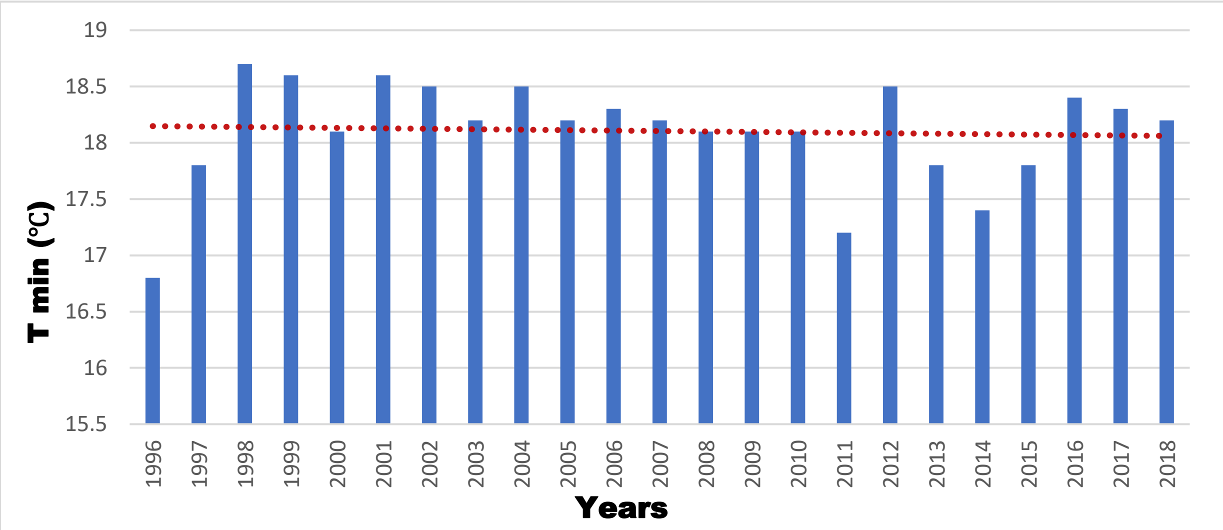

Fig. 3: Relationship between minimum temperature with time period.

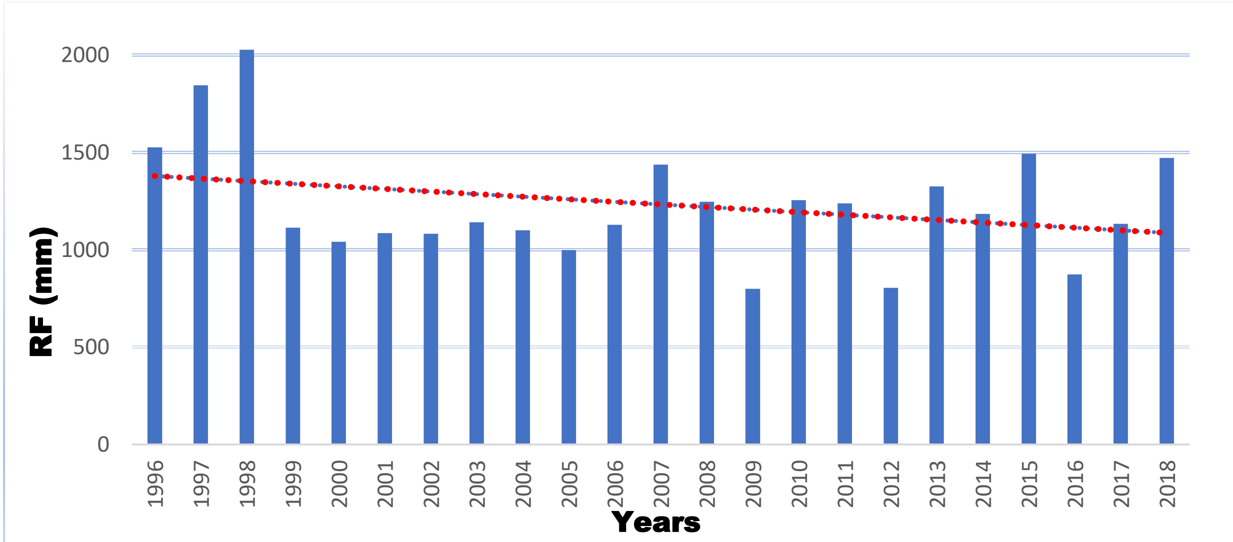

Fig. 4: Relationship between annual rainfall with time period.

4.2 ANALYSIS OF CORRELATION COEFFICIENT

4.2.1 Correlation analysis between selected weather parameters and fruit production

Karl Pearson's correlation coefficient showed relationship among different weather parameters *viz.*, maximum temperature, minimum temperature and rainfall with mango and citrus crop production during the year (1996 to 2018) as presented in table 4.4 and 4.5. The results revealed that the weather parameters did not show any significant correlation with mango and citrus production. However, all weather parameters were observed non-significant on the basis of fruit crops production.

Table 4.4: Correlation between mango production and weather parameters.

	T max	T min	RF	MP
T max	1.000			
T min	0.208	1.000		
RF	-0.185	-0.370	1.000	
MP	0.025	0.020	-0.135	1.000

MP = Mango production; **T min** = Maximum temperature; **T min** = Minimum temperature; **RF** = Rainfall

Table 4.5: Correlation between citrus production and weather parameters

	T max	T min	RF	CP
T max	1.000			
T min	0.208	1.000		
RF	-0.185	-0.370	1.000	
CP	-0.151	-0.036	-0.114	1.000

CP = Citrus production; **T max** = Maximum temperature; **T min** = Minimum temperature; **RF** = Rainfall

4.2.2 Correlation coefficient between temperature and fruit production of mango crop

The careful examination data acquired from KVK Berthin for 15 years (2004 – 2018) revealed that the minimum temperature of < 4 ℃ were observed only during the months of December and January. Therefore, it was utilized to work out whether such low temperatures exhibited any impact on the production of mango and citrus or not. The coefficient of correlation analysis between the monthly mean maximum temperature and minimum temperature for two months (December and January) of fifteen years (2004-2018) with fruit production (citrus and mango) are presented in table 4.6 and 4.7. It was observed that mango production showed positive significant relationship with maximum temperature (r = 0.623) at 5 percent level of significance. Whereas, minimum temperature showed negative non-significant correlation with mango production (r = -0.266) as presented in table 4.6.

Table 4.6: Correlation between temperature and mango production for winter period.

	MP	**T min**	**T max**
MP	1.000		
T min	-0.266^{NS}	1.000	
T max	**0.623***	0.105^{NS}	1.000

MP = Mango production; **Max T** = Maximum temperature; **Min T** = Minimum temperature;

***.** Correlation is significant at the 0.05 level (2-tailed).

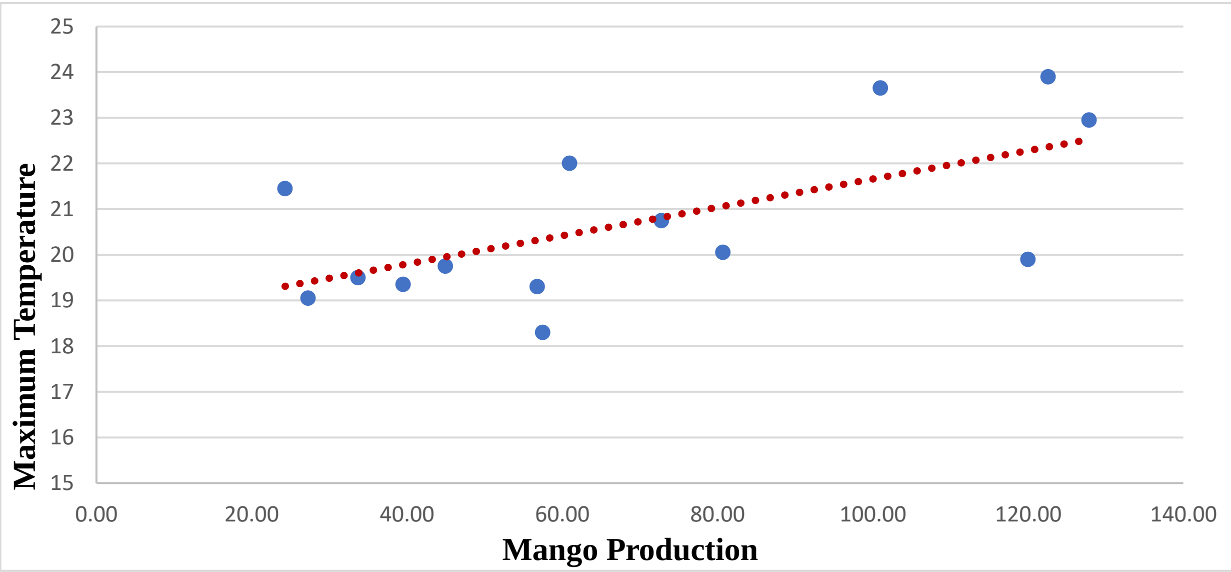

Fig 5: Scatterplot of maximum temperature with mango production from 2004 to 2018

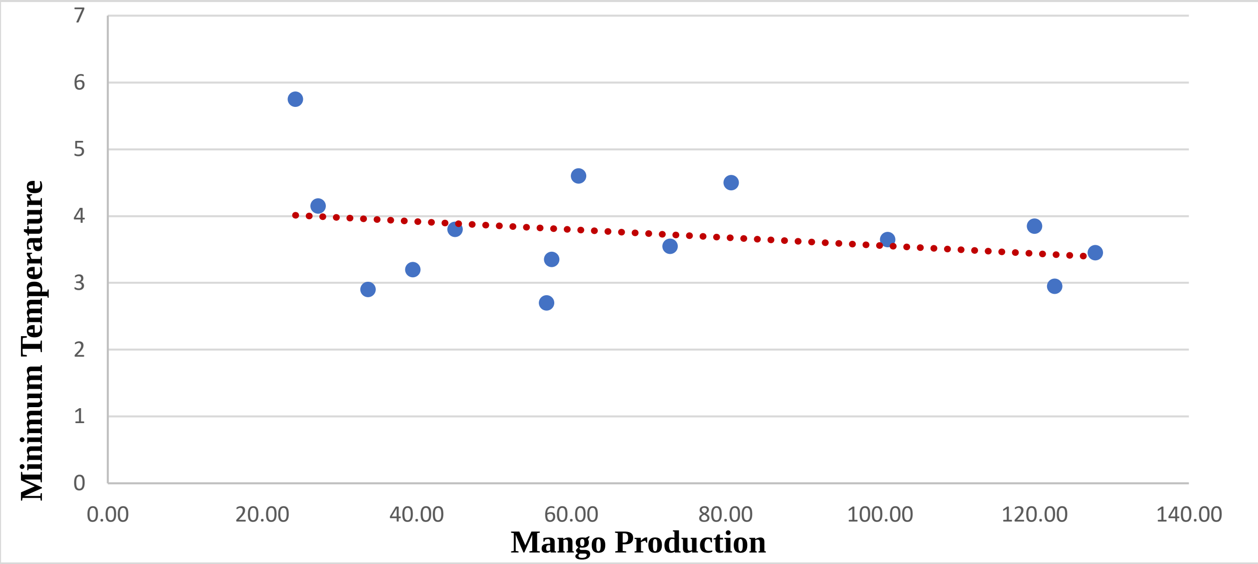

Fig 6: Scatterplot of minimum temperature and mango production from 2004 to 2018

The correlation between mango production and monthly mean maximum temperature showed moderately positive correlation (Fig.5). The graph showed an increases in mango production with increase monthly mean maximum temperature. However, mango production and monthly mean minimum temperature were negatively correlated (Fig.6). The graph indicated that increased mango production with decrease in monthly mean minimum temperature.

4.2.3 Correlation coefficient between temperature and fruit production of citrus crop

The analysis of aforementioned correlation coefficient presented in Table 4.7 indicated the relationship of maximum and minimum temperature with production of citrus crop. It was noticed that production of citrus crop significantly correlated with maximum temperature (r = 0.855) at 1 percent level of significance. However minimum temperature revealed negative non-significant correlation with production of citrus crop (-0.093).

Table 4.7: Correlation between temperature and citrus production for winter period.

