A Study on Climate Change Trend and its Impact on Productivity of Paddy Crop under Temperate Conditions of Kashmir

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Thesis

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Dedicated to
Farmers

Sher-e-Kashmir
University of Agricultural Sciences and Technology of Kashmir
Faculty of Horticulture, Division of Agricultural Statistics

Certificate – I

This is to certify that the thesis entitled **"A Study on Climate Change Trend and its Impact on Productivity of Paddy Crop under Temperate Conditions of Kashmir"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Statistics** to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Rohit Godara (Regd. No. MSST-2018-22)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation have duly been acknowledged.

(Dr. Nazir Ahmad Sofi)
Chairman
Advisory Committee

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Certificate – II

We, the members of the Advisory committee of **Mr. Rohit Godara (Regd. No. MSST-2018-22),** a candidate for the degree of **Master of Science in Statistics**, have gone through the manuscript of the thesis entitled **"A Study on Climate Change Trend and its Impact on Productivity of Paddy Crop under Temperate Conditions of Kashmir"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of degree.

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Certificate – III

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ABSTRACT

The present study attempts to know the trend of selected weather parameters and to analyze the impact of weather parameters on productivity of rice in Kashmir valley. The secondary data on weather parameter over period 1995-2019 was collected from, the Section of Agronomy, SKUAST-K Shalimar. Further, the secondary data of rice yield over period 1995-2019 was collected from, Directorate of Economics & Statistics, government of J&K. The parameters consider viz., average maximum temperature, average minimum temperature, average rainfall and rice yield for the study. The trend analysis revealed that the mean maximum temperature, mean minimum temperature and rainfall showed a positive insignificant trend over a period of time for most of the months. Also, the non-parametric method indicates that there is not a time dependent trend for all the months. The correlation analysis indicated that the productivity of rice was positive insignificant correlation with maximum temperature (0.271) and rainfall (0.374), whereas minimum temperature showing significant correlation (0.614). The minimum temperature contribution was higher (0.566 towards the productivity of rice, followed by maximum temperature (0.336) and rainfall (0.309).It was noticed that riced yield in Kashmir valley more dependent on minimum temperature.

Key words:

Signature of Student

Dated: ___________

Signature of Major Advisor

Dated: ________________

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Rohit Godara

Place: **Shalimar, Srinagar**

Dated:

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Chapter–1

INTRODUCTION

The agro-meteorological information is one of the most useful solutions for agricultural problems. The adoption of farming system to an area might be unsuccessful with the future climatic conditions without studying the trends. Meteorological data sets are used in the evaluation of potential aspects of crop production. Investigations of regional, global climatic changes & variability and their impacts on the society have received considerable attention in recent years.

To determine the risk involved in climate change for agriculture, it is necessary to define a set of agro meteorological parameters, derived from the classic climate parameters that are capable of indicating the consequences of climate change for crop production.

Climate change denotes changes beyond the average atmospheric conditions. They may be caused by natural factors like the orbit of earth's revolution, volcanoes, crustal movements, etc. and by anthropogenic influences such as a rise in the greenhouse gas concentration such as CO_2, methane and so on. Global climate change directly impacts human society via agriculture crop production. Climate change can disturb food availability, decrease access to food and affect the nutritional quality of food (USDA 2015). The estimated rise in temperature, fluctuation in precipitation forms, the occurrence of extreme weather events, reduced irrigation water availability may result in reduced agricultural productivity. General circulation models on climate change specify that due to the increasing concentration of greenhouse gases (GHGs); over the next 100 years, the average surface temperature will raise from 1.5 to 4.5°C globally (Senapati *et al.*, 2013).

Many studies propose a higher impact of climate change (increase in temperature) on developing countries' agriculture relative to developed ones (Stern, 2006). Changes in the climate such as an increase in temperature are likely to benefit agriculture in most developed countries as increase in temperature because which makes most of the snow-covered land available for agriculture in the equatorial region. But as the majority of developing countries wouldn't benefit against further warming, while mitigation and fertilization are projected to marginally reduce these effects (Cline, 2008). The impact on agriculture will reflect the degree of climate change, as well as other factors. An increase in temperature will significantly affect the physiology of crops and will indirectly influence plant through changes in the water availability and incidence of crop diseases and pests (Rosenzweig, 2000; Bale *et al*., 2002). India is expected to undergo temperature rises between 1.7 to 2°C by the 2030s and between 3.3 to 4.8°C by the 2080s. "In India rainfall under RCP 6 is projected to increase from 4 to 5% by the 2030s and from 6 to 14% towards the end of the century (the 2080s) compared to the 1961–1990 baseline" (Chaturvedi *et al*., 2012).

1.1 Statistical modelling in meteorological research

A relationship among the variables is represents by an equation or set of equations are known as statistical model. As models often make it easier to design experiments to address specific question or to differentiate between alternative mechanisms, modeling can lead to less ad hoc experimentation. To examine the reliance on the variable of interest and relation between them, many tools are used provides by modelling. On the basis of the observation of other variables the values of one or more variables are predicting for this purpose the relation between variable must be calculated.

In many field regression techniques or model building are currently applied i.e., Biometrics, Agriculture, Economics, Meteorology, etc., the weather parameters are extremely erratic in meteorological studies. Only by use of suitable statistical models a meaningful interpretation can be drawn in such instances.

1.2 Statistical models are:

1.2.1 Linear model:

Regression analysis is one of the most frequently use statistical methods to evaluate functional associations between variables represented as an equation relating the outcome (dependent) variable "Y" and one or more experimental (independent) variables X_1, X_2, X_3, …, X_n (time). As the goal is to model the functional relationship between a quantitative variable (Y) and periods of time (t) over which it is observed, the regression equation takes the form

$$Y = b_0 + b_1 t + e$$

Where,

b_0 : Intercept

b_1 : Slope

t: Independent variable

Y: Dependent variable

e: Error component.

1.2.2 Exponential Model:

An exponential regression is the process of finding the equation of the exponential function that fits best for a data set.

Exponential trend equation is given by

$$Y_t = A B^t$$

1.2.3 Logarithmic Model:

Logarithmic regression is used to model situations where growth or decay accelerates rapidly at first and then slow over time.

The equation of logarithmic model is given by

$$\Rightarrow Y_t = b_0 + b_1 \ln(t)$$

1.2.4 Path Analysis:

A standardize partial regression is path analysis which is a tool for elucidating the contribution of each variable to the coefficient of overall correlation.

Partial regression equation and is given by

$$Y=\mu+\beta_1 X_1+\beta_2X_2 + \beta_3X_3+R.$$

1.3 Agro-ecological Zones and Current Rice Production in Jammu & Kashmir

A significant number of crops (*Kharif* and *Rabi*) are grown in Kashmir Valley. Due to certain climatic restrictions, cultivation has remained limited to only a few crops like rice and maize are grown on a large scale, while in some isolated pockets wheat is also grown as a means of food security (Anonymous, 2015). Rice being the staple food of the valley's inhabitants of continues to be the main crop grown in Kashmir (Hangloo, 1995). It is cultivated mostly in the flat terrene of the valley having alluvial soil and assured irrigation facilities (Lawrence, 2002).

Rice is the major crop & it is grown on about 0.261 m ha which comprises 25% of the total area under food crops of the state and represents just 0.0006% of the total rice area in India. Rice cultivation is an integral component of the rich cultural heritage of the state. The crop is grown on 100% irrigated ecology in Kashmir valley and melting snow is the source of irrigation. The crop is grown in all districts of Kashmir valley over an area of 0.159 m ha. Total area of 261.35 thousand ha under rice crop are grown in the state out of which 137 thousand ha are cultivated in Kashmir and is a staple food of the valley; it is a primary source of calories in people's diet compared to wheat and maize (Anonymous, 2015).

Rice ecology of Kashmir valley is broad and divided into four distinct zones: Plain or valley basin area (1500-1700 m amsl) that enjoys relatively favorable growing conditions in terms of water availability, edaphic and climatic factors. Early maturing indices, with satisfactory levels of cold tolerance, are the predominant rice varieties grown in this zone. The growing period is limited to 140-145 days and double cropping is in vogue and usually, rice-oilseeds/rice-fodder oats cropping systems are in common practice. “Mountain agro-ecology (high altitude region) situated between 2000 to 2300 m amsl in foothills, constitutes 10-12% of total rice cultivated area of the valley and is characterized by short growing season, low atmospheric temperature, cold irrigation water and insufficient solar radiation” (Anonymous, 2015).

The cultivar rice varieties in this region are restricted to 120-125 days and there is typically no double cropping as an unpredictable climate leaves little room for the second crop. The population in this region is usually living in a harsher climate which frequently remains cut off during January month. This renders the food and nutritional security of the people quite precarious. Therefore, the main focus of development in this region has been to improve the household and food security for livelihood security through enhanced productivity.

In between the two agro-ecologies lies the intermediate agro-ecological zone (1900-2000 m amsl) where an amalgam of both subspecies can be found. It receives a relatively better environment than high altitude region but enjoys poor growing conditions when compared to the situation prevailing in the plain basins of the Kashmir valley. It is worth mentioning that most of the landraces are native and flourishes better in this particular zone and farmers are selling the milled rice of these indigenous landraces at a premium price in the local market.

The fourth zone is the entire waterlogged area; a bowl of conventional rice is grown ecology and encompasses more than 25 thousand ha, although relatively favorable growing ecology for rice but leaves no scope for the second crops like oilseed and fodder oat because of a very poor drainage system.

1.4 The climate of Kashmir Valley

Based on the data released by the Indian Meteorology Department's Additional Director General's office under the state series-number 20, January was the coldest month with an average temperature of -2 to -8 ºC in the low and high altitudinal areas respectively. Although the mean average temperature for the region is around 5 ºC, it ranges from 6 to 1ºC respectively in low and high altitudinal areas in the surrounding mountains. At western disturbance, the minimum temperature drops well under the freezing point of water. On 6th February 1895 Srinagar observatory records at any individual station the lowest minimum temperature of -20.0ºC. In March the temperature starts to rises slowly and continue until August. July is the hottest month with a mean maximum temperature in the valley of about 27ºC, with the slightly higher temperature (2 to 3ºC) and lower temperature (2 to 7ºC) reported at low and high altitude station in the surrounding mountains. The average temperature increase in the period from March to July is around 14ºC to 17ºC at individual stations while the minimum temperature increases from March to July by 10 to 15ºC at places in the surrounding mountains. With the monsoon's onset, the average temperature rises a little from the beginning of July, while the minimum temperature increases by around 2ºC to 4ºC. Both minimum & maximum temperatures at the mountains peaks can be 10ºC - 20ºC lower. After August, both daytime and night temperatures drop steadily until mid-February and continue until mid-March. At Srinagar on 10th July 1946, at any single station in the Kashmir valley, the highest maximum temperature ever-recorded is 38.3ºC, which is around 8ºC higher than the average of the warmest month (July).

Changes in climatic variables have intensified further issues about rice production and food security. The climate of Kashmir Valley is suitable for the cultivation of paddy crop but still, productivity is less as compared to other countries. The effect of weather events on crop build up slowly but are often wide enough to destabilize Valley agricultural production.

From the above-justified facts, it is evident that there is a considerable scope to study the behavior of the weather parameters. Due to this reason, the present study is designed with the following specific objectives confining to only Kashmir valley.

The main objectives of the present study would be as under:

- To study the trend in the weather parameter over the study period.
- Analysis of the impact of weather parameters on the productivity of rice crops.

Chapter – 2

REVIEW OF LITERATURE

2.1 To study the trend in the weather parameter over the study period.

Goutsidou *et al*. (1992) in their study on bare soils in Greece using mean temperature data of 50 years, with a standard deviation of 1.30 ^{0}C, the mean annual value was 20 ^{0}C and revealed that there was no notable spell of years with a value greater than or less than the normal. Annual and seasonal patterns, reported negative with the prediction of winter.

Marcelo and Kenneth (1998) examined spatial and temporal variability by ensuring that the weather station network provides consistent, reliable data. The detection of suspicious data and the provision of projection for inappropriate data and data gaps were important. The research was conducted in the USA High Plains to measure and correlate the spatial and temporal variability for two distinct climatic conditions for routine weather parameters, *viz*. "maximum and minimal air temperature, relative humidity, solar radiation, wind speed and precipitation and potential evapo-transpiration" (ETp). Real data for a period of 7 years (1989-1995) from 38 computerized weather stations, 19 stations from each region was taken. By using regression of routine observation between different stations coupling within the different climate regions like weather variables, the coefficient of variable (r^2) and standard estimate error (SEE) was evaluated. A temporal study was undertaken with a set of data and it was assessed that 7 years of monitoring were needed to maintain the difference between stations. Data from the SEE showed a substantial seasonal cycle for "maximum and minimal temperature, solar radiation and ETp". Findings suggest that the precision of projected data and related weakness of confidence will vary, with the period of year.

Moonen *et al*. (2002) "in their research analyzed daily rainfall, evaporation and mean maximum and minimum temperature, from data collected of 1878-

1999" time period. They analyzed time trend in intense rainfall and temperature situation and agro-meteorological parameters for seasonal and annual time-series data and with the Chi-square test, this time series tested for normality. They also performed least-square linear regression to assess the meteorological and agro-metrological parameters for rising or decreasing patterns. "They applied t-test and the non-parametric Kendall's, 'τ' significance test and they observed a trend toward more severe low rainfall events".

Pielke *et al*. (2002) in Eastern Colorado, USA, assessed long-term patterns in "average maximum and minimum temperature, threshold temperature and rising season" to investigate the possible shortcomings of such climate changes. It was found that the significant ($P < 0.2$) rise in minimum temperature in half of the station in "winter, spring and autumn" and even the number of days a year decreased significantly with temperatures of approximately −17.8 °C (≤0 °F) in the long-term data set (80 + years).

Anjum *et al*. (2005) reviewed that the annual mean surface temperature in Pakistan had had a steady upward trend since the beginning of the twentieth century. Average temperature rise of 0.6-1.0°C in arid coastal zones, arid mountains and hyper-arid plains, drop of 10- 15 per cent in coastal belt and hyper-arid plains in winter and summer rainfall, rise of 18- 32 per cent in monsoon zone rainfall, particularly sub-humid and humid areas. Relative humidity in Balochistan had decreased by 5 per cent. It was apparent that solar radiation raised by 0.5 to 0.7 per cent over the country's southern half. In central Pakistan, there was a 3-5 per cent decline in cloud cover with a rise in sunshine hours, 35 per cent rise in ETo due to an rise in temperature of 0.9°C.

Havaldar *et al*. (2005) analyzed the southwest monsoon rainfall at Dharwad (1So 26'N, 750 0TE, 678m) from 1950 to 2002 to study the trend of rainfall. The 12-year moving average technique was used for this purpose. The rainfall was nearly constant with around 500 mm in the period 1955 to 1964. Then the trend became mild oscillatory until 1982. The trend became gradual negative from the year 1983 to 1997 with the rainfall changing from 494 mm to 378 mm.

Arora *et al.* (2005) “conduct non-parametric Mann-Kendall test to detect monotonous annual and seasonal temperature trend during their research on temperature time series trends of 125 stations distributed throughout India. Temperature-related three variables *viz.* mean minimum, mean maximum and mean, both on the seasonal basis and annual and were considered for analysis. These were divided annually into four major seasons, *viz.* monsoon, pre-monsoon, post-monsoon and winter. For each variable, it presents the proportions of critical trend recorded in the various seasons. Temperature fluctuations were measured and it was logged that the annual mean temperature, mean minimum and mean maximum temperature had risen to (0.42, 0.92 and 0.09 ^{0}C) respectively. The regional stations in West and South India display an upward trend of 0.36 and 1.06 °C respectively, while downward trend of -0.38°C displayed by stations of the North Indian plains. The seasonal mean temperature for the post-monsoon and winter season had risen by 0.94°C and 1.1°C, respectively in past 100 years.

Jacob and Anil (2006) analyzed the meteorological data gathered since 1983 by the “Nimbkar Agricultural Research Institute” (NARI). The main goals were to provide average Phaltan weather figures and curves and to identifying potential trends since 1983, particularly warming. Study found that there was definite pattern of warming, but it appears to be affected by alterations in the station’s surroundings (microclimate). Wind speed and evaporation decline slightly, too.

Buytaert *et al.* (2006) examined especially in mountainous ecosystem; precipitation can vary enormously in space and time. Interpretation of point rainfall statistics is important for many hydrological applications like modeling. Judgments on the interpretation methods and feasibility of the facts presented from the final outcome were highly dependent on the degree and quality of the uncertainty involved. They analysed data on rainfall from 14 rain gauges in the

Ecuadorian Andes' western mountain range, which were in the west portion of the Rio Paute basin. It studied the patterns of spatial and temporal rainfall. On the other hand, the seasonal variation is low, with a gap of approximately 100 mm between both the driest as well as wettest month on an average of nearly 100 mm month and only 20 per cent dry days across the year. Rin gauges were strongly correlated at a mutual distance of less than 4000 m, with a Pearson correlation coefficient greater than 0.8.

Liu *et al*. (2006) during the period of 1961-2003, performed an analysis of temporal patterns over the eastern and central Tibetan Plateau on the daily and monthly basis maximum and minimum surface air temperatures at 66 different weather stations at high altitude exceeded 2000 m. Statistically, significant warming patterns had been detected in various temperature regime indicators, like as extreme temperatures events and diurnal temperature ranges. The local climate change resulted in a substantial reduction in the number of frost days and a rise in the number of days of warm weather. Over the 43 years of research, the time of the cultivation cycle was extended by around 17 days.

Luo *et al*. (2008) conducted a study using Mann-Kendall and Sen's -T non-parametric methods on the sequence of spatial and temporal rainfall in River basin of Beijiang. During the initial flood season, particularly in May, the finding demonstrated a decrease in periodic distribution patterns, while in July an increasing patterns were reported and the dry season, similarly decreasing and increasing pattern of spatial distribution were also observed in the Southern Beijiang river basin and Northern Region respectively. Results showed a late rainy season and a precipitation belt toward Northern region relative to recent years.

Murty *et al*. (2008) conducted a study on Ranichauri to evaluate temperature trends using moving averages for 3, 5 and 10-year periods at minimum and maximum temperatures during 1982-2002 and they found that the maximum temperature shown a significant decline while the minimum temperature at Hill Campus appeared quite unchanged during the time of study.

Deka *et al*. (2009) explore long and short-term variations in North East India’s atmospheric temperature in Brahmaputra Basin portion of the Eastern Himalayan region during 1901-2003. The Mann-Kendal rank statistic and moving average methods were used to analyze long-term linear patterns whereas Cramer’s test evaluated short-term fluctuations. The finding showed a significant warming pattern in overall annual and seasonal temperatures. During the monsoon season there is a significant drop in minimum temperature and its increase during the post-monsoon and winter season. Relatively high magnitudes of linear trends were found at maximum temperature higher than they were at minimum temperature. The maximum temperature in the recent five decades’ showed an increasing trend.

Kumar *et al*. (2009) intended to understand spatial changes in weekly, periodic and yearly rainfall across Kerala, India between the span of 1871 to 2005, by using Man-Kendall rank statistics and linear trend methods. The results indicated a significant decline in Southwest monsoon precipitation as a rise in post-monsoon season over Kerala, usually referred to this as the “Gateway of summer monsoon”. Winter and summer rainfall revealed a negligibly rising pattern. The June and July rainfall found a substantial decline pattern whereas rising pattern reported in January, February and April months. The State’s primary concern is hydel power production and water supply over the summer months were due to the June and July rainfall reduction, which were the rainiest months. At the very same moment, if there were robust and sustained, the majority of crops were able to succeed in the post-monsoon season from a rise in rainfall.