	CP	**T min**	**T max**
CP	1.000		
T min	-0.093^{NS}	1.000	
T max	**0.855^{**}**	0.105^{NS}	1.000

MP = Mango production; **Max T** = Maximum temperature; **Min T** = Minimum temperature;
**. Correlation is significant at the 0.01 level (2-tailed)

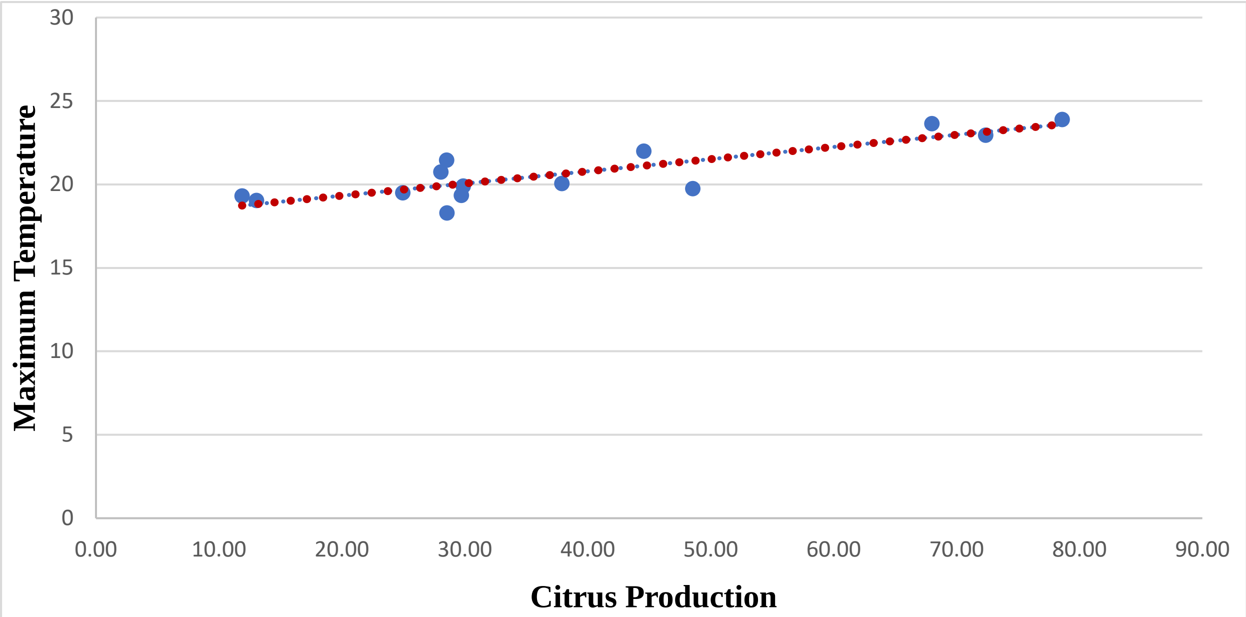

Fig 7: Scatterplot of maximum temperature with citrus production from 2004 to 2018

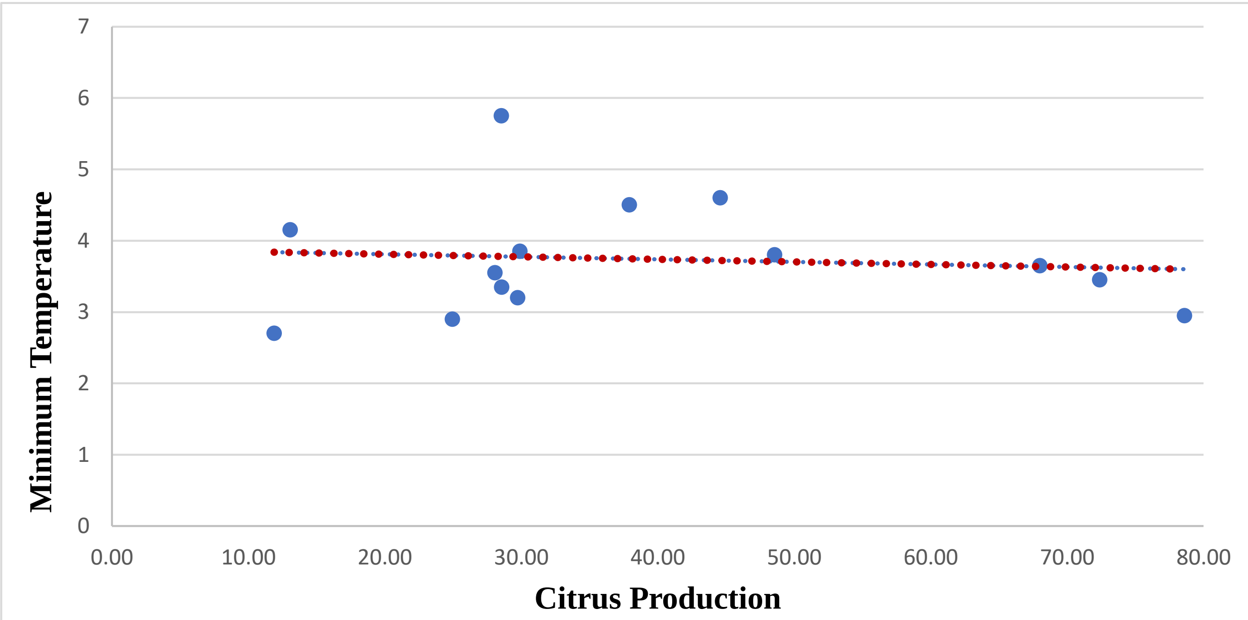

Fig 8: Scatterplot of minimum temperature with citrus production from 2004 to 2018

The correlation between citrus production and monthly mean maximum temperature showed moderate positive correlation. The trend line showed that citrus production increased with an increase in monthly mean maximum temperature (Fig.7). Whereas, the citrus production was found weakly negatively correlated with monthly mean minimum temperature. The graph displayed increase in citrus production with decrease in monthly mean minimum temperature (Fig.8).

The correlation analysis showed negative correlation of minimum temperature with fruit production shown in table 4.6 and 4.7. The production of mango and citrus had weakly negative correlation with the minimum temperature owing to various nutrient, crop protection and edaphology factors. However, maximum temperature showed positive correlation with mango as well as citrus crop production.

Hence, there was more influence of maximum temperature on fruit production and less influence of minimum temperature on fruit production. Similar results were observed by Swati *et al.,* (2019) in their studies where temperature had negative correlation with mango, sapota, papaya, banana production and had positive correlation with banana productivity. Similarly, Salau *et al.,* (2016) in their studies showed that, temperature had negative correlation with production of banana.

4.3 EFFECT OF WEATHER PARAMETERS ON PRODUCTION OF FRUIT CROPS

4.3.1 Regression models for citrus production with selected weather parameters

The data pertaining to effect of weather parameters on fruit production of citrus crop were examined with the help of regression models which included, fruit production as a dependent variable and weather parameters as an independent variable. The regression studies among linear (straight line) and nonlinear (logarithmic, quadratic, cubic, exponential, power, growth, compound, inverse and S curve) models were applied on the weather parameters *viz.*, maximum temperature, minimum temperature and rainfall in order to obtain the relationship between the weather parameters and production of citrus crop. The best fitted equations along with R^2 value and coefficient standard errors have been studied and shown in table 4.8 to 4.13.

Table 4.8: Linear and nonlinear functions for citrus production on the basis of maximum temperature

Models	Equations	SE (βi)	R^2	RMSE
Linear	CP = 112.94 - 2.84 T max	4.074 121.949	0.023	21.62
Logarithmic	CP = 310.71 – 83.24logT max	121.85 413.63	0.022	21.63
Inverse	CP = -53.54 + 2432.09/T max	3640.529 122.349	0.021	21.64
Quadratic	CP = -2806.1 + 192.49T max – 3.26T max^2	234.307 3.914 3502.938	0.056	21.78
Cubic	CP = -885.746 + 3.16T max – 0.07T max^2	3.904 0.087 1165.031	0.056	21.78
Compound	CP = 508.67 x $0.89^{T\ max}$	0.128 2152.871	0.026	0.75
Power	CP = 922661.8T $max^{-3.14}$	4.242 13285507	0.025	0.75
S	CP = Exp (-0.05 + 92.98/T max)	126.7 4.258	0.025	0.75
Growth	CP = Exp (6.23 – 0.10T max)	0.142 4.232	0.026	0.75
Exponential	CP = 508.67 $e^{-0.10T\ max}$	0.142 2152.87	0.026	0.75

CP = Citrus Production; **T max** = Maximum Temperature; **SE (βi) =** Coefficient of standard error; **RMSE** = Root mean square error; R^2 = R-squared

Table 4.9: Trend values of citrus production on the basis of weather parameter (maximum temperature) from 1996 to 2018.

Citrus	T max	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
11.96	31.81	22.47	22.69	22.91	14.95	14.82	17.49	17.60	17.70	17.49	17.49
7.93	28.19	32.76	32.75	32.73	26.94	27.06	25.67	25.72	25.76	25.67	25.67
7.67	29.88	27.96	27.90	27.85	31.99	31.98	21.46	21.42	21.37	21.46	21.46
8.68	29.42	29.26	29.19	29.12	32.46	32.38	22.54	22.49	22.44	22.54	22.54
10.62	28.82	30.97	30.91	30.85	31.00	30.93	24.01	23.99	23.97	24.01	24.01
19.76	28.84	30.91	30.85	30.79	31.09	31.01	23.96	23.94	23.91	23.96	23.96
9.35	29.98	27.67	27.62	27.58	31.70	31.71	21.24	21.19	21.15	21.24	21.24
17.21	29.83	28.10	28.04	27.99	32.11	32.09	21.58	21.53	21.49	21.58	21.58
9.35	30.93	24.97	25.03	25.09	25.73	25.84	19.20	19.22	19.23	19.20	19.20
13.06	30.83	25.25	25.30	25.34	26.64	26.74	19.41	19.41	19.42	19.41	19.41
11.88	31.31	23.89	24.01	24.13	21.70	21.75	18.45	18.49	18.54	18.45	18.45
24.95	31.11	24.46	24.54	24.63	23.94	24.03	18.84	18.87	18.90	18.84	18.84
28.56	30.64	25.79	25.81	25.83	28.18	28.27	19.80	19.79	19.79	19.80	19.80
28.52	31.79	22.52	22.74	22.96	15.25	15.13	17.53	17.63	17.73	17.53	17.53
28.05	29.67	28.55	28.49	28.43	32.38	32.33	21.95	21.90	21.85	21.95	21.95
29.73	28.36	32.28	32.25	32.21	28.30	28.33	25.21	25.23	25.25	25.21	25.21
29.88	29.01	30.43	30.36	30.29	31.72	31.63	23.54	23.50	23.46	23.54	23.54
48.55	28.26	32.56	32.54	32.52	27.52	27.60	25.48	25.52	25.55	25.48	25.48
37.90	28.61	31.57	31.52	31.46	29.94	29.90	24.55	24.55	24.54	24.55	24.55
44.56	28.47	31.97	31.93	31.88	29.07	29.07	24.92	24.93	24.94	24.92	24.92
68.00	30.22	26.99	26.96	26.94	30.75	30.79	20.70	20.67	20.64	20.70	20.70
72.38	30.02	27.56	27.51	27.47	31.57	31.58	21.15	21.11	21.07	21.15	21.15
78.59	29.78	28.24	28.18	28.12	32.21	32.18	21.69	21.64	21.60	21.69	21.69

The contents of different models revealed the relationship between production of citrus crop and maximum temperature. As shown in table 4.8 the cubic and quadratic equations were found very weakly fitted for maximum temperature and production of citrus crop with value of R^2 (5.6 %) along with value of RMSE (21.78). The trend values of linear and non-linear regression models for production of citrus with maximum temperature are presented in table 4.9.

Table 4.10: Linear and nonlinear functions for citrus production on the basis of minimum temperature

Models	Equations	SE (β_i)	R^2	RMSE
Linear	CP = 53.87 – 1.42T min	9.043 163.383	0.001	21.86
Logarithmic	CP = 87.08 – 20.37logT min	160.866 465.468	0.001	21.86
Inverse	CP = 12.96 + 273.78/T min	2859.266 158.502	0	21.86
Quadratic	CP = -11633.3 + 1313.13T min -36.92T min^2	563.364 15.824 5010.292	0.215	19.86
Cubic	CP = -7726.33 + 655.03T min -0.69T min^2	281.642 0.296 3339.853	0.215	19.86
Compound	CP = 235.60 x $0.87^{T\ min}$	0.275 1337.75	0.008	0.75
Power	CP = 10342.89T $min^{-2.13}$	5.593 167395	0.007	0.75
S	CP = Exp (1.18 + 33.99/T min)	99.469 5.514	0.006	0.75
Growth	CP = Exp (5.46 – 0.13T min)	0.314 5.678	0.008	0.75
Exponential	CP = 235.60 $e^{-0.13T\ min}$	0.314 1337.755	0.008	0.75

CP = Citrus Production; **T min** = Minimum Temperature; **SE (β_i) =** Coefficient of standard error; **RMSE** = Root mean square error; **R^2** = R-squared.

Table 4.11: Trend values of citrus production on the basis of weather parameter (minimum temperature) from 1996 to 2018.

Citrus	T min	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
11.96	16.84	29.88	29.55	29.22	7.82	8.03	25.40	25.07	24.73	25.40	25.40
7.93	17.02	29.62	29.34	29.05	19.12	19.10	24.80	24.50	24.21	24.80	24.80
7.67	18.68	27.25	27.44	27.62	10.53	10.40	19.91	20.09	20.27	19.91	19.91
8.68	18.62	27.34	27.51	27.67	14.39	14.32	20.07	20.23	20.39	20.07	20.07
10.62	18.10	28.08	28.08	28.09	36.66	36.70	21.50	21.49	21.49	21.50	21.50
19.76	18.55	27.44	27.58	27.72	18.55	18.53	20.26	20.39	20.53	20.26	20.26
9.35	18.55	27.44	27.58	27.72	18.55	18.53	20.26	20.39	20.53	20.26	20.26
17.21	18.16	28.00	28.02	28.04	35.11	35.17	21.33	21.34	21.36	21.33	21.33
9.35	18.52	27.48	27.62	27.75	20.22	20.22	20.34	20.47	20.59	20.34	20.34
13.06	18.24	27.88	27.93	27.98	32.63	32.70	21.10	21.14	21.18	21.10	21.10
11.88	18.32	27.77	27.84	27.91	29.68	29.74	20.88	20.94	21.01	20.88	20.88
24.95	18.16	28.00	28.02	28.04	35.11	35.17	21.33	21.34	21.36	21.33	21.33
28.56	18.11	28.07	28.07	28.08	36.42	36.47	21.47	21.47	21.47	21.47	21.47
28.52	18.06	28.14	28.13	28.13	37.55	37.58	21.61	21.59	21.58	21.61	21.61
28.05	18.13	28.04	28.05	28.07	35.92	35.97	21.41	21.42	21.42	21.41	21.41
29.73	17.18	29.39	29.15	28.90	27.15	27.02	24.28	24.02	23.76	24.28	24.28
29.88	18.46	27.57	27.68	27.80	23.37	23.40	20.50	20.61	20.72	20.50	20.50
48.55	17.77	28.55	28.46	28.37	40.44	40.36	22.46	22.35	22.25	22.46	22.46
37.90	17.40	29.08	28.89	28.70	35.11	34.94	23.58	23.38	23.18	23.58	23.58
44.56	17.79	28.52	28.44	28.36	40.44	40.37	22.40	22.30	22.20	22.40	22.40
68.00	18.44	27.60	27.71	27.81	24.36	24.40	20.55	20.66	20.76	20.55	20.55
72.38	18.34	27.74	27.82	27.89	28.86	28.93	20.83	20.90	20.97	20.83	20.83
78.59	17.97	28.27	28.23	28.20	39.11	39.11	21.87	21.82	21.78	21.87	21.87

As evident from table 4.10 the regression models showed relationship between minimum temperature and production of citrus crop. Among all equations, cubic and quadratic models were found more suited than other equations with value of R^2 (21.5 %) and value of RMSE (19.86). Therefore, minimum temperature slightly impacted the citrus crop production. The trend values of citrus production are presented in table 4.11. On the basis of R^2 and coefficient of standard error (SE β_i) value, quadratic (CP = -11633.3 + 1313.13T min -36.92T min^2) and cubic (CP = -7726.33 + 655.03T min -0.69T min) equation were observed optimally fitted.