Ogolo and Adeyemi (2009) had been observed the variations and pattern of some meteorological variables over a tropical-humid station, Ibadan (07026‘‘N, 03° 54′E) in the southwestern part of Nigeria by using daily mean data of each of the parameters taken at the International Institute of Tropical Agriculture

(I.T.T.A), Ibadan, between 1988 and 1997. The monthly series of the meteorological parameters showed an annual decreasing trend, which is not statistically significant except those of rainfall and relative humidity data series that showed a rising pattern, which is statistically significant when the Mann-Kendall (MK) and Spearman rho statistics were applied. The yearly series of the parameters show that solar radiation and evaporation rate had a significant decreasing trend, while other parameters show a rising pattern that is not statistically significant. Also, the yearly data series for temperature and sunshine hour appear to show similar behavior to global warming trends.

Sadiq and Qureshi (2010) found that the mean surface air temperature of Earth and oceans had raised by 0.74 ± 0.18^0C over the last 100 years. The effect of this for large urban areas of Pakistan had been investigated in the presented study. Mean-maximum and mean-minimum temperature for the period 1961 to 2007 had been analyzed for this long-term mean study. Even the rainfall in the major cities of Pakistan was also studied. The maximum and minimum rise in mean temperature (in Peshawar), respectively, is found to be 0.057^oC to $0.019\ ^o$C per year. Both of these percentages outweigh the global norm. There had been an isolated discrepancy in Lahore's mean maximum temperature but the same can be represented in term of heavy and sustained monsoon rains. In addition, it is found that rainfall in Karachi is getting lower and requires to be further analyzed.

Rao *et al*. (2010) "recorded a maximum temperature growing pattern with the lowest (20 %) and the highest (75 %) at stations in north and south zone, respectively, using the annual mean, maximum and minimum temperature of 47 stations spread throughout various parts of India". In comparison, an increase in minimum temperature is observed above 60 per cent.

Geethalakshmi *et al*. (2011) observed a growing trend toward maximum, minimum temperatures and rainfall for the expected climate change over the A1B scenario of Tamil Nadu's Cauvery basin using regional climate models.

Arun *et al*. (2012) studied the evolving rainfall pattern of an Orissa river basin close to the coastal area. It almost every year experiences the detrimental effects of floods. This was an experiment to picture among the most significant climatic factors to examine the distribution of rainfall in the region i.e. precipitation. The research analyzed 40 years regular rainfall data between 1971 to 2010 to assess the monthly rainfall intensity for which trend and slope severity were evaluated by using Modified Mann-Kendall Test, Mann-Kendall (MK) test and Sen's Slope Estimator. In order to achieve the goal that had been demonstrated by 40 years of results, the monthly pattern in precipitation had been established here. Precipitation rates had risen in several months, although a declining pattern in other months and overall negligible changes in the region was obtained from these statistical tests.

Carmen and Alina (2012) analyzed temporal characteristics of precipitation evolution in Dobrudja, an area in South-eastern Romania by using a database of ten monthly series, collected between January 1965 to December 2005. They described different methods to detect the breakpoint's existence to detect changes in the monthly series of precipitation evolutions. The study indicates a constant trend of precipitation before 2000 and an increasing one after 2000, in concordance with the predictions for this region.

Choudhury *et al*. (2012) examined long-term (1983-2010) weather variables to intercept trend changes using non-parametric Mann Kendall test at Meghalaya mid-altitude region. Finding showed a moderate rise in the overall trend in annual rainfall at the rate of 3.72 mm year^{-1}. The share of monsoon months' decreased slightly at the rate of 1.70 mm while pre and post-monsoon months dramatically increased significantly at an annual increase of 3.18 mm and 1.16 mm. Probability analysis includes a massive level of deviations (p>0.6) of either deficiency or surplus in daily occurrences of monsoon rainfall. The average rainfall and extreme heavy rainfall days (>100mm), respectively, showed a non-significant upward growth at 1.7 days and 1.9 days per decade. The maximum and minimum temperature reflected a substantial upward trend (+ 0.086 ^{0}C year^{-1}) and non-significant decline pattern (-0.011^{0}C year^{-1}), respectively. Whereas mean temperature and evaporation found a substantially upward (0.031^{0}C) and downward (at 5.75 mm year^{-1}) trend, respectively. According to correlation, atmospheric evaporative was significantly more prone to changes in the sunshine cycle (r = +0.63), accompanied by wind flow (r = +0.41) and vapor pressure imbalance (r = -0.11). Climatic water balance studies (rainfall and PET) demonstrates the growing demographic shift in water excess from May to July (Z: +0.08 to 1.56) while opposite trends (declining, Z: -0.56 to -0.87) were confirmed in post-monsoon (December to February) months.

Sivakumar *et al*. (2012) analyzed the trend of the climatic parameters (2001-2007) in the northeastern zone of Tamilnadu and reported that rainfall increased from 2001 to 2005 and decreased during 2006 while temperature showed the same trend. Temperature, rainfall, relative humidity and wind velocity had positive regression when compared with the years (2001-2007).

Elbariki *et al*. (2014) conducted their study in Solan district of HP to understand the trend of weather parameters and how cereal production effected by these. In all the selected weather parameters between year 1984-2011 there was insignificant trend on an monthly, seasonal and annual basis that result was obtained by regression analysis and descriptive statistics. The best fit in the regression model was considered to be quadratic and cubic function. Sen's estimation study indicated a rising pattern of maximum and minimum temperature by 2.95 ^{0}C and 0.50 ^{0}C, respectively while in rainfall, relative humidity and sunshine hours a decline trend was reported. For selected crops an increasing trend revealed by Sen's estimate. In both cases of multiple regression analysis, no significant correlation of particular weather parameters with agriculture production was detected, suggesting that crop yield was affected by weather parameter combinations.

Latief Ahmad *et al*. (2017) performed a time series analysis of rainfall and temperature variance in Srinagar district of Kashmir by using parametric linear regression as well as non-parametric Mann-Kendall tests. Sen-Slope index was used to compute trend severity. They utilized Shalimar weather station's annual and monthly time series data over a span of 31 years (1985 - 2015) to carried out temporal trend analysis. They reported that there was insignificant change in the annual maximum temperature ($Z = 1.979$), annual precipitation ($Z = 0.48$) and annual number of rainy days ($Z = 0.194$). Both linear regression ($Z = -2.492$) and Mann- Kendall methods ($Z = -2.02$) found a very small substantial declining pattern in the annual mean minimum temperature (0.02 ^{0}C per year).

Bhuyan *et al.* (2018) "used 28 years of data to research the pattern of the weather variables in Bangladesh. Within the framework of the Intergovernmental Panel on Climate Change (IPCC) diagnostic exercise for the Fifth Assessment Report (AR5) and existing data gathered by the Bangladesh Meteorological Department (BMD) during the period 1981-2008, the maximum temperature, precipitation and their potential strategic variations were assessed in the 5th Phase Coupled Model Inter-comparison Project (CMIP5) in the north-western region of Bangladesh and also the comparison between these two values". It had been noticed that for BMD data and MPI-ESM-LR (CMIP5) model data, average temperature demonstrates a strong pattern of exponential rise at a rate of 0.29 ^{0}C and 5.3 ^{0}C per century respectively, while as rainfall shows a decline trend at a rate of 8.8 mm and 40.1 mm per century respectively. July had been seen as the highest precipitation and January was the lowest month of rainfall. The maximum duration was significantly lower than 12 months, suggesting that perhaps the key events happen prior to the actual end of a year as opposed to the previous year. As per MPI-ESM-LR (CMIP5) model data, during the period 2040-2100 the projected normal temperature in the north-western area will be raised at an average rate of 1.62 ^{0}C.

Shafiq *et al.* (2019) examined the evolving pattern in precipitation and temperature factors in Kashmir valley over various elevation zones in the north western part of India for the period 1980-2014. They registered a steeper rise in the annual mean maximum temperature than annual mean minimum temperature, in contrast, mean maximum temperature in plain regions had showed higher levels of increase compared to mountainous areas, but mountainous regions demonstrated a good rate of growth in the mean minimum temperature. Assessment of meteorological data for the same duration showed a downward trend with mountainous regions representing the greatest rate of decline which can be very dangerous to the fragile mountain environment of the Kashmir valley hosting a significant number of glaciers.

2.2 To analyze the impact of weather parameters on the productivity of rice crops.

Jain *et al*. (1980) "used yield data of 25 years and weekly weather variables *viz*., maximum temperature, relative humidity, total rainfall and number of rainy days to research climate factors rice yield modeling at different growth stages in Raipur District". Weather parameters were derived on the basis of the principal component analysis and used in the regression equation as independent variables. Two models were deemed appropriate among the various models. Weighted averages of weekly weather parameters in the first model and their associations were used as weights using the power of the week. The respective correlation coefficients with yield were taken in the second model, instead of week numbers. The analysis indicated that rice yield forecasting was achievable through weekly climatic variables, 2.5 months after seeding for a crop of 5 months duration. Using the second model, the study demonstrated that instead of weather variables, weighted weather index/ principal component might be used.

Kulkarni *et al*. (2004) performed a crop yield weather study analysis using a non-parametric approach based on the idea of two-way contingency tables, which were advocated to account for the cumulative effect of rainfall pattern on the crops.

Das *et al*. (2007) studied a crop simulator model, ORYZA 2000 in the baro seasons during 1999-2000 and 2000-2001 in West Bengal. The model assumes dramatic yield swings by 10, 45.8 and 72.1 per cent with temperature fluctuations of, +10 ^{0}C, +20 ^{0}C and +30 ^{0}C respectively. They also disclosed that in an atmosphere with doubled CO_2 concentration, although with warmer climate up to 10 ^{0}C, production could increase by 10%.

Geethalakshmi *et al*. (2008) evaluated the consequences of climate change on agricultural productivity for 2020, 2050 and 2080 baseline data and daily weather data. As predicted in the IPCC (2001) study, the CO_2 concentration used throughout the model for the baseline runs 2020, 2050 and 2080 was 376, 414, 522 and 682 ppm, respectively. Simulated finding showed that rice production in Tamil Nadu probably revealed a reduction of 8.7, 23.6 and 42.2 per cent, respectively, from the scale of output of the year 2000 in 2020, 2050 and 2080.

Guruswamy *et al*. (2008) measured mean annual and seasonal precipitation behavior and calculated the impact of weather variables on coconut cultivation. South West Monsoon and the winter rain had a detrimental impact, whereas summer and North East Monsoons had a positive correlation with the productivity of coconut. The proportion of coconut sterile nut development had a positive correlation with summer rainfall and negative correlation with monsoons in winter, southwest and northeast. There was a positive correlation between the weather variables, *viz*. “maximum temperature, minimum temperature, relative humidity, evaporation and rainfall” and coconut productivity. But palm productivity was not greatly affected.

Kersebaum *et al*. (2008) tested the influence of the climate change expected on winter wheat yield simulated at 9 locations throughout Germany using the HERMES dynamic agro-ecosystem model and downscaled GCM ECHAM5 performance scenarios for SRESM emission scenario A1B by 2050. For the period 2031-2050, yield declines between 2 and 11 per cent were forecasted at 8 sites. Diminishing summer precipitation had led to reduced nitrogen fertilizers performance.

Khadtare *et al*. (2008) conducted a 5 years sunflower study using 4 separate sowing windows to gain insight into the relationship between weather variables and yield interaction in the Rabi season. At all the phonological stages the minimal temperature, RH and bright sunshine had a very strong positive correlation with grain production. The substantial negative interaction with grain yield by pan evaporation suggested that Rabi sunflower did not favored the state of moisture stress at early stages of growth. A substantial positive interaction with grain yield by reducing temperature at all phases of development demonstrates that during the growth period, Rabi sunflower responds well to the low-temperature situation.

Chaudhari *et al*. (2009) "developed regional framework to understand the temperature (minimum, maximum and its diurnal range) yield response and rainfall for India's meteorological (met) sub-divisions and to evaluate the impact of global climate change on staple food crops *viz*. wheat, rice, potato and rapeseed-mustard". The area-weighted distribution of district-wise crop production data were calculated for 9, 16, 6 and 8 major wheat, rice, potatoes and rapeseed-mustard producing met sub-divisions level for 1977–2007 for, respectively. Fortnightly correlation weighted weather parameters such as minimum and maximum temperature and precipitation were used to establish the statistical models for the various met sub-division and crop season. The analysis demonstrated that for all three Rabi crops, such as wheat, potato and rapeseed-mustard, there was a significant negative yield result of a rising minimum temperatures while *Kharif* rice was reported with mixed reaction. The effect of the significant decrease on Rabi crop was high in compared with *Kharif* rice.

Rojalin *et al*. (2009) examined the effect of temperature and CO_2 on the performance of the four main grain food crops (wheat, rice, maize and pearl millet) in New Delhi. This research was aimed to classify certain crop' most vulnerable growth process to the growing temperature. For this reason, a Crop-Syst model soil-plant growth simulator was used. Their research indicated that Rabi crops were more susceptible to high-temperature stress than the Kharif crops. Compared with C3 plants, the beneficial impact of CO_2 was more in C4 crops (maize). The existing study also suggested that the negative impact of increasing temperature could be ameliorated in pearl millet by doubled CO_2 up to 10^0C, in rice and wheat up to 20^0C and in maize up to 30^0C.

Mahdi *et al.* (2013) performs a rice yield forecasting by using 20 years (1991-2010) data on rice yield and weather variables, i.e., weekly average of rainfall (mm), maximum and minimum temperature (^{0}C), morning relative humidity (%) and after noon relative Humidity (%), of Srinagar district of Kashmir Valley, focused on the coefficients of determination (R2), Standard Error of estimates (SE) as well as relative deviation (RD). The study found that the agro-meteorological yield model demonstrated approximately 58% of the yield variability resulting from minimum temperatures (Tmin) with SE ranged from 130.88 kg ha^{-1}.

Bhoomika *et al.* (2015) in their study found that the crops such as potato and rapeseed-mustard had shown a favorable response to raised maximum temperature. This may be because of their strong positive interaction with the diurnal temperature range (DTR). The mix effect of seasonal rainfall was reported on production of rice. The unit's projected effect of rise in the DTR on crop yield was generally less for wheat and rice crops compared to potato and rapeseed-mustard crops.

Kour *et al.* (2018) used 34 years of data to perform a study on the impact of climate variation on rice yield in Kheda district of Gujarat. The annual rice yield of the Kheda district of Gujarat from 1980 to 2013 comprises 34 data points were obtained from the Directorate of Agriculture, Gandhinagar, Gujarat. The first 30 observations i.e. the data from 1980 to 2009 were used for model building and the remaining 4 data points, i.e. the data from 2010 to 2013 were used for validating the model. Bright sunshine hours had an unfavorable effect on rice productivity during the 3rd week, which corresponds to the seedling stage. When the crop was tillering, a higher temperature was required than for growth. A higher average temperature varying between 25 to 32°C per day will decrease the growth time and encourage flowering while an average temperature of less than 15°C will slow down during vegetative growth and plants fail to bloom. Hence comparatively higher temperature was needed for substantial vegetative growth. Moist, humid weather was most ideal throughout vegetative growth and dry-sunny weather during flowering. Relative humidity was said to be ideal 60- 80 per cent. Rice crop needs around 1400 to 1800 mm of water, that was, if this great amount of rain occurs with good distribution during the crop season, it will be enough for the crop. The correlation coefficient between rice yield with minimum temperature, morning, afternoon and mean vapour pressure at the tillering stage was statistically significant at a 5% level of significance. Only these variables were used for subsequent model development.

Yasmin *et al*. (2018) studying the effect of weather factors on saffron cultivation in J&K, reported a clear positive correlation between weather parameters and floral attributes. From 21st October to 5th November 2009, saffron recovery kg^{-1} of fresh saffron flowers was found to be maximum (37.7 g) indicating ideal maximum and minimum temperatures combined with 0 mm rainfall. However, 116.5 mm rainfall obtained from October 26th to 31st, 2010 resulted in delayed flowering (November 1st to 10th) leading to 14.8 per cent lighter flowers with a poor saffron production of 23 g $fresh^{-1}$ saffron flowers. More wet days recorded mostly during crucial flowering stage in 2010 led to an increase of 35 per cent in the number of lighter flowers ha^{-1} leading to an increase of 8 per cent in the production of saffron ha^{-1}. To encourage efficient flowering when weather conditions were within healthy saffron output limits, it is important to predict the problems faced by climate change saffron irrigation during August until November.

Chapter - 3

MATERIALS AND METHODS

The ultimate objective of the research was to study the variability of weather parameters and their effect on rice yield in Kashmir during the period 1995-2019. The emphasis in this section is on presenting a concise summary of materials and methods of statistical analysis used in present study.

The material & methodology is presented under the following sub headings

1. Description of the study area.
2. Data base.
3. Analytical tools and techniques applied.

Materials: -

3.1 Description of the study area

The present study is carried out to know the trend and temporal variation of weather parameters in Kashmir Valley.

Kashmir is part of the western Himalayan range and lies between $32^{0}17^{'}$-$37^{0}20^{'}$N and $73^{0}25^{'}$-$80^{0}30^{'}$E. The region covers an area of about 222235 km^{2} (Hussain 2002). The severe climatic variability at high altitude ranging from 300-8400 m above the sea level is due to the undulation topography of the land in this region. Various food crops are grown in all districts of Kashmir valley on an area of 0.159 m ha. Total area of 261.35 thousand ha cultivated under rice in the Jammu & Kashmir out of which 137 thousand ha are cultivated in Kashmir and is a staple food of the valley.

3.2 Data base

The time-series data on rice production and productivity for the Kashmir region was collected by Directorate of Economics & Statistics, Government of

J&K for the period of 25 years from (1995-2019). Also secondary data of weather parameters of Kashmir region was collected for the same time span from the Division of Agronomy, SKUAST-K, Wadoora.

Yield

Rice (q/ha)

Weather Parameters;

1. Maximum Temperature(^{0}C)
2. Minimum Temperature(^{0}C)
3. Rainfall(mm)

Methods: -

3.3 Analytical tools and techniques

Analytical instruments are an essential part of investigative methods. Relevant analytical methods applicable to the research topic aid in meeting the study's target. The analytical methods usually begin with a description and summarization of the details obtained from each analysis. These have been subjected to numerous descriptive statistical analyses to analyze the essence of each sequence. Descriptive statistics are used to depict the essential characteristics of the data in a sample. These give the simple summary of the findings and the interventions. They form the basis of nearly any quantitative analysis of the results, along with basic graphics. We usually differentiate descriptive statistics from inferential statistics. In descriptive statistics, we explain precisely what the data indicates or what it is. For each of the selected weather parameters, descriptive statistics such as the mean, standard deviation (SD), coefficient of variance (CV), first quartile (Q_1) and third quartile (Q_3) and in turn used to analyze the variability of the weather parameters in Kashmir valley. The basic formulae are used to measure the various results.

Mean:

The arithmetic mean is most commonly used in estimation and description for its simplicity. "The arithmetic mean of a set of observations is their sum divided by the number of observations", e.g. the arithmetic mean x of n observation x_1, x_2, x_3,..., x_n is given by

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$

Standard deviation:

It is a more reliable and thorough calculation of dispersion, as an outlier will considerably exaggerate the range. It is expressed by

$$\sigma = +\sqrt{\sum_{i=1}^{n}\frac{1}{n}(x_i - \bar{x})^2}$$

Where,

x_i = value of the variable for the i^{th} observation

$\bar{x}$ = the mean or average

n= the number of observations.

3.3.1 Model Adequacy Checking

The adequacy of the model relies on the correctness of the underlying assumptions. In addition to the linear dependency of `Y` on regressors, the claims made in a linear regression model are the independence and identical distribution (normal) of regressors with zero mean. In the sense that different samples may lead to a different model with the opposite conclusions, gross violations of the assumptions will produce an unstable model. By analyzing summary statistics such as `t` or `F` statistics, we can 'not identify deviations from the underlying assumptions. These are "global" model properties and as such, the adequacy of the model is not guaranteed. Therefore, diagnostic approaches are used, mainly based on a study of the residual model. Diagnostic tests are used for residual randomness and normality.