Table 4.12: Linear and nonlinear functions for citrus production on the basis of rainfall

Models	Equations	SE (β_i)	R^2	RMSE
Linear	CP = 38.20 – 2.97RF	5.708 19.839	0.013	21.73
Logarithmic	CP = 38.51 – 8.69logRF	20.293 24.637	0.009	21.78
Inverse	CP = 20.36 + 25.01/RF	66.93 21.29	0.007	21.80
Quadratic	CP = -19.93 + 29.66RF – 4.32 RF^2	39.49 5.18 72.42	0.046	21.89
Cubic	CP = 414.117 – 349.05RF + 100.91 RF^2 – 9.29RF^3	236.92 65.179 5.73 276.93	0.162	21.05
Compound	CP = 43.04 x 0.81^{RF}	0.159 29.231	0.049	0.74
Power	CP = 45.87 RF$^{-0.63}$	0.697 38.840	0.038	0.74
S	CP = Exp (2.49 + 1.86/RF)	2.307 0.734	0.030	0.75
Growth	CP = Exp (3.76 – 0.20RF)	0.195 0.679	0.049	0.74
Exponential	CP = 43.04 e$^{0.20RF}$	0.195 29.231	0.049	0.74

CP = Citrus Production; **Rainfall** = Rainfall; **SE (β_i) =** Coefficient of standard error; **RMSE** = Root mean square error; **R^2** = R-squared.

Table 4.13: Trend values of citrus production on the basis of weather parameter (rainfall) from 1996 to 2018.

Citrus	RF	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
11.96	4.17	25.78	26.07	26.34	28.48	39.50	18.41	18.63	18.93	18.41	18.41
7.93	5.05	23.13	24.38	25.27	19.50	28.67	15.38	16.50	17.50	15.38	15.38
7.67	5.56	21.60	23.53	24.81	11.24	-2.97	13.86	15.53	16.91	13.86	13.86
8.68	3.05	29.15	28.83	28.58	30.25	24.69	23.15	22.72	22.33	23.15	23.15
10.62	2.87	29.69	29.37	29.11	29.53	24.00	24.01	23.61	23.21	24.01	24.01
19.76	2.97	29.39	29.07	28.81	29.97	24.24	23.53	23.10	22.70	23.53	23.53
9.35	3.01	29.27	28.95	28.69	30.12	24.44	23.34	22.91	22.51	23.34	23.34
17.21	3.13	28.91	28.61	28.37	30.49	25.35	22.77	22.35	21.98	22.77	22.77
9.35	3.01	29.27	28.95	28.69	30.12	24.44	23.34	22.91	22.51	23.34	23.34
13.06	2.74	30.08	29.78	29.53	28.83	24.32	24.66	24.32	23.94	24.66	24.66
11.88	3.11	28.97	28.66	28.42	30.43	25.16	22.86	22.44	22.06	22.86	22.86
24.95	3.92	26.53	26.62	26.73	29.82	36.72	19.38	19.38	19.48	19.38	19.38
28.56	3.41	28.07	27.85	27.70	30.86	28.83	21.50	21.17	20.92	21.50	21.50
28.52	2.24	31.59	31.56	31.60	24.79	34.29	27.31	27.63	27.89	27.31	27.31
28.05	3.44	27.98	27.77	27.63	30.86	29.28	21.37	21.05	20.82	21.37	21.37
29.73	3.39	28.13	27.90	27.74	30.86	28.54	21.59	21.25	20.99	21.59	21.59
29.88	2.20	31.71	31.72	31.81	24.38	35.82	27.54	27.95	28.32	27.54	27.54
48.55	3.63	27.40	27.30	27.25	30.69	32.28	20.56	20.34	20.24	20.56	20.56
37.90	3.25	28.55	28.27	28.07	30.73	26.65	22.22	21.82	21.50	22.22	22.22
44.56	4.09	26.02	26.24	26.46	28.97	38.77	18.71	18.86	19.09	18.71	18.71
68.00	2.39	31.14	30.99	30.89	26.23	29.61	26.49	26.52	26.46	26.49	26.49
72.38	3.23	28.61	28.33	28.12	30.70	26.41	22.31	21.91	21.57	22.31	22.31
78.59	4.03	26.20	26.37	26.55	29.29	38.12	18.95	19.04	19.22	18.95	18.95

As clear from table 4.12 the Cubic equation (CP = 414.117 – 349.05RF + 100.91RF^2 – 9.29RF^3) of regression model was observed weakly fitted for rainfall and citrus production with the value of R^2 (16.2 %) and RMSE (21.05). However, the trend values for relationship between production (dependent) and rainfall (independent) are presented in table 4.13.

4.3.2 Regression models for mango production with selected weather parameters

To determine the effect of weather parameters on the production of mango crop, regression models *viz.*, linear and non-linear (logarithmic, quadratic, cubic, exponential, power, growth, compound, inverse and S curve) were applied on weather parameters such as maximum temperature (T max), minimum temperature (T min) and rainfall (RF). The data was pooled in order to estimate mango production using selected regression function. The optimum suited equation along with the value of R^2, RMSE and standard error of coefficient have been presented in tables 4.14 to 4.19.

Table 4.14: Linear and non-linear functions for mango production on the basis of maximum temperature.

Models	Equations	SE (β_i)	R^2	RMSE
Linear	MP = 28.34 + 0.82T max	7.059 210.628	0.001	37.47
Logarithmic	MP = -45.51 + 28.97logT max	211.028 716.352	0.001	37.47
Inverse	MP = 86.32 – 997.74/T max	6300.937 211.758	0.001	37.46
Quadratic	MP = -7140.7 + 480.56T max – 8.01T max^2	398.853 6.663 5962.931	0.068	37.08
Cubic	MP = -7140.7 + 480.56T max – 8.01T max^2	398.853 6.663 5962.931	0.068	37.08
Compound	MP = 2.77 x 1.09$^{T\ max}$	0.172 12.973	0.015	0.83
Power	MP = 0.004T max$^{2.73}$	4.688 0.06	0.016	0.83
S	MP = Exp (6.48 – 83.17/ T max)	139.945 4.703	0.017	0.83
Growth	MP = Exp (1.02 – 0.09T max)	0.157 4.68	0.015	0.83
Exponential	MP = 2.77 e$^{0.09T\ max}$	0.157 12.973	0.015	0.83

MP = Mango Production; **T max** = Maximum temperature; **SE (β_i) =** Coefficient of standard error; **RMSE** = Root mean square error; **R^2** = R-squared

Table 4.15: Trend values of mango production on the basis of weather parameter (maximum temperature) from 1996 to 2018.

Mango	T max	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
66.20	31.81	54.45	54.71	54.96	35.99	35.99	48.08	48.08	48.07	48.08	48.08
8.23	28.19	51.48	51.21	50.93	37.19	37.19	34.75	34.55	34.36	34.75	34.75
36.27	29.88	52.87	52.90	52.93	62.77	62.77	40.44	40.52	40.60	40.44	40.44
9.45	29.42	52.49	52.45	52.41	60.35	60.35	38.80	38.83	38.87	38.80	38.80
21.61	28.82	52.00	51.85	51.71	52.08	52.08	36.77	36.71	36.65	36.77	36.77
21.90	28.84	52.02	51.87	51.73	52.45	52.45	36.83	36.78	36.72	36.83	36.83
34.16	29.98	52.95	53.00	53.05	62.85	62.85	40.80	40.89	40.98	40.80	40.80
7.54	29.83	52.83	52.85	52.88	62.67	62.67	40.25	40.33	40.41	40.25	40.25
39.52	30.93	53.73	53.90	54.07	55.61	55.61	44.43	44.53	44.62	44.43	44.43
27.25	30.83	53.65	53.81	53.96	57.05	57.05	44.03	44.14	44.24	44.03	44.03
56.80	31.31	54.04	54.25	54.46	48.66	48.66	45.97	46.04	46.10	45.97	45.97
33.70	31.11	53.88	54.07	54.26	52.61	52.61	45.15	45.24	45.32	45.15	45.15
57.50	30.64	53.49	53.63	53.76	59.35	59.35	43.29	43.40	43.50	43.29	43.29
24.30	31.79	54.44	54.69	54.94	36.57	36.57	47.99	48.00	47.99	47.99	47.99
72.80	29.67	52.70	52.70	52.70	62.09	62.09	39.68	39.74	39.81	39.68	39.68
39.50	28.36	51.62	51.39	51.15	41.84	41.84	35.28	35.13	34.97	35.28	35.28
120.00	29.01	52.16	52.04	51.93	55.32	55.32	37.40	37.37	37.35	37.40	37.40
44.95	28.26	51.54	51.28	51.02	39.16	39.16	34.97	34.79	34.61	34.97	34.97
80.71	28.61	51.83	51.64	51.45	47.83	47.83	36.08	35.98	35.88	36.08	36.08
60.95	28.47	51.71	51.50	51.28	44.60	44.60	35.63	35.50	35.37	35.63	35.63
100.98	30.22	53.15	53.23	53.31	62.39	62.39	41.69	41.79	41.89	41.69	41.69
127.88	30.02	52.98	53.03	53.09	62.84	62.84	40.95	41.04	41.13	40.95	40.95
122.61	29.78	52.79	52.80	52.82	62.53	62.53	40.07	40.15	40.22	40.07	40.07

The data presented in table 4.14 revealed that the cubic and quadratic regression function were weakly fitted for production of mango crop and maximum temperature because the value of R^2 (6.8 %) was lower and root mean square error (37.08) was higher. Trend values of all regression models for production of mango with maximum temperature are presented in table 4.15.

Table 4.16: Linear and nonlinear functions for mango production on the basis of minimum temperature.

Models	Equations	SE (β_i)	R^2	RMSE
Linear	MP = 25.70 – 1.501T min	15.502 280.092	0	37.48
Logarithmic	MP= 32.58 + 29.51logT min	275.705 797.756	0.001	37.48
Inverse	MP= 84.60 - 573.60/T min	4899.377 271.594	0.001	37.47
Quadratic	MP= -6729.63 + 761.33T min – 21.34T min^2	1076.038 30.224 9569.77	0.025	37.93
Cubic	MP= -4510.15 + 384.21T min - 0.40T min^2	537.744 0.565 6376.83	0.025	37.93
Compound	MP= 32.14 x $1.01^{T\ min}$	0.351 201.54	0	0.83
Power	MP= 17.11T $min^{0.295}$	6.172 305.658	0	0.83
S	MP= Exp (4.05 - 6.55/T min)	109.688 6.081	0	0.83
Growth	MP= Exp (3.47 – 0.01T min)	0.347 6.27	0	0.83
Exponential	MP= 32.14 $e^{0.01T\ min}$	0.347 201.548	0	0.83

MP = Mango Production; **T min** = Minimum temperature; **SE (β_i) =** Coefficient of standard error; **RMSE** = Root mean square error; **R^2** = R-squared.

Table 4.17: **Trend values of mango production on the basis of weather parameter (minimum temperature) from 1996 to 2018.**

Mango	T min	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
66.20	16.84	50.98	50.76	50.54	38.23	38.25	39.60	39.39	39.17	39.60	39.60
8.23	17.02	51.25	51.08	50.90	45.18	45.12	39.69	39.51	39.33	39.69	39.69
36.27	18.68	53.75	53.82	53.90	44.08	43.92	40.52	40.61	40.70	40.52	40.52
9.45	18.62	53.66	53.73	53.80	46.17	46.06	40.49	40.57	40.66	40.49	40.49
21.61	18.10	52.88	52.89	52.91	57.84	57.90	40.23	40.24	40.25	40.23	40.23
21.90	18.55	53.55	53.62	53.68	48.41	48.36	40.45	40.53	40.60	40.45	40.45
34.16	18.55	53.55	53.62	53.68	48.41	48.36	40.45	40.53	40.60	40.45	40.45
7.54	18.16	52.97	52.99	53.02	57.08	57.15	40.26	40.28	40.30	40.26	40.26
39.52	18.52	53.51	53.57	53.63	49.31	49.27	40.44	40.51	40.58	40.44	40.44
27.25	18.24	53.09	53.12	53.15	55.83	55.89	40.30	40.33	40.36	40.30	40.30
56.80	18.32	53.21	53.25	53.29	54.31	54.36	40.34	40.38	40.42	40.34	40.34
33.70	18.16	52.97	52.99	53.02	57.08	57.15	40.26	40.28	40.30	40.26	40.26
57.50	18.11	52.89	52.91	52.93	57.72	57.79	40.23	40.24	40.26	40.23	40.23
24.30	18.06	52.82	52.83	52.84	58.26	58.32	40.21	40.21	40.22	40.21	40.21
72.80	18.13	52.92	52.94	52.96	57.48	57.54	40.24	40.26	40.27	40.24	40.24
39.50	17.18	51.49	51.35	51.21	50.20	50.11	39.77	39.62	39.48	39.77	39.77
120.00	18.46	53.42	53.47	53.53	50.99	50.99	40.41	40.47	40.53	40.41	40.41
44.95	17.77	52.38	52.35	52.32	59.25	59.26	40.06	40.02	39.98	40.06	40.06
80.71	17.40	51.83	51.73	51.64	55.31	55.24	39.88	39.77	39.67	39.88	39.88
60.95	17.79	52.41	52.38	52.36	59.30	59.32	40.07	40.03	40.00	40.07	40.07
100.98	18.44	53.39	53.44	53.50	51.52	51.52	40.40	40.46	40.52	40.40	40.40
127.88	18.34	53.24	53.28	53.33	53.89	53.93	40.35	40.39	40.44	40.35	40.35
122.61	17.97	52.68	52.68	52.68	58.95	59.00	40.16	40.15	40.14	40.16	40.16

It is clear from table 4.16 that the minimum temperature did not showed any relation with mango production due to lowest value of R^2 and highest value of RMSE. Both linear and nonlinear models of R^2 and RMSE ranged from 0.0 to 0.025 and 0.83 to 37.93, respectively. According to values of R^2 and RMSE of all the regression models were recorded poorly fitted to annual mango production. The trend values for all regression models are presented in table 4.17.