3.3.1.1 Assumptions of Error Term

A significant principle of Linear regression is that normal distribution followed by the residual ε. For the test of hypothesis about the regression coefficients, this assumption is necessary. There are several approaches for determining whether or not data is normally distributed. Two wide categories in which these methods fall: Graphical and statistical method.

3.3.1.1.1 Graphical method:

The normal probability plot, a quantile-quantile plot (Q-Q plot) with uniform data against the standardized normal distribution, is a graphical method for measuring normality. Here, the correlation between normal quantities (a measure of the consistency of fit) and sample data, measures how well data modeled by a normal distribution. For normal data, the points plotted in the Q-Q plot should fall on a straight line approximately, suggesting a strong positive correlation. It is easy to understand these plots and often have the advantage of quickly distinguishing outliers.

3.3.1.1.2 Statistical method:

- Shapiro-Wilk test
- Anderson-Darling test

a.) Shapiro-Wilk test (W)

The standard measure for normality is Shapiro-Wilk test. The test statistic ‘W’ is the ratio of the best estimator of the variance (based on the square of a linear combination of the order statistics) to the commonly corrected number of variance estimator square. The associate between given data and their corresponding normal scores can be assumed to be `W`. The value of ‘W’ ranges from 0 to 1. When W = 1 the given data is perfectly normal in distribution

(Shapiro *et al.* 1968). When 'W' is significantly smaller than 1, the assumption of normality does not meet. A significant 'W' statistic causes to reject the assumption that the distribution is normal. Shapiro-Wilks 'W' is recommended for small and medium samples up to n = 2000

NH (H_0): A sample $x_1,..., x_n$ is from a normally distributed population.

AH (H_1): A sample $x_1,..., x_n$ is not from a normally distributed population.

The test statistic is

$$W = \frac{(\sum_{i=1}^{n} a_i x_i)^2}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

Where,

$x_{(i)}$ is the ith order statistic, i.e., the ith smallest number in the sample;

$\bar{x} = (x_1 + ... + x_n) / n$ is the sample mean;

The constants a_i are given by

$$(a_1,...,a_n) = \frac{m^T V^{-1}}{(m^T V^{-1} V^{-1} m)^{1/2}}$$

Where,

$$m = (m_1,...,m_n)^T$$

and $m_1,...,m_n$ are the expected values of the order statistics of independent and identically-distributed random variables sampled from the standard normal distribution and V is the covariance matrix of those order statistics.

Then values a_i, coefficients (a_i) are tabulated by Shapiro and Wilk (1965). Reject the null hypothesis if W is too small (near to zero).

b.) Anderson-Darling test

The Anderson-Darling test (Stephens, 1974) is used to test whether a sample data comes from certain distribution. It is a modification of Kolmogorov-Smirnov (K-S) test which gives more weight to the tails than the K-S test does. In the sense that the critical values do not depend on the particular distribution being evaluated, the K-S test is distribution-free. In the estimation of critical values, the Anderson-Darling test uses a particular distribution. This has the advantage of enabling a more sensitive test and the drawback that for each distribution, critical values must be determined.

Stephens (1974) found that most variations from normality were one of the easiest EDF (Empherical Distribution Function) statistics to detect. To evaluate the P-value, the test statistics will then be compared against the crucial values of the theoretical distribution (depending on which F is used).

The procedure is as follows;

1. The data x_i, for i= 1, 2, …., n is taken from a population, we have to test whether it is from a normal distribution or not.
2. The mean ($\overline{x}$) and standard deviation (S) are calculated from the sample of X.
3. The values $x_{(i)}$ are standardized as

$$Y_i = \frac{X_i - \overline{X}}{s}$$

4. The test statistic A^2 is calculated using

Where,

$$A^2 = -n - \frac{1}{2} \sum_{i=1}^{2} (2_i - 1)(\ln \varphi(Y_i) + \ln(1 - \varphi(Y_{n+1-i}))$$

Φ (Yi): Standard normal CDF (cumulative distribution function)

n: Sample size

The test statistic can then be compared against the critical values of the theoretical distribution (dependent on which ‘F’ is used) to determine the P-value.

3.3.1.2 Test for the randomness of the residuals (Sidney and Castellan, 1988)

Let m be the number of elements of one kind (+ve sign residuals) and n be the number of elements of the other kind (-ve sign residuals) in a sequence of N = m + n. To use one sample run test, first, observe the m and n events in which they occurred and determined the value of r (i.e. no. of runs). If m or n is larger than 20, determine the value of Z as under

$$\text{Mean} = \mu = \frac{2mn}{N} + 1 \text{ and standard deviation} = \sigma_r = \left[\frac{2mn(2mn - N)}{N^2 (N - 1)} \right]^{1/2}$$

$$Z = \frac{r - \mu_r}{\sigma_r} = \frac{r + h - \frac{2mn}{N} - 1}{\sqrt{\frac{2mn(2mn - N)}{N^2 (N - 1)}}}$$

Where; h = +0.5 if $r < \frac{2mn}{N} + 1$ and h = -0.5 if $r > \frac{2mn}{N} + 1$

Use normal table Appendix A by Sidney and Castellan (1988) for testing Z value. The residuals said to be random; if Z value is non-significant.

3.3.2 Trend analysis

3.3.2.1 Fitting trends based on parametric models

A basic challenge in statistics is the construction of models which is based on a sample of observation and the model so developed is used to draw inferences. Regression and time series models have played an important part in mathematical modeling and data processing over the past few decades. Regression (linear and non-linear) and time series models give information of the relationship between an outcome (dependent) variable and one or more experimental (independent) variables. Sometimes, only by looking at data, it is very difficult to ascertain the most suitable function and often there might not be an acceptable parametric form to represent the linear function.

3.3.2.1.1 Linear model:

Regression analysis has been one of the most frequently used statistical methods to evaluate functional associations between variables represented as an equation relating the outcome (dependent) variable "Y" and one or more experimental (independent) variables X_1, X_2, X_3, …, X_n(time). As the goal is to model the functional relationship between a quantitative variable (Y) and periods of time (t) over which it is observed, the regression equation takes the form

$$Y = b_0 + b_1 t + e$$

Where,

b_0 : Intercept

b_1 : Slope

t: Time period

Y: Maximum temperature, minimum temperature, rainfall (one parameter at a time has been taken).

e: Error component.

3.3.2.1.2 Non-linear models (Draper and Smith, 1998)

Statistical modeling consists primarily of building a model described by a series of equations to explain the interaction between input and output between variables of interest. This interaction between variables in biological and agriculture sciences is 'nonlinear' in nature, from a practical point of view. In such models, an increase in the unit value of the experimental variable does not result in an increase in the outcome variable of an equal amount. That occurs non-linearly if at least one of the parameters is non-linear in regression model.

Mathematically, at least one of the derivatives of the expectation equation with regards to at least one parameter is a factor of the parameter in non-linear model. Any non-linear model that can be converted into a linear model by some transformation is called "intrinsically linear", else it is called as "intrinsically non-linear". In the ongoing inquiry, the following non-linear equation should be considered. Care of all sorts of growth rate can be taken by these models, i.e. decreasing, increasing and steady and thus chosen for review.

a.) Exponential trend equation (intrinsically linear):

Exponential trend equation is given by

$$Y_t = AB^t$$

Where,

Y_t refers to the realised value of the phenomenon under consideration in the year t,

t is the time in year,

A is the constant,

B is the parameter.

b.) Logarithmic Model:

The equation of logarithmic model is given by

$$\Rightarrow Y_t = b_0 + b_1 \ln(t)$$

“In order to implement these models to data, on the right hand side of the equations, the error terms are assumed to be independently and identically distributed with constant variances, thereby generating corresponding “statistical models”. To fitting the model, the non-linear estimation procedures are used, such as Levenberg-Marquardt algorithms, or Does not Use Derivatives (DUD) procedures.

3.3.2.1.2 Non-Parametric Trend Analysis using Mann Kendall (MK) Trend Test

A non-parametric technique for recognizing patterns in time series data is Mann-Kendall test. Instead of data values themselves, the evaluation compares the relative magnitude of sample data (Gilbert, 1987). The value of this test is that the data does not need to adhere to any standard distribution. The second advantage of the test is its low sensitivity to sudden breaks due to inhomogeneous time series (Jaagus, 2006). This measure was first used by Mann (1945) and the test statistics distribution was subsequently derived by Kendall (1975).

According to this test, the null hypothesis in the test is that within the data series there is no significant pattern. If the null hypothesis is dismissed, it is an indicator of a significant pattern within the data series that can be either positive or negative, as defined by its score. The test statistic S is given by:

$$S = \sum_{K=1}^{n=-1} \sum_{j=k+1}^{n} sng(x_j - x_k)$$

The trend test is applied to a time series x_k, which is ranked from $k = 1, 2, 3, \ldots n - 1$ and x_j, which is ranked from $j = i + 1, i + 2, i + 3, \ldots n$. Each of the data points x_j is taken as a reference point, which is compared with the rest of the data points x^k, so that,

$$sgn(x_j - x_k) = \begin{cases} +1 & if \;\; x_j - x_k > 0 \\ 0 & if \;\; x_j - x_k = 0 \\ -1 & if \;\; x_j - x_k < 0 \end{cases}$$

Here x_j and x_k are the sequential data values and n is the length of the data set. For samples greater than 10, the test is conducted using a normal distribution (Helsel *et al.* 1992) with the mean and variance as follows:

The variance σ^2 for the S statistic is defined by:

$$E(s) = 0$$

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right]$$

Here t_p is the number of data points in the p^{th} tied group and q is the number of tied groups in the data set.

The standardized test statistic Z_{mk} is calculated by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{VAR(s)}} & if \; S > 0 \\ 0 & if \;\; S = 0 \\ \dfrac{S+1}{\sqrt{VAR(S)}} & if \;\; S < 0 \end{cases}$$

where the value of Z_{mk} is the Mann-Kendall test statistics that follow the standard normal distribution with a mean of zero and a variance of one. Thus, in a two-sided trend test, the null hypothesis H_o is accepted if $(–Z1 - \alpha/2) \leq Z_{mk} \leq (Z1 - \alpha/2)$, where α is the level of significance that indicates the trend’s strength.