Table 4.18: Linear and nonlinear functions for mango production on the basis of rainfall.

Models	**Equations**	**SE (βi)**	R^2	**RMSE**
Linear	**MP**= 73.20 - 6.02RF	9.757 33.910	0.018	37.15
Logarithmic	**MP=** 78.56 - 21.57logRF	34.609 42.018	0.018	37.14
Inverse	**MP=** 29.47 + 75.10/RF	113.918 36.235	0.020	37.10
Quadratic	**MP=** $51.29 + 6.27RF - 1.63\,RF^2$	68.616 9.003 125.830	0.019	38.04
Cubic	**MP=** $738.44 – 593.27\,RF + 164.97\,RF^2 – 14.70\,RF^3$	416.444 114.564 10.084 486.769	0.119	37.01
Compound	**MP=** 59.49×0.89^{RF}	0.195 45.267	0.013	0.83
Power	**MP=** $63.32\,RF^{-0.38}$	0.777 59.767	0.011	0.83
S	**MP=** Exp (3.31 + 1.23/RF)	2.562 0.815	0.011	0.83
Growth	**MP=** Exp (4.08 - 0.11RF)	0.219 0.761	0.013	0.83
Exponential	**MP=** $59.49\,e^{-0.11RF}$	0.219 45.267	0.013	0.83

MP = Mango Production; **RF** = Rainfall; **SE (βi) =** Coefficient of standard error; **RMSE** = Root mean square error; $\mathbf{R^2}$ = R-squared.

Table 4.19: Trend values of mango production on the basis of weather parameter (rainfall) from 1996 to 2018.

Mango	RF	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
66.20	4.17	48.07	47.72	47.43	49.02	66.72	36.70	36.75	36.80	36.70	36.70
8.23	5.05	42.75	43.55	44.24	41.47	56.20	33.13	34.13	34.92	33.13	33.13
36.27	5.56	39.66	41.45	42.85	36.03	13.21	31.22	32.89	34.14	31.22	31.22
9.45	3.05	54.86	54.54	54.15	55.24	46.30	41.81	41.45	41.09	41.81	41.81
21.61	2.87	55.95	55.87	55.72	55.89	47.00	42.70	42.43	42.17	42.70	42.70
21.90	2.97	55.34	55.12	54.82	55.54	46.34	42.20	41.88	41.55	42.20	42.20
34.16	3.01	55.10	54.83	54.48	55.39	46.27	42.01	41.66	41.32	42.01	42.01
7.54	3.13	54.37	53.98	53.51	54.92	46.67	41.42	41.04	40.67	41.42	41.42
39.52	3.01	55.10	54.83	54.48	55.39	46.27	42.01	41.66	41.32	42.01	42.01
27.25	2.74	56.73	56.88	56.98	56.30	49.04	43.35	43.20	43.05	43.35	43.35
56.80	3.11	54.49	54.12	53.67	55.00	46.54	41.52	41.14	40.77	41.52	41.52
33.70	3.92	49.59	49.07	48.59	50.74	61.83	37.79	37.63	37.51	37.79	37.79
57.50	3.41	52.68	52.11	51.51	53.66	50.39	40.10	39.71	39.35	40.10	40.10
24.30	2.24	59.76	61.27	63.20	57.38	72.64	45.94	46.68	47.68	45.94	45.94
72.80	3.44	52.49	51.92	51.31	53.51	50.96	39.96	39.57	39.22	39.96	39.96
39.50	3.39	52.80	52.24	51.64	53.75	50.02	40.19	39.80	39.44	40.19	40.19
120.00	2.20	60.00	61.66	63.82	57.44	75.82	46.16	47.00	48.16	46.16	46.16
44.95	3.63	51.34	50.75	50.15	52.49	55.06	39.08	38.76	38.48	39.08	39.08
80.71	3.25	53.64	53.16	52.61	54.41	47.85	40.85	40.45	40.07	40.85	40.85
60.95	4.09	48.56	48.14	47.78	49.59	65.34	37.05	37.02	37.02	37.05	37.05
100.98	2.39	58.85	59.86	61.06	57.14	62.56	45.15	45.53	46.03	45.15	45.15
127.88	3.23	53.77	53.29	52.75	54.50	47.60	40.95	40.54	40.16	40.95	40.95
122.61	4.03	48.92	48.47	48.06	50.01	64.18	37.31	37.23	37.19	37.31	37.31

The data pertaining to the effect of rainfall on production of mango crop with the help of regression model equations is presented in table 4.18. Among all regression model equations , cubic model equation was observed moderately fitted for mango production and rainfall with value of R^2 (11.9 %) along with value of root mean square error (37.01). The trend values for all regression models are presented in table 4.19. However, the rainfall had weakly influenced mango the production of the study area.

4.1.3 The analysis of multiple linear regression of citrus and mango.

The analysis of multiple linear regression for fruit crops were carried out to assess the combined effect of weather parameters on production of citrus as well as mango as presented in table 4.20 the value of R^2 was recorded 0.033 for citrus and 0.038 for mango, whereas value of Adj R^2 was -0.120 for citrus and -0.113 for mango. On the basis of R^2 values the variations due to weather parameters on the production of citrus and mango were 3.3 percent and 3.8 percent, respectively. Hence, multiple linear regression equation showed very weak relation between the fruit production and selected weather parameters.

Table 4.20: Multiple linear function for citrus and mango production with weather parameters

Crop	Equation	SE (β_i)	$\overline{R^2}$	R^2
Citrus	CP = 174.10 – 2.20 T max – 3.65 T min – 4.165 RF	231.204 4.430 10.632 6.239	-0.120	0.033
Crop	**Equation**	**SE (β_i)**	$\overline{R^2}$	R^2
Mango	MP = 75.36 + 4.09 T max – 6.95 T min – 5.61 RF	395.102 7.570 18.169 10.661	-0.113	0.038

Where, **MP** = Mango Production; **CP** = Citrus Production; **T max**= Maximum temperature; **T min** = Minimum temperature; **RF** = Rainfall; **SE (β_i) =** Coefficient of standard error; **R^2 =** R squared; $\overline{R^2}$ = Adj R^2

The relationship between the weather parameters and fruit (citrus and mango) production is depicted in table 4.20. Weather parameters *viz.,* maximum temperature (T max), minimum temperature (T min) and rainfall (RF) exhibited negative effect on citrus production i.e. there was a significant fall in the citrus production with the decreases in maximum temperature, minimum temperature and rainfall. However, the mango production was positively influenced with maximum temperature i.e. with the increase in maximum temperature, mango production was also increased. Other parameters *viz.,* rainfall and minimum temperature showed negative impact on mango production.

During the evaluation of the effect of weather parameters on mango and citrus production, it was observed that most of the weather parameters had no substantial impact on citrus and mango production as seen in table 4.8 to table 4.19. However, the multiple or composite weather parameters showed very weak or negligible influence on the production of citrus as shown in table 4.20. The results revealed that maximum temperature had negative effect on the citrus crop production because occurrence of stress condition due to high temperature, On other hand high temperature is also necessary for plant growth and better fruit quality. The related effects were also observed by Rachel *et al.* (2014), who observed that crop production had non-significant correlation and regression with weather parameters.

Maximum temperature showed positive impact on mango crop production. Increase in temperature resulted in an increase in mango fruit production. The results indicated that temperature is a major factor in the sub-tropical regions for the crop growth and production. However, Una district is the subtropical warm region so temperature plays a key role in production of fruits. Similar finding were reported by Abobatta (2019) who observed that temperature plays a main role in citrus cultivation, which means citrus crop growth and yield is deeply associated with temperature. The temperature below 10 ℃ adversely affects the metabolism activity, reduce the new growth of citrus tree, but if temperature rises above 35 ℃, it may improve the fruit quality at maturity and can increase fruit production. Also, Sobrinho *et al.* (2004) estimated that mango yield was directly influenced by temperature, they observed fruit production in all four directions of mango farm, South – West direction had maximum mango production (59.11 kg per tree) while north-west direction had minimum mango production (45.41 kg per plant). Their finding revealed that South – West direction received more sunlight and in turn the temperature remains higher than in North – West direction and canopy of plant took less amount of temperature and solar radiation which cause reduction in the mango production and indicated that temperature is directly proportional to fruit production. On the other hand rainfall had weak and negative impact on both mango and citrus production. The results are in accordance with the findings of Parmar *et al.* (2012) who reported that rainfall negatively correlated with mango production while, temperature reduce 2 °C had influenced on flowering, fruit quality and mango production.

4.4 COMPUTED TREND VALUE OF IMPORTANT WEATHER PARAMETERS

In present investigation on selected weather parameters, the annual data on weather parameters was collected and analyzed through regression models, which resulted in computing trend values of linear as well as non-linear models of weather parameters. Twenty three years secondary weather data (1996 – 2018) of Una district, Himachal Pradesh was analyzed. Trend equations worked out for all weather parameters are presented in the table 4.21 to 4.24.

4.4.1 Regression models for selected weather parameters.

The annual weather parameters *viz.* maximum temperature, minimum temperature and rainfall were estimated with help of regression models such as linear as well as non-linear (logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential). The models were worked out for computation of trend values of weather parameters on the basis of R^2 value, coefficient of standard error and RMSE (root mean square error) values.

Table 4.21: Linear and nonlinear functions for maximum temperature on the basis of time period (1996 – 2018)

Models	Equations	SE (β_i)	R^2	RMSE
Linear	**Y** = 30.13 - 0.02T max	0.036 0.493	0.025	1.14
Logarithmic	**Y** = 30.23 – 0.18logT max	0.296 0.706	0.018	1.14
Inverse	**Y =** 29.63 + 1.10/T max	1.136 0.3	0.043	1.13
Quadratic	**Y =** 29.58 + 0.10T max – 0.005 T max^2	0.151 0.006 0.786	0.063	1.14
Cubic	**Y =** 29.21 + 0.27T max– 0.02 T max^2	0.411 0.039 0.001 1.162	0.073	1.17
Compound	**Y =** 30.10 x $0.99^{T\ max}$	0.001 0.497	0.024	0.03
Power	**Y =** 30.19T $max^{-0.006}$	0.01 0.714	0.017	0.03
S	**Y =** Exp (3.38 + 0.03/T max)	0.038 0.01	0.04	0.03
Growth	**Y =** Exp (3.40 – 0.001T max)	0.001 0.016	0.024	0.03
Exponential	**Y =** 30.10 $e^{-0.001T\ max}$	0.001 0.497	0.024	0.03

Table 4.22: Trend values of maximum temperature on the basis of time period (1996-2018) with help of regression model.

Max Temp.	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
31.81	30.11	30.23	30.74	29.68	29.46	30.08	30.20	30.70	30.08	30.08
28.19	30.08	30.10	30.19	29.77	29.67	30.06	30.07	30.16	30.06	30.06
29.88	30.05	30.03	30.01	29.85	29.84	30.03	30.00	29.98	30.03	30.03
29.42	30.03	29.98	29.91	29.92	29.98	30.00	29.95	29.89	30.00	30.00
28.82	30.00	29.93	29.86	29.97	30.07	29.98	29.91	29.84	29.98	29.98
28.84	29.98	29.90	29.82	30.02	30.14	29.95	29.88	29.80	29.95	29.95
29.98	29.95	29.87	29.79	30.05	30.18	29.93	29.85	29.78	29.93	29.93
29.83	29.92	29.85	29.78	30.08	30.20	29.90	29.83	29.76	29.90	29.90
30.93	29.90	29.83	29.76	30.09	30.19	29.87	29.80	29.74	29.87	29.87
30.83	29.87	29.81	29.75	30.09	30.16	29.85	29.79	29.73	29.85	29.85
31.31	29.84	29.79	29.74	30.08	30.12	29.82	29.77	29.72	29.82	29.82
31.11	29.82	29.77	29.73	30.06	30.06	29.80	29.75	29.71	29.80	29.80
30.64	29.79	29.76	29.72	30.03	29.99	29.77	29.74	29.71	29.77	29.77
31.79	29.76	29.74	29.72	29.98	29.91	29.74	29.73	29.70	29.74	29.74
29.67	29.74	29.73	29.71	29.93	29.83	29.72	29.71	29.69	29.72	29.72
28.36	29.71	29.72	29.71	29.86	29.74	29.69	29.70	29.69	29.69	29.69
29.01	29.68	29.71	29.70	29.79	29.66	29.67	29.69	29.69	29.67	29.67
28.26	29.66	29.70	29.70	29.70	29.58	29.64	29.68	29.68	29.64	29.64
28.61	29.63	29.69	29.70	29.60	29.50	29.61	29.67	29.68	29.61	29.61
28.47	29.60	29.68	29.69	29.49	29.44	29.59	29.66	29.68	29.59	29.59
30.22	29.58	29.67	29.69	29.38	29.38	29.56	29.65	29.67	29.56	29.56
30.02	29.55	29.66	29.69	29.24	29.34	29.54	29.65	29.67	29.54	29.54
29.78	29.53	29.65	29.69	29.10	29.32	29.51	29.64	29.67	29.51	29.51

The annual secondary data of maximum temperature for selected regression models along with value of R^2 and RMSE from 1996 to 2018 are presented in table 4.21. The equation of cubic model ($Y = 29.21 + 0.27T\ max - 0.02T\ max^2$) was weakly suited to compute the trend values, due to lower values of R^2 (7.3 percent) along with higher value of root mean square error (1.17). The trend values of maximum temperature for all regression models are presented in table 4.22.

Table 4.23: Linear and nonlinear functions for minimum temperature on the basis of time period (1996 – 2018)

Models	Equations	SE (β_i)	R^2	RMSE
Linear	**Y** = 18.04 + 0.001T min	0.017 0.227	0	0.52
Logarithmic	**Y =** 17.72 + 0.14logT min	0.132 0.315	0.057	0.51
Inverse	**Y =** 18.25 – 1.19/T min	0.461 0.122	0.241	0.45
Quadratic	**Y =** 17.64 + 0.09T min – 0.004T min^2	0.067 0.003 0.351	0.1	0.51
Cubic	**Y =** 16.56 + 0.58T min – 0.05T min^2 + 0.001Min T^3	0.139 0.013 0.393	0.488	0.39
Compound	**Y =** 18.03 x $1^{T\ min}$	0.001 0.23	0.001	0.03
Power	**Y =** 17.70T $min^{0.009}$	0.007 0.313	0.062	0.03
S	**Y=** Exp (2.90 – 0.06/T min)	0.026 0.007	0.251	0.03
Growth	**Y=** Exp (2.89 +0T min)	0.001 0.013	0.001	0.03
Exponential	**Y=** $18.032e^{0.001T\ min}$	0.001 0.23	0.001	0.03

T min = Minimum temperature; **SE (β_i) =** Coefficient of standard error; **R^2 =** R squared: **RMSE** = Root mean square error.

Table 4.24: Trend values of minimum temperature on the basis of time period (1996-2018) with help of regression model

Min Temp	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
16.84	18.05	17.73	17.06	17.74	17.10	18.03	17.70	17.05	18.03	18.03
17.02	18.05	17.83	17.66	17.82	17.53	18.04	17.81	17.64	18.04	18.04
18.68	18.05	17.89	17.86	17.90	17.88	18.04	17.87	17.84	18.04	18.04
18.62	18.05	17.93	17.96	17.97	18.14	18.04	17.92	17.95	18.04	18.04
18.10	18.05	17.97	18.02	18.03	18.32	18.04	17.95	18.01	18.04	18.04
18.55	18.05	17.99	18.06	18.09	18.44	18.04	17.98	18.05	18.04	18.04
18.55	18.06	18.02	18.08	18.13	18.51	18.04	18.01	18.08	18.04	18.04
18.16	18.06	18.04	18.11	18.17	18.52	18.05	18.03	18.10	18.05	18.05
18.52	18.06	18.05	18.12	18.20	18.49	18.05	18.05	18.12	18.05	18.05
18.24	18.06	18.07	18.14	18.22	18.43	18.05	18.06	18.13	18.05	18.05
18.32	18.06	18.08	18.15	18.23	18.34	18.05	18.08	18.14	18.05	18.05
18.16	18.06	18.10	18.16	18.24	18.24	18.05	18.09	18.15	18.05	18.05
18.11	18.06	18.11	18.16	18.24	18.13	18.06	18.10	18.16	18.06	18.06
18.06	18.06	18.12	18.17	18.23	18.02	18.06	18.12	18.17	18.06	18.06
18.13	18.06	18.13	18.18	18.21	17.92	18.06	18.13	18.17	18.06	18.06
17.18	18.07	18.14	18.18	18.18	17.83	18.06	18.14	18.18	18.06	18.06
18.46	18.07	18.15	18.18	18.14	17.77	18.06	18.15	18.18	18.06	18.06
17.77	18.07	18.16	18.19	18.10	17.74	18.07	18.16	18.19	18.07	18.07
17.40	18.07	18.17	18.19	18.05	17.76	18.07	18.16	18.19	18.07	18.07
17.79	18.07	18.17	18.20	17.99	17.82	18.07	18.17	18.19	18.07	18.07
18.44	18.07	18.18	18.20	17.92	17.95	18.07	18.18	18.20	18.07	18.07
18.34	18.07	18.19	18.20	17.85	18.14	18.07	18.19	18.20	18.07	18.07
17.97	18.07	18.19	18.20	17.76	18.40	18.07	18.20	18.20	18.07	18.07

The perusal of annual secondary data of minimum temperature and trend values of minimum temperature as presented in table 4.23 and 4.24 respectively, As clear from table 4.23 R^2 value varied from 0.00 to 0.488. Among all the equation of regression models, cubic model ($Y = 16.56 + 0.58T\ min - 0.05T\ min^2 + 0.001Min\ T^3$) was observed best suited for minimum temperature due to higher value of R^2 (48.8 percent) along with lower value of root mean square error (0.39).

Table 4.25: Linear and nonlinear functions for rainfall on the basis of time period (1996 - 2018)

Models	Equations	SE (βi)	R^2	RMSE
Linear	$Y = 3.81 - 0.03RF$	0.025 0.342	0.087	0.79
Logarithmic	$Y = 4.38 - 0.44\log RF$	0.191 0.456	0.205	0.74
Inverse	$Y = 3.09 + 1.78/RF$	0.736 3.097	0.219	0.73
Quadratic	$Y = 4.8 - 0.27RF + 0.01RF^2$	0.092 0.004 0.479	0.326	0.69
Cubic	$Y = 5.30 - 0.50RF + 0.03 RF^2 - 0.001RF^3$	0.245 0.023 0.001 0.693	0.360	0.69
Compound	$Y = 3.68 \times 0.99^{RF}$	0.007 0.358	0.072	0.22
Power	$Y = 4.28RF^{-0.11}$	0.055 0.56	0.177	0.21
S	$Y = Exp\ (1.11 + 0.48/RF)$	0.21 0.055	0.199	0.20
Growth	$Y = Exp\ (1.30 - 0.009RF)$	0.007 0.097	0.072	0.22
Exponential	$Y = 3.68\ e^{-0.009RF}$	0.007 0.358	0.072	0.22

RF = Rainfall; **SE (βi) =** Coefficient of standard error; **RMSE** = Root mean square error; $\mathbf{R^2}$ = R-squared.

Table 4.26: Trend values of rainfall on the basis of time period (1996-2018) with help of regression model

RF	Linear	Logarithmic	Inverse	Quadratic	Cubic	Compound	Power	S	Growth	Exponential
4.17	3.78	4.38	4.88	4.54	4.84	3.65	4.29	4.93	3.65	3.65
5.05	3.74	4.08	3.99	4.29	4.43	3.61	3.95	3.88	3.61	3.61
5.56	3.70	3.90	3.69	4.07	4.08	3.58	3.77	3.58	3.58	3.58
3.05	3.67	3.77	3.54	3.87	3.79	3.55	3.65	3.44	3.55	3.55
2.87	3.63	3.67	3.45	3.68	3.55	3.52	3.55	3.36	3.52	3.52
2.97	3.60	3.59	3.39	3.52	3.35	3.49	3.48	3.31	3.49	3.49
3.01	3.56	3.52	3.35	3.38	3.20	3.45	3.42	3.27	3.45	3.45
3.13	3.53	3.46	3.32	3.25	3.09	3.42	3.36	3.24	3.42	3.42
3.01	3.49	3.41	3.30	3.15	3.01	3.39	3.32	3.22	3.39	3.39
2.74	3.46	3.36	3.28	3.06	2.96	3.36	3.28	3.20	3.36	3.36
3.11	3.42	3.32	3.26	3.00	2.95	3.33	3.24	3.19	3.33	3.33
3.92	3.39	3.28	3.25	2.95	2.95	3.30	3.21	3.18	3.30	3.30
3.41	3.35	3.24	3.23	2.93	2.98	3.27	3.18	3.17	3.27	3.27
2.24	3.32	3.21	3.22	2.92	3.02	3.24	3.15	3.16	3.24	3.24
3.44	3.28	3.18	3.22	2.93	3.07	3.21	3.13	3.15	3.21	3.21
3.39	3.25	3.15	3.21	2.97	3.13	3.18	3.10	3.15	3.18	3.18
2.20	3.21	3.12	3.20	3.02	3.20	3.15	3.08	3.14	3.15	3.15
3.63	3.17	3.10	3.20	3.10	3.26	3.13	3.06	3.14	3.13	3.13
3.25	3.14	3.07	3.19	3.19	3.32	3.10	3.04	3.13	3.10	3.10
4.09	3.10	3.05	3.19	3.30	3.38	3.07	3.02	3.13	3.07	3.07
2.39	3.07	3.03	3.18	3.43	3.42	3.04	3.01	3.12	3.04	3.04
3.23	3.03	3.01	3.18	3.59	3.45	3.01	2.99	3.12	3.01	3.01
4.03	3.00	2.99	3.17	3.76	3.46	2.99	2.98	3.12	2.99	2.99

The annual data on rainfall, R^2 value and RMSE value from 1996 to 2018 are presented in table 4.25. The equation of regression models (linear, logarithmic, inverse, quadratic, cubic, compound, power, S, growth and exponential) were found optimally fitted and the R^2 values varied from 7.2 to 36 %. Cubic model ($Y = 5.30 – 0.50RF + 0.03RF^2 – 0.001RF^3$) was found well suited to calculate the trend value of rainfall due to the high value of R^2 (36 %) along with low value of RMSE (0.69). The trend values of rainfall for all regression models are presented in table 4.26.

On the computation of trend values of selected weather parameter it was observed that there were considerable fluctuations in weather parameters over the period (1996 to 2018) for study area. Cubic and quadratic trend equation were fitted to the weather data and cubic trend equation was observed best fitted on the basis of R^2 value and root mean square error of these weather parameter for Una district of Himachal Pradesh. Throughout the study period, the cubic equation of trend revealed that among selected weather parameters *viz.,* minimum temperature and rainfall showed positive trend and minimum temperature exhibited more variation than other parameters. Hence cubic function was fitted to represent the trend value. The result showed that minimum temperature and rainfall was significant on the basis of R^2 value 48 % and 36 % respectively. On other hand results from table 4.21 indicated that maximum temperature showed decreasing trend by accounting R^2 value (7.3 percent). Similar findings were also reported by Singh *et al.* (2008) in their study which revealed increasing trend in rainfall and minimum temperature. Also Rachel *et al.* (2014) reported increasing trend in minimum temperature at Solan district. The results of present investigation were in close agreement with the finding of Kumar *et al.* (2010) in which they observed increasing trend of annual rainfall at sub-division of country.

4.5 PREPARATION OF PHYSIOGRAPHIC MAPS

The physiographic map provide valuable information regarding the physical appearance of earth surface and different landforms of earth surface. These maps were prepared for geographic study of certain area. The physiography of the particular land is determined by physiographic maps such as DEM (Digital elevation model), contour map, hill shade map, slope map, aspect map and study area maps. Arc Map 10.5.1 software is used for preparation of physiographic maps and GIS (geographic information system) technology was used for various type of mapping such as surface mapping, planetary mapping and satellite mapping with the help of spatial data, satellite images and software *viz.*, ERDAS, ArcMap etc.

4.5.1 Preparation of Digital elevation model (DEM)

Digital elevation model (DEM) is a 3D depiction of terrain or topography surface, which shows the range of elevation from the level of sea. The elevation model showed the range of elevation of the study area which varied from 329 to 1119 m. The elevation map was classified into five natural breaks such as first range (329 – 441 m), second range (442 – 528 m), third elevation range (529 – 619 m), forth range (620 – 740 m) and fifth elevation range (741 – 1119 m). The lowest elevation area was reported in Una and Amb block of the district (329 – 500 m) whereas, highest elevation was observed in the hills of Piplu Dhar area (700 – 1119 m) under Bangana block. The total geographic area classified under different elevation range and are presented in table 4.27 and DEM of study area (Una district) was shown in (Fig. 9).

Table 4.27: Area percentage under elevation range.

Elevation range (meter)	Area percentage (%)	Area sq.km
329 – 441 m	39.41%	610.46
442 – 528 m	7.77%	120.35
529 – 619 m	8.13%	125.93
620 – 740 m	10.87%	167.60
741 – 1119 m	33.87%	524.64
Total	**100%**	**1549 sq. km**

4.5.2 Preparation of Contour map

Contour map represents the contour lines on study area and it was prepared through digital elevation model. During the preparation of contour map it revealed that the altitude of the study area was ranged between 300 m to 1100 m from the sea level.

As clear from the contour map, the contour lines passing closely around the hills of Piplu Dhar represented the steepest slopes in the region of investigation whereas, plain area in the map represented contour lines separated from each other. The contour lines and height of contour are presented in the contour map. The map of contour of the study area are given in (Fig. 10).