Sen’s Slope Estimator

The magnitude of a trend in a time series can be determined using a non-parametric method known as Sen’s estimator (Sen, 1968). To estimate the true slope of an existing trend such as the amount of change per year, Sen’s nonparametric method is used. Sen’s method can be used in cases where the trend can be assumed to be linear such as:

$$f(t) = Qt + B$$

Here Q is the slope and B is a constant.

To get the slope estimate Q, the slopes of all the data value pairs are calculated as:

$$Q_i = \frac{x_j - x_k}{j - k}$$

Here x_j *and* x_k are the data values in years j and $k, j > k$. If there are n values of x_j in the time series, one gets as many as $N = n(n - 1)/2$ slope estimates Qi.

Sen's estimator of the slope is the median of these N values of Qi. The N values of Qi are ranked from the smallest to the largest and Sen's estimator is

$$Q = Q_{[(N+1)/2]} \qquad \text{if N is odd}$$

$$Q = \frac{1}{2}(Q_{[N/2]} + Q_{[(N+1)/2]}) \qquad \text{if N is even}$$

At 100 (1-α)% two-sided confidence interval about the slope estimate is obtained by the nonparametric technique based on the normal distribution. The method is valid for n as small as 10 unless there are many ties. A positive value of Q_i indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

3.3.3 Analysis of the impact of weather parameters on the productivity of rice crop

3.3.3.1 Correlation analysis

Pearson correlation coefficients shall be computed between all the above-mentioned weather parameters and rice yield for twenty-five years of data (1995-2019).

Karl Pearson's correlation coefficient (r_{YV})

$$\rho_{YV} = Corr(Y,V) = \frac{Corr(Y,V)}{\sigma_Y \sigma_V}$$

$Corr(Y,V)$=Covariance between weather variables

σ_Y = Standard deviation of weather parameters (Y)

σ_V = Standard deviation of rice (V)

Testing the significance of the correlation coefficient

The significance of the correlation coefficient was tested by t-test.

(a) Hypothesis:

$$H_0 : \rho_{YV} = 0$$

$$H_1 : \rho_{YV} \neq 0$$

(b) Test statistic:

$$t_{cal} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \sim t_{\alpha,(n-2)df}$$

Where,

‘r’ is the correlation coefficient commutated from the sampled data.

(n-2) is the degree of freedom.

(c) Critical region:

Reject H_0 at α% level of significance if $|t_{cal}| \geq t_{(n-2,\alpha/2)}$

3.3.3.2 Path Analysis

We used path analysis to analyze the effect of weather parameters, including maximum temperature, minimum temperature and rainfall on rice yield. The direct and indirect influence of weather parameters on rice yield can be established by path analysis.

Study of path analysis provides a tool for assessing the direct and indirect impact of weather parameters on rice yield. A standardize partial regression is path analysis which is a tool for elucidating the contribution of each variable to the coefficient of overall correlation. The direct and indirect effects of each variable are quantifies by the path analysis and thus help in the determination of selected indices by visualize correlation in its entirety. The correlation coefficient with various weather parameters of rice yield were further categorized into indirect and direct effects. It contains a set of simultaneous regression equation that logically define the relationship in the path model between observed variables. In addition to the direct influence that is often available in regression analysis, path analysis expands the concept of regression modeling and gives the versatility to measure indirect and overall causal effects (Bollen, 1989). However, path analysis provides more variability and experimental variables which are allowed to indirectly as well as directly impact the dependent variable.

Path analysis attempts to include measures of the extent and significance of the hypothesized casual relations across sets of variables presented by the use of path diagrams.

Path Diagram

The diagrammatical or schematic representation of the path analysis is referred as the path diagram. In general, arrows are used to represent the relationship, a single headed arrow is intended to indicate cause to effect. There are two types of variables in the path diagram, the experimental variables known as casual variables and the outcome variables known as endogenous variables.

If Y is a character that, due to the closed system, is linearly defined by the correlated variables X_1, X_2 and X_3, a path diagram can be implemented as shown in Fig. 3.1

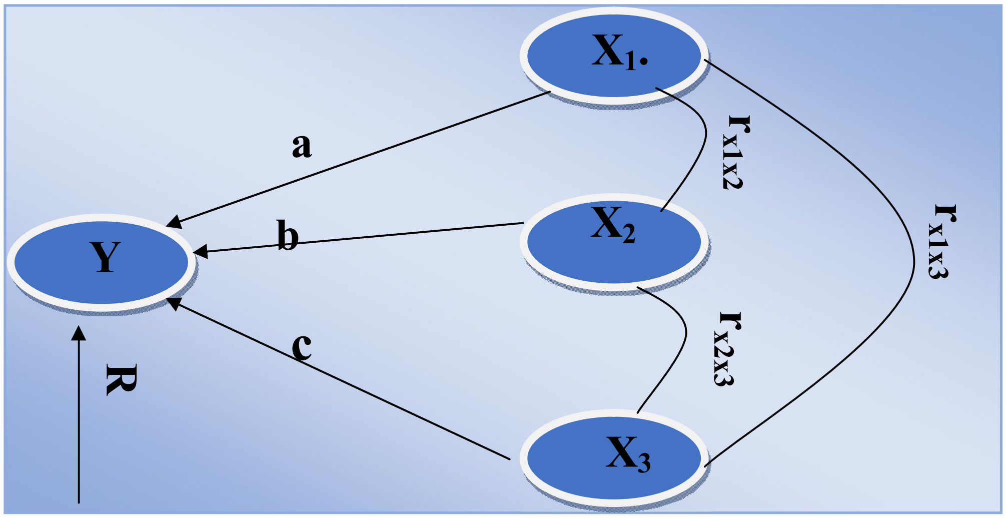

Fig. 3.1 Path diagram of rice yield

In Fig 3.1, symbols a, b and c represent direction coefficients from causes X_1, X_2 and X_3; and r_{x1x2}, r_{x2x3} and r_{x1x3} are coefficients of correlation and R is residual (variation in Y due to some unnamed factors). Using a double headed arrow for the coefficient of correlation and one-directional arrow for the direct path of effect from one variable in the system to the outcome variable is a convention.

A character Y is determined by three correlated variables, *viz.* X_1, X_2 and X_3. The relationship can be expressed in the form of a partial regression equation and is given by

$$Y=\mu+\beta_1 X_1+\beta_2X_2 + \beta_3X_3+R.$$

Where,

β_1, β_2 and β_3 are the partial regression coefficients. β_1 is the partial regression coefficient of Y on X_1, measures the amount of change that can be brought about in Y due to one unit change in X_1 and X_2, X_3 are held constant. β_2 and β_3 have similar meanings. R is the residual component.

A set of three simultaneous equations is then formulated from the path diagram as:

$$r_{YX_1} = a + br_{X_1X_2} + cr_{X_1X_3}$$

$$r_{YX_2} = ar_{X_2X_1} + b + cr_{X_2X_3}$$

$$r_{YX_3} = ar_{X_3X_1} + br_{X_3X_2} + c$$

Where,

r_{X1x2}	Estimates of simple correlation coefficient between x_1 and x_2 variables.
r_{x2x3}	Estimates of simple correlation coefficient between x_2 and x_3 variables.
r_{x1x3}	Estimates of simple correlation coefficient between x_1 and x_3 variables.
a	Direct effect of variable X_1.
b	Direct effect of variable X_2.
c	Direct effect of variable X_3.
y	Dependent variable.

Chapter-4

EXPERIMENTAL FINDING

This chapter looks at the study`s findings according to the framed Chapter III dealt with methods. The data have been examined and the results are explained correspondence to ambition as follows;

4.1 To study the trend in the weather parameter over the study period

4.2 Analysis of the impact of weather parameters on productivity of rice crop

4.1 To study the trend in the weather parameter over the study period.

4.1.1 Descriptive statistics

To investigate the variability of selected weather parameter in Kashmir valley, descriptive statistics such as the Mean, Standard Deviation (SD), Coefficient of Variation and Quartiles were measured and the result are shown in the section below.

4.1.1.1 Maximum Temperature

The results of Maximum temperature over study period for all months (January to December) are shown in Table 4.1.

The results of Table 4.1 shows that the average maximum temperature increased from the month of February (7.82) to July (27.16) and thereafter start declining. The standard deviation found to be more during January (2.31), March (2.45), May (2.13) and found less during July (0.78), August (0.82). The coefficient of variation of Maximum temperature ranges from (2.86) to (41.03 %) over all the months. The month of January shows more variation (41.03 %) followed by February and March; (24.95 %) and (18.66 %) respectively, maximum temperature less variation in July moth which is 2.86 %.

Table 4.1: Mean and Variability of Maximum Temperature for the period Jan-Dec during 1995-2019

Period	Maximum Temperature (^{o}C)				
	Mean	SD	CV	Q_1	Q_3
Jan	05.64	2.31	41.03	03.63	07.55
Feb	07.82	1.95	24.95	06.81	08.91
Mar	13.14	2.45	18.66	11.25	14.40
Apr	18.19	1.78	09.78	17.22	18.81
May	22.49	2.13	09.46	21.03	23.66
Jun	25.62	1.48	05.77	24.55	26.75
Jul	27.16	0.78	02.86	26.68	27.58
Aug	26.74	0.82	03.05	26.04	27.09
Sep	24.95	1.32	05.33	24.00	25.79
Oct	20.50	1.74	08.48	19.28	21.94
Nov	13.87	1.99	14.37	12.72	15.13
Dec	08.98	1.52	17.95	07.78	08.98

CV: Coefficient of variation (%), Q_1: First Quartile, Q_3: Third Quartile.

4.1.1.2 Minimum Temperature

The results of minimum temperature over study period for all months (January to December) are shown in Table 4.2.