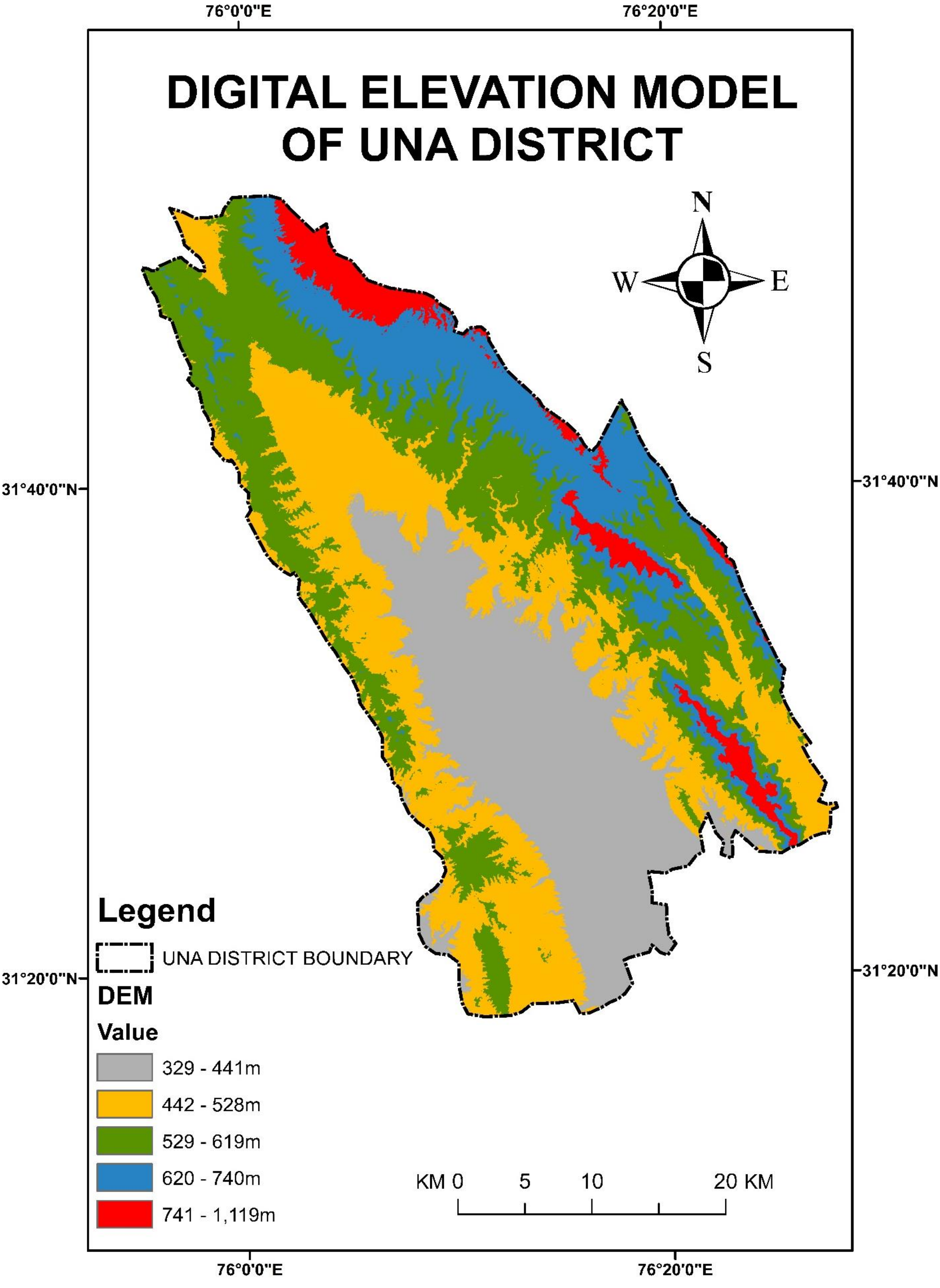

Fig. 9: DEM (Digital elevation model) of the study area.

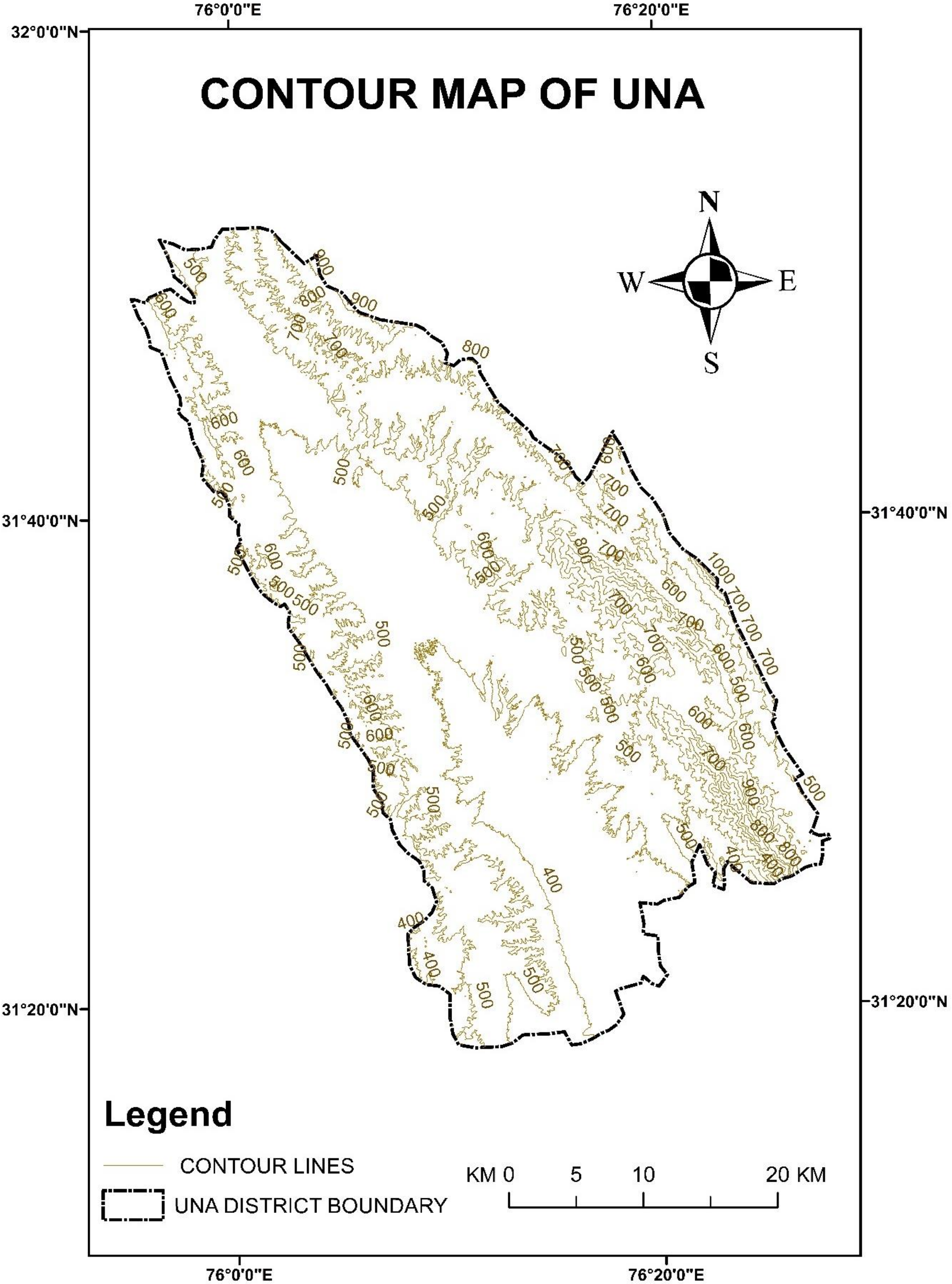

Fig. 10: Contour map of the study area.

4.5.3 Preparation of Aspect map

Aspect map was prepared from DEM of region under analysis. It shows that how much amount of light received from sun by surface of study region. The northern region with southern aspects have drier and warmer slopes than area having northern aspects. Aspect map were categorized into ten different aspects and had various degrees of aspect, each aspects show different color in the map. The ranges of aspect degree varied from flat (-1) to North (360°) and the slope of aspect map was measured in clockwise direction from flat aspect to north aspect.

The map of the study area having Southern point of view aspect showed different color on the basis of aspects such as light green color (southeast), blue color (south) and sky-blue (southwest) while, the northern point of view in aspect had different colors such as north (red), northeast (orange) and northwest (purple). All aspects were categorized under different classes and area under different aspects are presented in table 4.28. The aspect map of the study area is shown in (Fig. 11).

Table 4.28: Aspect classes and area percentage of the Una district

Class of aspects	**Degree of aspects**	**Area percentage (%)**	**Area sq. km**
Flat	-1 – 30.12	8.37%	129.65
North	30.13 – 68.32	10.62%	164.50
North-east	68.33 – 105.10	10.22%	158.30
East	105.11 – 140.47	9.83%	152.26
South-east	140.48 – 175.83	9.83%	152.26
South	175.84 – 211.20	9.61%	148.85
South-west	211.21 – 247.98	10.23%	158.46
West	247.99 – 283.35	9.83%	155.73
North-west	283.36 – 320.13	10.22%	158.30
North	320.14 - 360	11.02%	170.69
	Total	**100%**	**1549 sq. km**

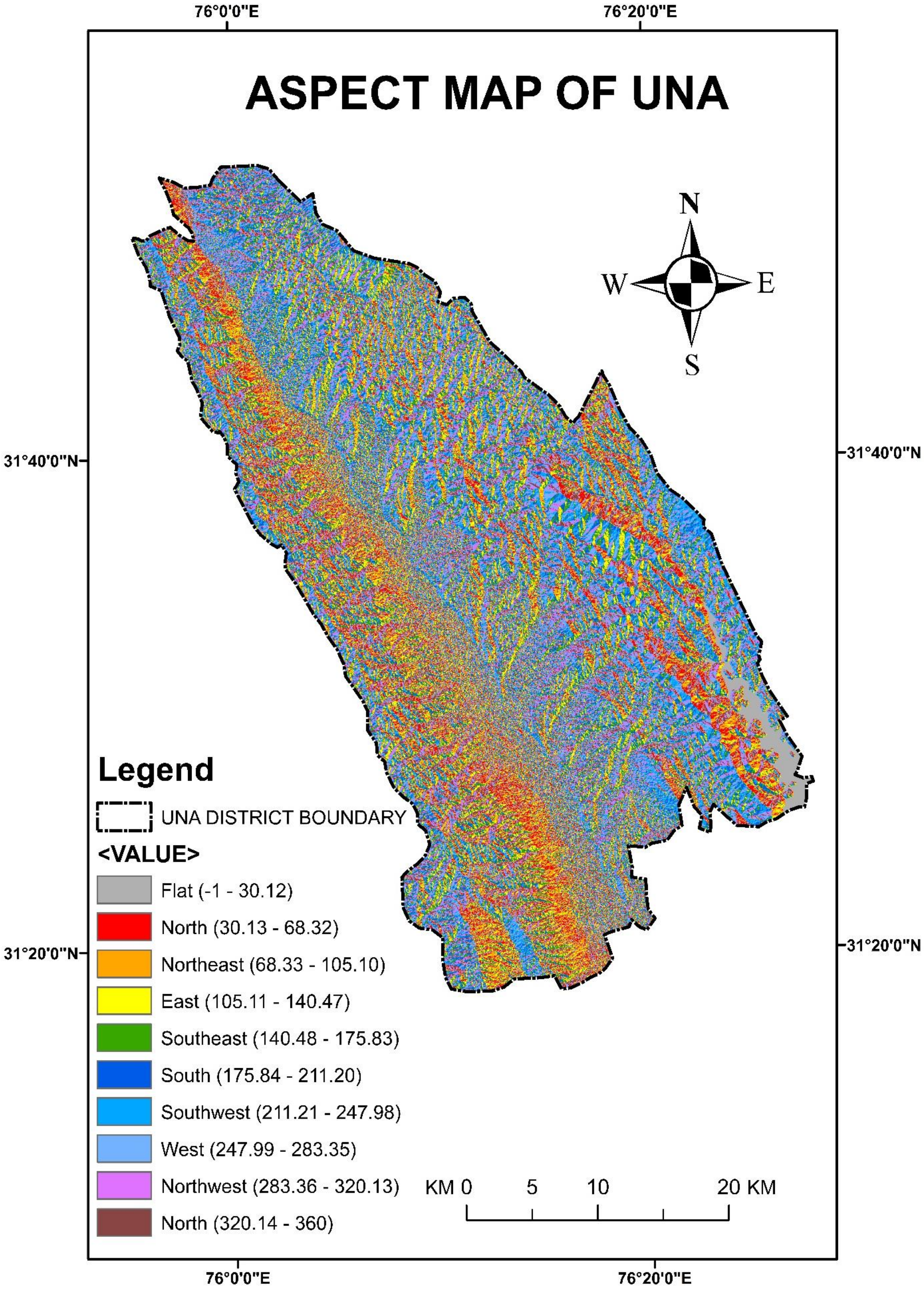

Fig. 11: Aspect map of the study area.

4.5.4 Preparation of hill-shade map.

Hill-shade map represents the realistic view of terrain and mountain on the study area. The map was prepared by digital elevation model of the study area with the help of ArcMap 10.5.1 software. For this digital elevation model (DEM) was fitted with the help of area examination tool as an input for preparation of hill-shade map of Una district.

As shown in the map, the hill-shade range varied from 0 to 254 and the map was classified into five classes on the basis of brightness and darkness of map. The area percentage under shade were classified on the basis of hill-shade range values (Table 4.29). The area with a low value 0 showed darker, indicating that they were under shade and gain less radiation energy from sun whereas, the highest value was 254 which lies under light shade and indicated that these regions are directly toward the sun. These area take full solar exposure from the sun. The hill-shade map of the study area was shown in (Fig 12).

Table 4.29: Hill-shade range and area under shade.

Hill-shade range	Area percentage (%)	Area sq. km
0 – 129	50.78%	786.58
130 – 158	11.42%	176.89
159 – 176	7.09%	109.82
177 – 196	7.87%	121.90
197 – 254	22.84%	353.79
Total	100%	1549 sq. km

4.5.5 Preparation of slope map

Slope map indicated the degree of steepness in the study area. The map was also prepared using digital elevation model (DEM) with the help of software i.e. ArcMap 10.5.1. DEM was used as an input for preparation of slope map.