Table 4.2: Mean and Variability of Minimum Temperature for the period Jan-Dec during 1995-2019

Period	Minimum Temperature (^{o}C)				
	Mean	SD	CV	Q_1	Q_3
Jan	-04.02	1.22	-30.27	-04.80	-03.16
Feb	-01.84	1.31	-71.27	-02.56	-01.26
Mar	01.71	0.95	55.96	01.21	02.16
Apr	05.60	0.69	12.42	04.97	06.15
May	08.67	1.08	12.43	07.87	09.43
Jun	12.21	1.16	09.53	11.78	12.71
Jul	15.57	0.79	05.07	15.14	16.06
Aug	15.06	0.61	04.04	14.55	15.59
Sep	10.84	0.91	08.43	10.59	11.51
Oct	05.16	0.95	18.45	04.61	05.63
Nov	01.58	0.87	55.06	00.92	01.94
Dec	-02.83	1.07	-37.74	-03.62	-01.88

CV: Coefficient of variation (%), Q_1: First Quartile, Q_3: Third Quartile.

The results of Table 4.2 shows that the average minimum temperature increased from month of January (-4.02) to July (15.57) and thereafter it decreased. The result of table 4.2 shows that the variation is more in February (-71.27%) followed by March and November month (55.96%, 55.06%) respectively.

4.1.1.3 Rainfall

The results of rainfall over study period for all months (January to December) are shown in Table 4.3.

The results of Table 4.3 showed that the average rainfall was found to be more during January (105.32), February (145.82), March (150.32), April (129), as compare to other months. The coefficient of variation ranges from 41.84% to 97.37% over the months, September month showing more variation followed by November (97.37%, 95.16%) respectively.

Table 4.3: Mean and Variability of Rainfall for the period Jan-Dec during 1995-2019

Period	Rainfall (mm)				
	Mean	SD	CV	Q_1	Q_3
Jan	105.32	68.18	64.74	48.77	138.07
Feb	145.82	75.62	51.86	84.25	175.14
Mar	150.02	83.79	55.86	89.18	214.28
Apr	129.31	54.12	41.84	98.82	156.13
May	98.57	50.40	51.13	64.58	114.50
Jun	78.57	39.92	50.81	54.18	095.75
Jul	85.61	36.25	42.34	58.08	105.13
Aug	86.71	46.04	53.12	62.35	106.90
Sep	67.29	65.66	97.37	32.18	090.07
Oct	37.67	29.90	79.37	20.87	050.32
Nov	53.23	50.65	95.16	17.07	060.37
Dec	47.93	36.01	75.13	27.07	055.10

CV: Coefficient of variation (%), Q_1: First Quartile, Q_3: Third Quartile.

4.1.2 Assumptions of Error Term

4.1.2.1 Graphical Method

In order to test whether the data is normal or not, a quantile-quantile plot (Q-Q plot) of standardize data against the standard normal distribution was done.

The Q-Q plot chart for maximum temperature, minimum temperature and rainfall indicate that the data points approximately fall on straight line, hence the data is normal.

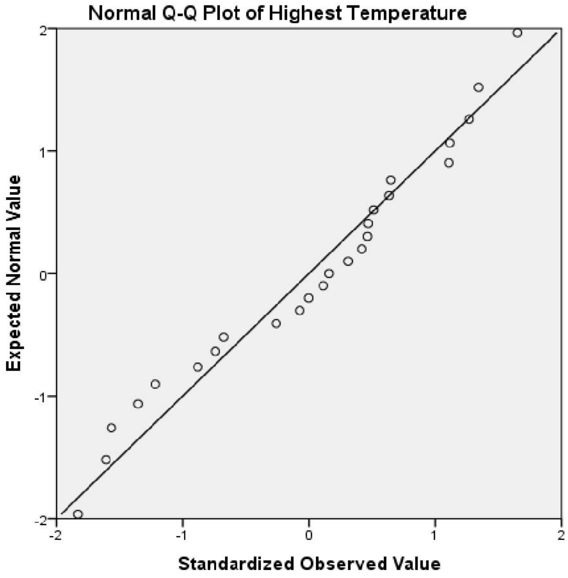

Fig.4.1. Normal Q-Q Plot of Maximum Temperature

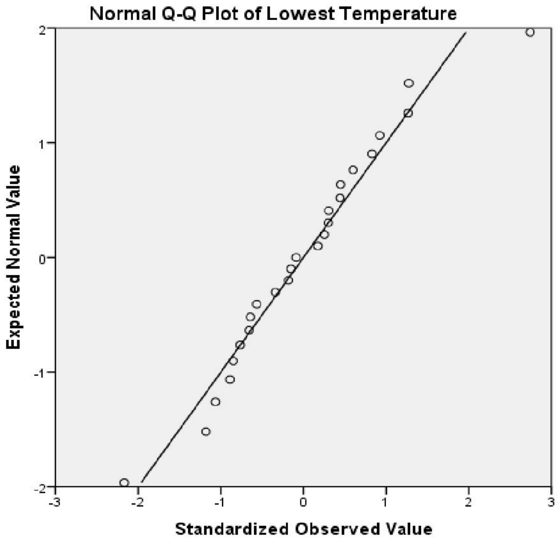

Fig.4.2. Normal Q-Q Plot of Minimum Temperature

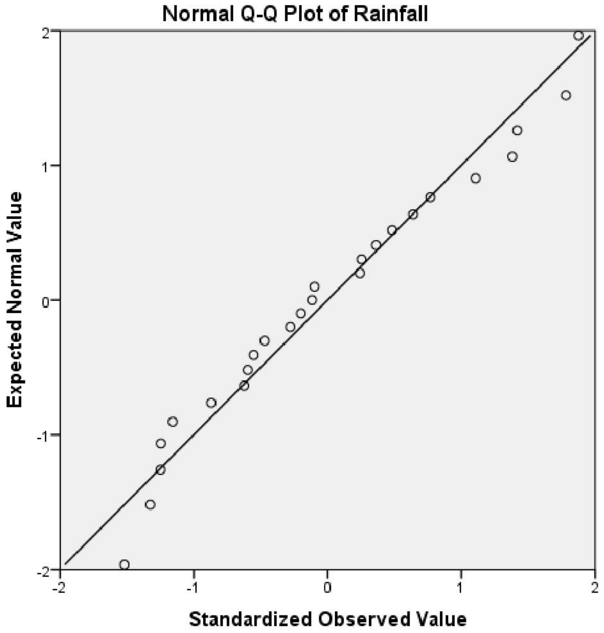

Fig. 4.3: Normal Q-Q Plot of Rainfall

4.1.2.2 Test for Normality

Anderson-Darling test and Shapiro-Wilk test

Anderson-Darling test and Shapiro-Wilk test was used to test the normality of error term, the outcomes are shown in the Table 4.4. The outcomes of table indicate that the error term follows the normal distribution.

Table 4.4: Results of test of Normality

Parameters	1995-2007		2007-2019	
	A^2	W	A^2	W
Maximum temp.	0.270^{NS}	0.932^{NS}	0.409^{NS}	0.933^{NS}
Minimum temp.	0.331^{NS}	0.950^{NS}	0.328^{NS}	0.938^{NS}
Rainfall	0.280^{NS}	0.947^{NS}	0.376^{NS}	0.934^{NS}

NS: Non-Significant

4.1.2.3 Test for the randomness of the residual-Run test

Randomness-run test was done to check the adequacy of the model. The residuals were evaluated for their randomness through run test; the results of test are shown in Table 4.5. The p-value in table is grater then (.05), which indicate that the residuals are randomly distributed.

Table 4.5: Results of run test for randomness of residuals

Parameters	P-value	
	1995-2007	2007-2019
Maximum Temp.	0.575^{NS}	0.235^{NS}
Minimum Temp.	0.575^{NS}	0.982^{NS}
Rainfall	0.575^{NS}	0.982^{NS}

NS: Non-Significant

4.1.3 Trend Analysis

Trend investigation was made by using sundry models, such as parametric model (linear regression, logarithmic model, exponential model) and non-parametric model (Mann-Kendal trend test, Sen-Slope estimator) to peg the monthly trend pattern in weather parameters in Kashmir valley for the period of 1995-2019.

4.1.3.1 Results of Parametric Models

The pattern related to particular weather parameters was found by fitting regression models which are Logarithmic model, Exponential model and Linear regression model for monthly data and results are shown in Table 4.6, 4.7 and 4.8. The comparison between Exponential, Logarithmic and Linear model was executed in order to divine the best fit.

It was unearthed that Maximum temperature has aired an insignificant pattern over 25 years for all months except July in Linear, Exponential models and excepts January, March and December in Logarithmic model. All month airs (+ve) trend except June, July and November exhibits negative trend in all three models. Beside this May month exhibit negative trend in Linear model and also October exhibit negative trend in Logarithmic model. It was found that the

Table 4.6: Fitted regression models for Maximum temperature between the periods of 1995-2019

Month	**Logarithmic**		**Linear**		**Exponential**	
	(b)	**R^2 Value**	**(b)**	**R^2 Value**	**(b)**	**R^2 Value**
January	0.969·	0.122	0.077	0.061	0.014	0.058
February	0.703	0.090	0.069	0.068	0.009	0.064
March	1.009·	0.118	0.073	0.049	0.005	0.050
April	0.327	0.023	0.000	0.000	0.000	0.002
May	0.099	0.001	-0.023	0.006	-0.001	0.004
June	-0.403	0.052	-0.057	0.082	-0.002	0.085
July	-0.243	0.068	-0.038·	0.134	-0.001·	0.133
August	0.158	0.026	0.006	0.003	0.000	0.004
September	-0.035	0.000	0.005	0.001	0.000	0.001
October	0.638	0.094	0.038	0.257	0.002	0.032
November	-0.154	0.004	-0.068	0.064	-0.005	0.073
December	0.659*	0.130	0.044	0.046	0.006	0.066

· Significant at 0.05 level, * significant at 0.01 level, others are: Non-Significant

Logarithmic model had greater R^2 value compared to Exponential and Linear model, so logarithmic model considered as best fit for maximum temperature. Logarithmic Trend for Maximum temperature exhibits in “Fig.5 to Fig. 16”.