The slope map showed the height change ratio value of a particular region on the earth's surface and direction of the slope change indicates the aspect change in certain region at the earth

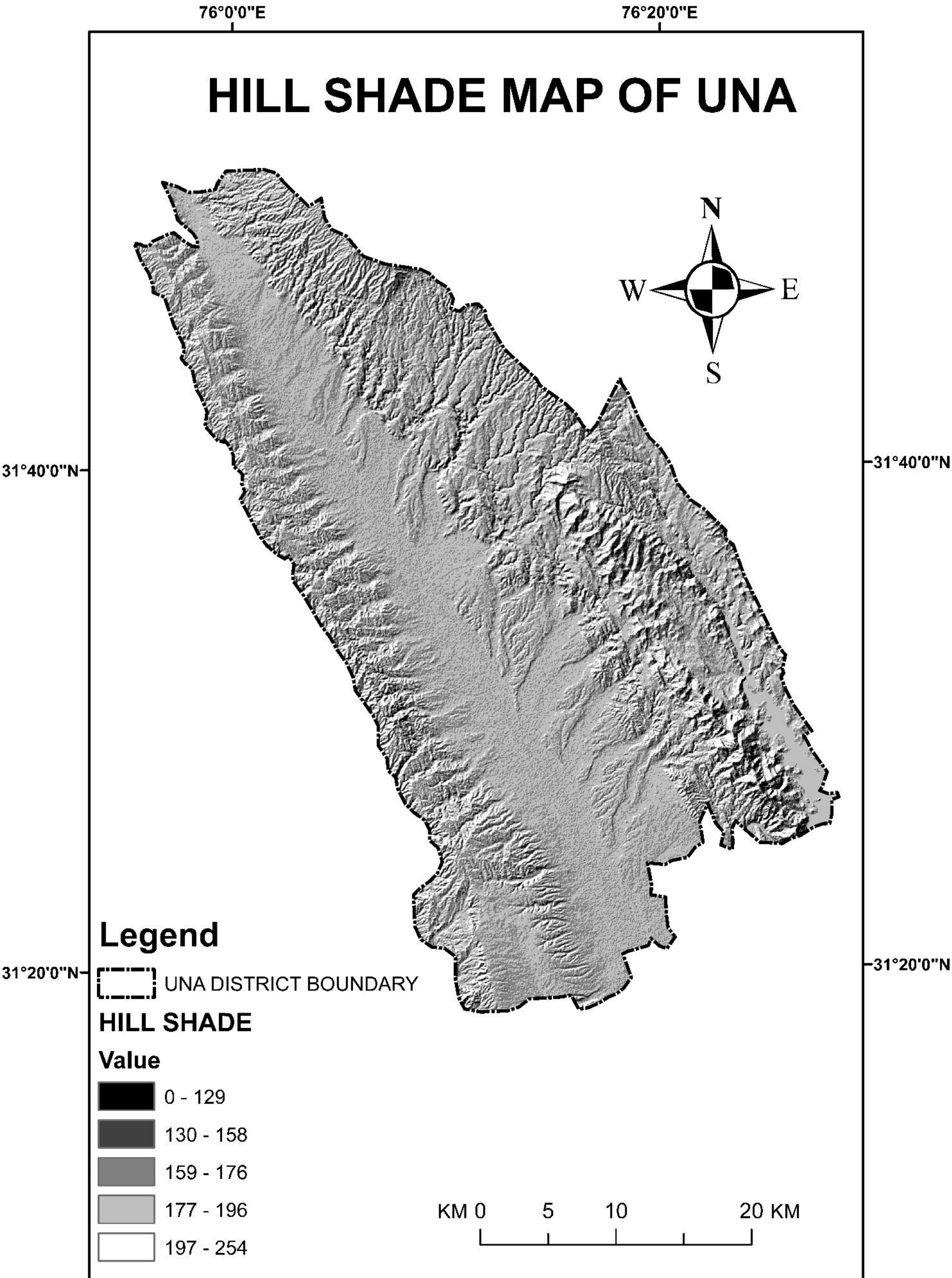

Fig. 12: Hill-shade map of study area.

surface. The slope map was categorized into eight different classes as per recommendation of ALS & LUS (All India Soil and Land Use Survey). Slope map shown in Fig. 13 and the area was categorized into eight groups of slope (Table 4.30). The map revealed that the maximum slope varied from 0 to 31.70 % covering 52.92 percent of the geographical area whereas, very steep slopes (31.71 to 59.87 %) covered 47.06 percent of the total geographical area in the district. Very steep area (31.71 to 59.87 %) was found in the upper hills of Piplu Dhar.

Table 4.30: Classification of slope and area percentage

Slope classes	Slope percentage (%)	Area percentage (%)	Area sq. km
Level	0 – 3.05	5.09%	78.84
Nearly gentle	3.06 – 6.57	5.89%	91.23
Very gentle	6.58 – 10.33	6.27%	97.12
Gentle	10.34 – 14.32	6.67%	103.31
Moderate	14.33 – 18.78	7.45%	115.40
Strong	18.79 – 24.18	9.02%	139.71
Steep	24.19 – 31.70	12.53%	194.08
Very steep	31.71 – 59.87	47.06%	728.95

The maximum area was reported under very steep class of slope (47.06 %) while the minimum area was described under level class of slope (5.09 %).

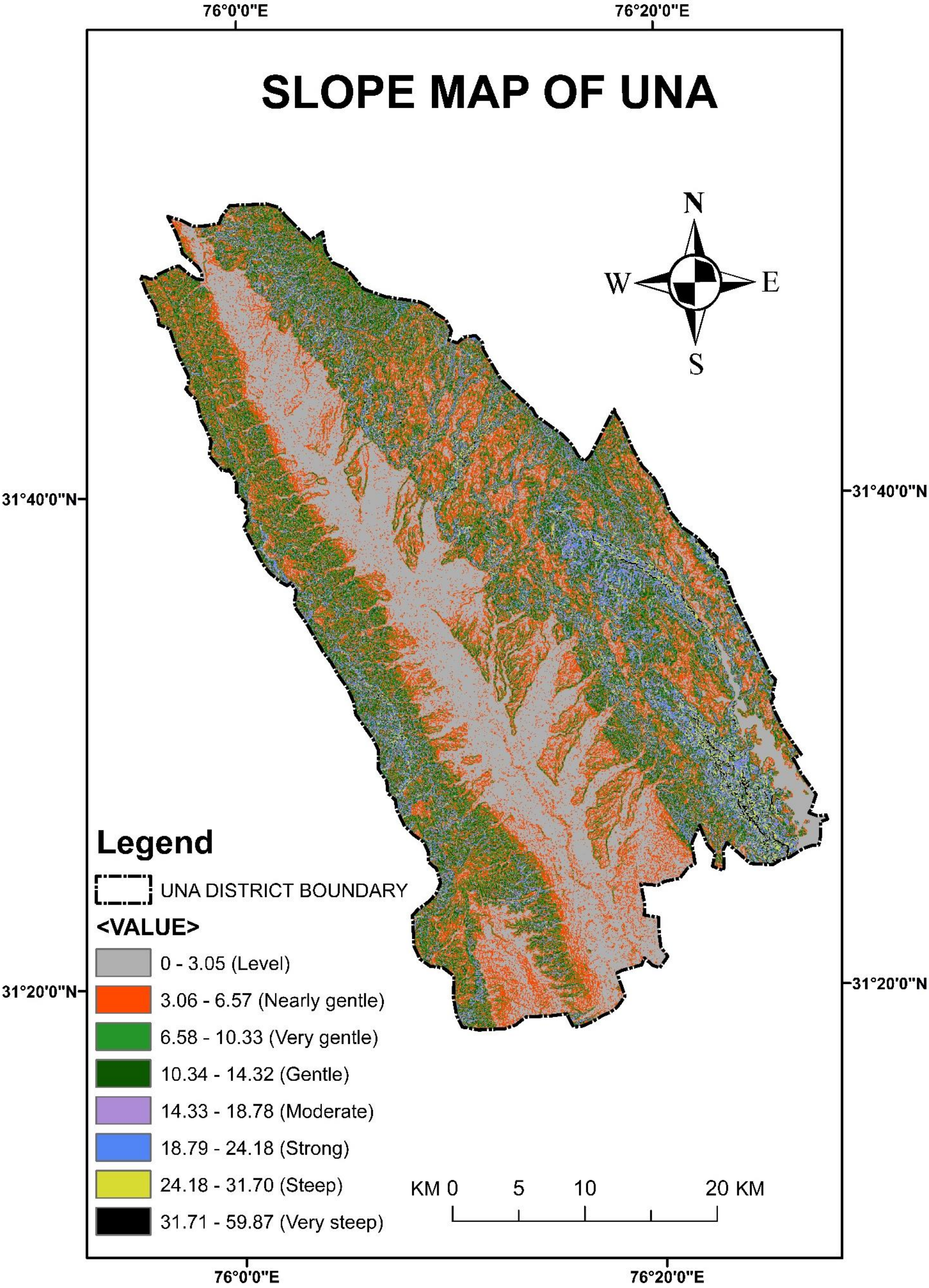

Fig. 13: Slope map of the study area.

Chapter – 5

SUMMARY AND CONCLUSION

The present research entitled **"Effect of weather parameters on the production of mango and citrus in Una district of Himachal Pradesh."** was carried out by using spatial data to generate physiographic map of research site and using secondary data on weather parameters *viz.,* maximum temperature, minimum temperature and rainfall of twenty three years (1996 – 2018) from BBMB weather station, Bhakra and for 15 years (2004 – 2018) from KVK Berthin. The spatial data (Landsat images) were downloaded from Earth explorer. The crop production data of mango and citrus were taken from Directorate of Horticulture, Shimla, Himachal Pradesh. The physiographic map were generated through ESRI ArcMap 10.5.1 software in the Geoinformatics lab, Department of Fruit Science, College of Horticulture and Forestry, Neri Hamirpur. The effect of weather parameters on the production of these fruit crops were assessed using regression models (linear and non-linear) for a particular weather parameter and multiple-linear regression analysis of combined weather parameters with fruit production. The trend analysis of different weather parameters, yearly variability analysis of weather variables and correlation coefficient (weather parameters and fruit production) were calculated and conclusions were drawn. Different maps (DEM, slope, aspect, hill-shade and contour) were prepared for the physiographic study of the region of research. The results of each objective are summarized as below:

Effect of weather variables on fruit yield

The influence of weather parameters on mango and citrus production was assessed using regression models. In this study annual production of fruit crops was taken as dependent variable and weather parameters were used as an independent variable. The multiple linear regression analysis did not reveal any significant relationship between fruit production and weather parameters whereas, individual regression models as well as multiple linear regression model equation did not fit in the fruit production to the optimum level. Among particular regression models, impact of minimum temperature on citrus production was found lowest on the basis of R^2 value (21.5%) and cubic model was observed suitable. In case, mango production in relation to particular weather parameters did not fit in regression function because the value of R^2 was very low and didn't had any influence of weather parameters on mango crop production. However, multiple linear regression also showed non-significant relation between fruit production and weather parameters due to low value of R^2 and Adj R^2. Weather parameters *viz.*, rainfall, maximum and minimum temperature had negative impact on the citrus crop production. However, maximum temperature had positive effect on mango crop, while minimum temperature and rainfall presented a negative effect.

During examination of correlation coefficient of fruit production in Una district, were obtained non-significant correlation with average annual rainfall, maximum and minimum temperature. With regard to bimonthly (December – January) minimum and maximum temperature data taken for the period of 2004–2018 recorded at KVK Berthin, there was significant positive correlation between maximum temperature and fruit production (mango and citrus). Whereas, coefficient of correlation between minimum temperature and fruit production (mango and citrus) was found negative and non-significant.

Trend analysis of selected weather parameters

The analysis of trend value of weather parameters using regression model showed no significant trend of weather parameters (rainfall and maximum temperature) for the study period 1996 to 2018. The trend of minimum temperature increased moderately due to R^2 value (48 %) which was best fitted in cubic equation. However, maximum temperature and rainfall followed decreasing trend during 1996 to 2018.

Variability analysis of selected weather parameters

The annual variability analysis of the selected weather parameters revealed non-significant trend in weather parameters. Under this analysis, weather variability was calculated using mean standard error, standard deviation, coefficient of variation, skewness and kurtosis while, coefficient of variation was used to evaluate the consistency of different weather parameters. Skewness and Kurtosis were used to evaluate normality assumptions of selected weather parameters and the skewness value was far away from zero and the value of kurtosis was not observed 03 indicating no significant variability under this analysis.

Physiographic maps

The physiographic maps were obtained from terrain data of the region under study and are presented in the form of maps such as DEM (elevation range), slope (slope percentage), aspect, hill-shade (area under shade) and contour map (contour percentage). Results are summarized as below:

1. Digital elevation models (DEM) were used for the measurement of elevation from the mean sea level.
2. Aspect map represents amount of sun light received by surface, This map showed a wide range of degrees of aspects between North to southern region of the study area.
3. Contour map displayed the varying altitude ranges and sturdiest or steepest slope of the region. The contour map depicted the contour height through the contour lines.
4. Hill-shade map represented the shaded portion by hills of the study area.
5. Slope map were generated to study the percentage of slope of the study region. The slopes recorded in slope map were categorized as level, nearly gentle, very gentle, gentle, moderate, strong, steep and very steep.

Conclusions

In a nut shell, it can be concluded that weather parameters had no major influence on fruit production. None of the regression models fit well for weather parameters and production of fruit crops. Trend analysis of minimum temperature was found increasing while, maximum temperature and rainfall did not show significant trend. However, variability analysis of weather parameters did not show any significant trend from 1996 to 2018. Physiographic maps are useful to researchers and land planners for establishment of orchards and crop planning. These maps provided valuable inputs on topographic information of the study area, slope, contour and hill-shade area which are very useful for maximizing the utilization of available solar energy for better growth of plant, less incidence of diseases and ultimately enhanced fruit production.

Finally, the research highlighted those variations in weather parameters, which were affecting the production of fruit crops during study period. Therefore, further consistent observations on changes in weather parameters and their effects on the production of horticultural as well as agricultural crops are of paramount importance. Sufficient data on weather parameters for different microclimatic situations must be recorded so as to reach any conclusive interpretation.

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APPENDIX-I

Table 4.8: Linear and non-linear functions for citrus production on the basis of maximum temperature

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	228.071	1	228.071	0.488	0.493
Residual	9823.142	21	467.769		
Total	10051.21	22			

The independent variable is T max.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	218.548	1	218.548	0.467	0.502
Residual	9832.665	21	468.222		
Total	10051.21	22			

The independent variable is T max.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	209.17	1	209.17	0.446	0.511
Residual	9842.043	21	468.669		
Total	10051.21	22			

The independent variable is T max

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	558.081	2	279.04	0.588	0.565
Residual	9493.132	20	474.657		
Total	10051.21	22			

The independent variable is T max.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	558.893	2	279.446	0.589	0.564
Residual	9492.32	20	474.616		
Total	10051.21	22			

The independent variable is T max.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.316	1	0.316	0.558	0.463
Residual	11.91	21	0.567		
Total	12.227	22			

The independent variable is T max.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.311	1	0.311	0.548	0.467
Residual	11.916	21	0.567		
Total	12.227	22			

The independent variable is T max.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.306	1	0.306	0.539	0.471
Residual	11.921	21	0.568		
Total	12.227	22			

The independent variable is T max.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.316	1	0.316	0.558	0.463
Residual	11.91	21	0.567		
Total	12.227	22			

The independent variable is T max..

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.316	1	0.316	0.558	0.463
Residual	11.91	21	0.567		
Total	12.227	22			

The independent variable is T max.

Table 4.10: Linear and non-linear functions for citrus production on the basis of minimum temperature

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.872	1	11.872	0.025	0.876
Residual	10039.34	21	478.064		
Total	10051.21	22			

The independent variable is T min.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	7.671	1	7.671	0.016	0.9
Residual	10043.54	21	478.264		
Total	10051.21	22			

The independent variable is T min.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.386	1	4.386	0.009	0.925
Residual	10046.83	21	478.42		
Total	10051.21	22			

The independent variable is T min.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2160.492	2	1080.246	2.738	0.089
Residual	7890.721	20	394.536		
Total	10051.21	22			

The independent variable is T min.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2157.82	2	1078.91	2.734	0.089
Residual	7893.393	20	394.67		
Total	10051.21	22			

The independent variable is T min.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.102	1	0.102	0.177	0.678
Residual	12.124	21	0.577		
Total	12.227	22			

The independent variable is T min.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.084	1	0.084	0.145	0.707
Residual	12.143	21	0.578		
Total	12.227	22			

The independent variable is T min.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.068	1	0.068	0.117	0.736
Residual	12.159	21	0.579		
Total	12.227	22			

The independent variable is T min.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.102	1	0.102	0.177	0.678
Residual	12.124	21	0.577		
Total	12.227	22			

The independent variable is T min.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.102	1	0.102	0.177	0.678
Residual	12.124	21	0.577		
Total	12.227	22			

The independent variable is T min.

Table 4.12: Linear and non-linear functions for citrus production on the basis of rainfall

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	131.455	1	131.455	0.278	0.603
Residual	9919.759	21	472.369		
Total	10051.21	22			

The independent variable is RF.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	89.635	1	89.635	0.189	0.668
Residual	9961.578	21	474.361		
Total	10051.21	22			

The independent variable is RF.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	68.614	1	68.614	0.144	0.708
Residual	9982.599	21	475.362		
Total	10051.21	22			

The independent variable is RF.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	464.83	2	232.415	0.485	0.623
Residual	9586.383	20	479.319		
Total	10051.21	22			

The independent variable is RF.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1609.398	3	536.466	1.207	0.334
Residual	8441.815	19	444.306		
Total	10051.21	22			

The independent variable is RF.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.606	1	0.606	1.096	0.307
Residual	11.62	21	0.553		
Total	12.227	22			

The independent variable is RF.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.462	1	0.462	0.825	0.374
Residual	11.765	21	0.56		
Total	12.227	22			

The independent variable is RF.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.372	1	0.372	0.659	0.426
Residual	11.855	21	0.565		
Total	12.227	22			

The independent variable is RF.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.606	1	0.606	1.096	0.307
Residual	11.62	21	0.553		
Total	12.227	22			

The independent variable is RF.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.606	1	0.606	1.096	0.307
Residual	11.62	21	0.553		
Total	12.227	22			

The independent variable is RF.

APPENDIX-II

Table 4.14: Linear and non-linear functions for mango production on the basis of maximum temperature

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	18.995	1	18.995	0.014	0.909
Residual	29498.86	21	1404.708		
Total	29517.85	22			

The independent variable is T max.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	26.465	1	26.465	0.019	0.892
Residual	29491.39	21	1404.352		
Total	29517.85	22			

The independent variable is T max.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	35.203	1	35.203	0.025	0.876
Residual	29482.65	21	1403.936		
Total	29517.85	22			

The independent variable is T max.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2009.519	2	1004.759	0.731	0.494
Residual	27508.34	20	1375.417		
Total	29517.85	22			

The independent variable is T max.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2009.519	2	1004.759	0.731	0.494
Residual	27508.34	20	1375.417		
Total	29517.85	22			

The independent variable is T max.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.227	1	0.227	0.327	0.573
Residual	14.561	21	0.693		
Total	14.788	22			

The independent variable is T max.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.236	1	0.236	0.34	0.566
Residual	14.553	21	0.693		
Total	14.788	22			

The independent variable is T max.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.245	1	0.245	0.353	0.559
Residual	14.544	21	0.693		
Total	14.788	22			

The independent variable is T max.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.227	1	0.227	0.327	0.573
Residual	14.561	21	0.693		
Total	14.788	22			

The independent variable is T max.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.227	1	0.227	0.327	0.573
Residual	14.561	21	0.693		
Total	14.788	22			

The independent variable is T max.

Table 4.16: Linear and non-linear functions for mango production on the basis of minimum temperature

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	13.173	1	13.173	0.009	0.924
Residual	29504.68	21	1404.985		
Total	29517.85	22			

The independent variable is T min.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	16.102	1	16.102	0.011	0.916
Residual	29501.75	21	1404.845		
Total	29517.85	22			

The independent variable is T min.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	19.254	1	19.254	0.014	0.908
Residual	29498.6	21	1404.695		
Total	29517.85	22			

The independent variable is T min.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	731.026	2	365.513	0.254	0.778
Residual	28786.83	20	1439.341		
Total	29517.85	22			

The independent variable is T min..

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	742.557	2	371.278	0.258	0.775
Residual	28775.3	20	1438.765		
Total	29517.85	22			

The independent variable is T min.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.001	0.972
Residual	14.787	21	0.704		
Total	14.788	22			

The independent variable is T min.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.002	1	0.002	0.002	0.962
Residual	14.787	21	0.704		
Total	14.788	22			

The independent variable is T min.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.003	1	0.003	0.004	0.953
Residual	14.786	21	0.704		
Total	14.788	22			

The independent variable is T min.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.001	0.972
Residual	14.787	21	0.704		
Total	14.788	22			

The independent variable is T min.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.001	0.972
Residual	14.787	21	0.704		
Total	14.788	22			

The independent variable is T min.

Table 4.18: Linear and non-linear functions for mango production on the basis of rainfall

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	532.29	1	532.29	0.386	0.541
Residual	28985.56	21	1380.265		
Total	29517.85	22			

The independent variable is RF.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	546.742	1	546.742	0.396	0.536
Residual	28971.11	21	1379.577		
Total	29517.85	22			

The independent variable is RF.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	615.454	1	615.454	0.447	0.511
Residual	28902.4	21	1376.305		
Total	29517.85	22			

The independent variable is RF.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	573.17	2	286.585	0.198	0.822
Residual	28944.68	20	1447.234		
Total	29517.85	22			

The independent variable is RF.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3527.329	3	1175.776	0.86	0.479
Residual	25990.53	19	1367.922		
Total	29517.85	22			

The independent variable is RF.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.196	1	0.196	0.283	0.601
Residual	14.592	21	0.695		
Total	14.788	22			

The independent variable is RF

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.17	1	0.17	0.245	0.626
Residual	14.618	21	0.696		
Total	14.788	22			

The independent variable is RF.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.166	1	0.166	0.238	0.631
Residual	14.622	21	0.696		
Total	14.788	22			

The independent variable is RF.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.196	1	0.196	0.283	0.601
Residual	14.592	21	0.695		
Total	14.788	22			

The independent variable is RF.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.196	1	0.196	0.283	0.601
Residual	14.592	21	0.695		
Total	14.788	22			

The independent variable is RF.

APPENDIX-III.

Table 4.20: Multiple linear function for citrus and mango production with weather parameters

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	331.676	3	110.559	.216	.884
Residual	9719.538	19	511.555		
Total	10051.213	22			

a. Predictors: (Constant), T max, T min and RF

b. Dependent Variable: CP

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1133.896	3	377.965	.253	.858
Residual	28383.957	19	1493.892		
Total	29517.853	22			

a. Predictors: (Constant), Rf, Min, Max

b. Dependent Variable: MP

APPENDIX-IV

Table 4.21: Linear and nonlinear functions for maximum temperature on the basis of time period

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.709	1	0.709	0.542	0.47
Residual	27.479	21	1.309		
Total	28.188	22			

The independent variable is T max.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.515	1	0.515	0.391	0.539
Residual	27.673	21	1.318		
Total	28.188	22			

The independent variable is T max.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.214	1	1.214	0.945	0.342
Residual	26.974	21	1.284		
Total	28.188	22			

The independent variable is T max

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.778	2	0.889	0.673	0.521
Residual	26.411	20	1.321		
Total	28.188	22			

The independent variable is T max.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.048	3	0.683	0.496	0.689
Residual	26.14	19	1.376		
Total	28.188	22			

The independent variable is T max.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.525	0.477
Residual	0.031	21	0.001		
Total	0.032	22			

The independent variable is T max.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.365	0.552
Residual	0.031	21	0.001		
Total	0.032	22			

The independent variable is T max.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.879	0.359
Residual	0.03	21	0.001		
Total	0.032	22			

The independent variable is T max.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.525	0.477
Residual	0.031	21	0.001		
Total	0.032	22			

The independent variable is T max..

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	0.525	0.477
Residual	0.031	21	0.001		
Total	0.032	22			

The independent variable is T max.

Table 4.32: Linear and nonlinear functions for minimum temperature on the basis of time period

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	11.872	1	11.872	0.025	0.876
Residual	10039.34	21	478.064		
Total	10051.21	22			

The independent variable is T min.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.331	1	0.331	1.261	0.274
Residual	5.515	21	0.263		
Total	5.847	22			

The independent variable is T min.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.411	1	1.411	6.678	0.017
Residual	4.436	21	0.211		
Total	5.847	22			

The independent variable is T min.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.586	2	0.293	1.113	0.348
Residual	5.261	20	0.263		
Total	5.847	22			

The independent variable is T min.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.855	3	0.952	6.046	0.005
Residual	2.991	19	0.157		
Total	5.847	22			

The independent variable is T min.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0	1	0	0.012	0.913
Residual	0.018	21	0.001		
Total	0.018	22			

The independent variable is T min.

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.001	1	0.001	1.387	0.252
Residual	0.017	21	0.001		
Total	0.018	22			

The independent variable is T min.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.005	1	0.005	7.053	0.015
Residual	0.014	21	0.001		
Total	0.018	22			

The independent variable is T min.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0	1	0	0.012	0.913
Residual	0.018	21	0.001		
Total	0.018	22			

The independent variable is T min.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0	1	0	0.012	0.913
Residual	0.018	21	0.001		
Total	0.018	22			

The independent variable is T min.

Table 4.25: Linear and nonlinear functions for rainfall on the basis of time period

Linear Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	1.263	1	1.263	2.001	0.172
Residual	13.254	21	0.631		
Total	14.517	22			

The independent variable is RF.

Logarithmic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	2.975	1	2.975	5.414	0.03
Residual	11.542	21	0.55		
Total	14.517	22			

The independent variable is RF.

Inverse Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	3.176	1	3.176	5.881	0.024
Residual	11.341	21	0.54		
Total	14.517	22			

The independent variable is RF.

Quadratic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	4.731	2	2.366	4.835	0.019
Residual	9.786	20	0.489		
Total	14.517	22			

The independent variable is RF.

Cubic Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	5.225	3	1.742	3.561	0.034
Residual	9.293	19	0.489		
Total	14.517	22			

The independent variable is RF.

Compound Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.083	1	0.083	1.639	0.214
Residual	1.067	21	0.051		
Total	1.15	22			

The independent variable is RF

Power Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.204	1	0.204	4.527	0.045
Residual	0.946	21	0.045		
Total	1.15	22			

The independent variable is RF.

S Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.229	1	0.229	5.228	0.033
Residual	0.921	21	0.044		
Total	1.15	22			

The independent variable is RF.

Growth Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.083	1	0.083	1.639	0.214
Residual	1.067	21	0.051		
Total	1.15	22			

The independent variable is RF.

Exponential Model

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Regression	0.083	1	0.083	1.639	0.214
Residual	1.067	21	0.051		
Total	1.15	22			

The independent variable is RF.

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ABSTARCT

The present investigations entitled **"Effect of weather parameter on the production of mango and citrus in Una district of Himachal Pradesh"** were conducted during 2019 – 2020 in the Department of Fruit Science, College of Horticulture and Forestry, Neri. Weather data for the period 1996 to 2018 and bimonthly (December – January) weather data from 2004 – 2018 and the data on fruit production for the period 1996 – 2018 with respect to Una district of Himachal Pradesh were analyzed. Spatial data were used for preparation of physiographic map of the district. Effect of weather parameters on fruit crop production were assessed using regression analysis whereby individual parameters were correlated with fruit production and the multiple linear regression equations were obtained. To compute the trends of weather parameters and variability analysis (mean, standard error, standard deviation, skewness and kurtosis), regression coefficient whereby different functions considering linear, logarithmic, inverse, quadratic, cubic, compound, power, s curve, growth and exponential functions were fitted and best fit equations were selected on the basis of R^2 and RMSE. The results of variability analysis revealed no significant trend for weather parameters. Skewness and kurtosis did not follow any normality assumptions. In case of trend analysis, regression function (cubic and quadratic) were found best fit for weather parameters with highest value of R^2 (0.48) in case of minimum temperature, while R^2 varied from 0.04 – 0.36. The coefficient of correlation between maximum temperature and mango production showed positive correlation (r = 0.623) whereas, citrus production also showed positive significant correlation with maximum temperature (r = 0.855) at 1 % level of significance. The analysis of regression for fruit production, minimum temperature on citrus production was found significant with an R^2 value 0.21, indicating thereby that citrus production is influenced by minimum temperature but not weather parameters in combination. The physiographic maps used to identify the topographic situation with the help of DEM, slope, contour, aspect and hillshade maps. These maps are very useful for land use planning.

Signature of the Student | **Signature of the Major Advisor**

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