The minimum temperature shown insignificant trend during all months for all the three models except January and March in logarithmic model show significant trend & also in exponential model for January month shows significant trend (Table 4.7). All month shows positive trend except May, June, July in all three models shows negative trend & October months also shows negative trend in both logarithmic and exponential model. December shows negative trend in linear and exponential model. The logarithmic model was considered best fit for minimum temperature in comparison with linear and exponential model, because Logarithmic model had greater R^2 value compared to Exponential and Linear model (Fig.17 to Fig. 28).

Table 4.7: Fitted regression models for minimum temperature between the periods of 1995-2019

Month	Linear		Logarithmic		Exponential	
	(b)	R^2 Value	(b)	R^2 Value	(b)	R^2 Value
January	0.053	0.102	0.737**	0.255	0.022$^{\cdot}$	0.136
February	0.046	0.065	0.571	0.131	0.019	0.042
March	0.023	0.033	0.322$^{\cdot}$	0.079	0.026	0.072
April	0.005	0.003	0.128	0.019	0.001	0.002
May	-0.014	0.009	-0.000	0.000	-0.001	0.008
June	-0.029	0.035	-0.120	0.008	-.0027	0.044
July	-0.004	0.002	-0.110	0.013	-0.000	0.001
August	0.013	0.025	0.067	0.008	0.0008	0.025
September	0.000	0.000	0.001	0.000	0.0001	0.000
October	0.001	0.000	-0.019	0.001	-0.001	0.001
November	0.011	0.009	0.167	0.026	0.007	0.018
December	-0.026	0.034	0.091	0.005	-0.007	0.003

** Significant at 0.001 level, $^{\cdot}$Significant at 0.05 level, Others are: non-significant

Table 4.8: Fitted regressions models of rainfall for the period I 1995-2019

Month	Linear		Logarithmic		Exponential	
	(b)	R^2 Value	(b)	R^2 Value	(b)	R^2 Value
January	0.277	0.001	-0.155	0.019	-0.018	0.021
February	0.227	0.000	0.030	0.002	0.004	0.004
March	-0.945	0.007	-0.188	0.045	-0.009	0.009
April	2.268	0.095	0.068	0.009	0.019	0.058
May	-0.855	0.015	-0.098	0.031	-0.005	0.006
June	0.916	0.028	-0.004	0.000	0.009	0.015
July	-0.320	0.004	-0.086	0.034	-0.001	0.001
August	-1.627	0.067	-0.154	0.068	-0.010	0.023
September	1.903	0.045	0.172	0.038	0.010	0.010
October	-0.563	0.019	-0.372	0.042	-0.028	0.019
November	1.756	0.057	-0.201	0.008	-0.015	0.003
December	0.559	0.013	0.151	0.005	0.024	0.012

All are: non-significant

It was observed that throughout the study time the rainfall followed insignificant pattern for all months for all three models (linear, exponential and logarithmic). Negative trend exhibits for March, May, July, August and October months in linear model; exponential model and logarithmic model also shows

Maximum Temperature

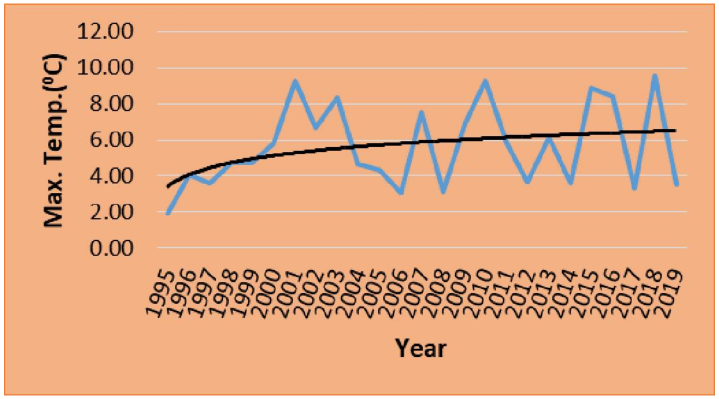

Fig. 4.5: Logarithmic trend of Max. temp for month of Jan

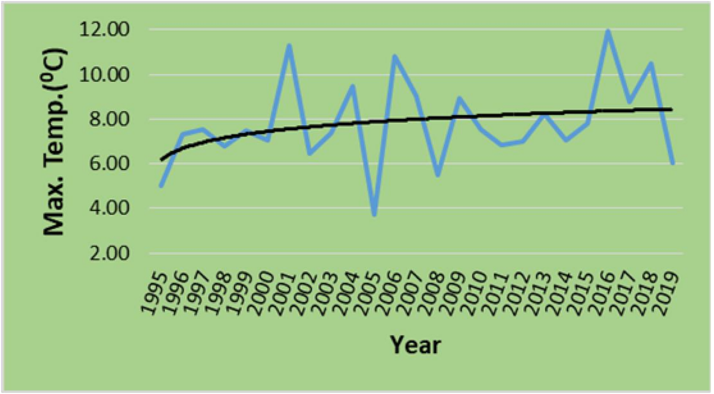

Fig. 4.6: Logarithmic trend of Max. temp for month of Feb

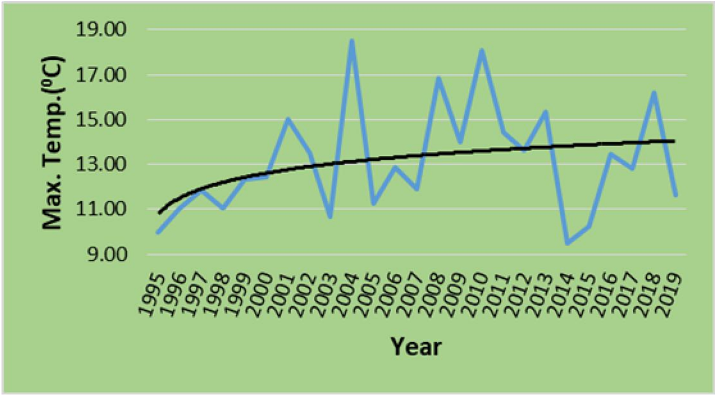

Fig. 4.7: Logarithmic trend of Max. temp for month of Mar.

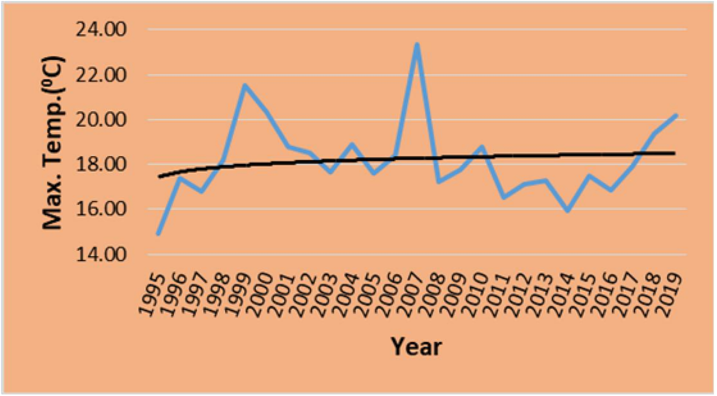

Fig. 4.8: Logarithmic trend of Max. temp for month of Apr.

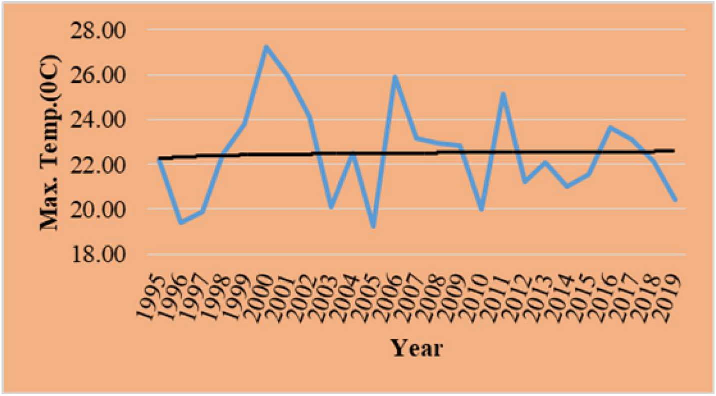

Fig. 4.9: Logarithmic trend of Max. temp for month of May.

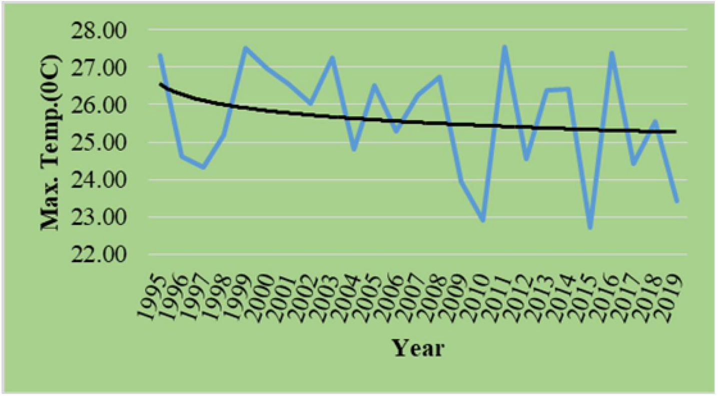

Fig. 4.10: Logarithmic trend of Max. temp for month of Jun.

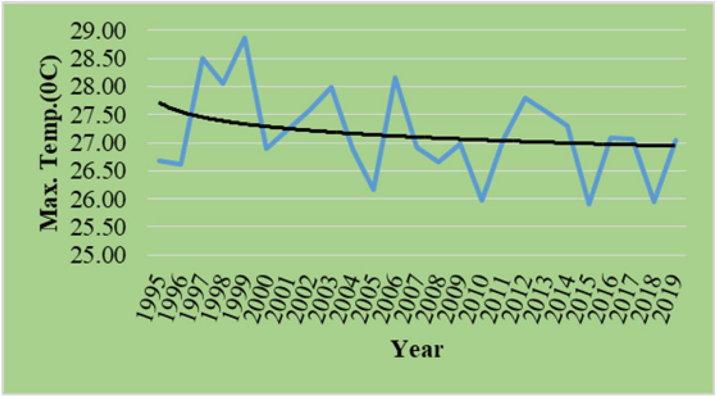

Fig. 4.11: Logarithmic trend of Max. temp for month of Jul.

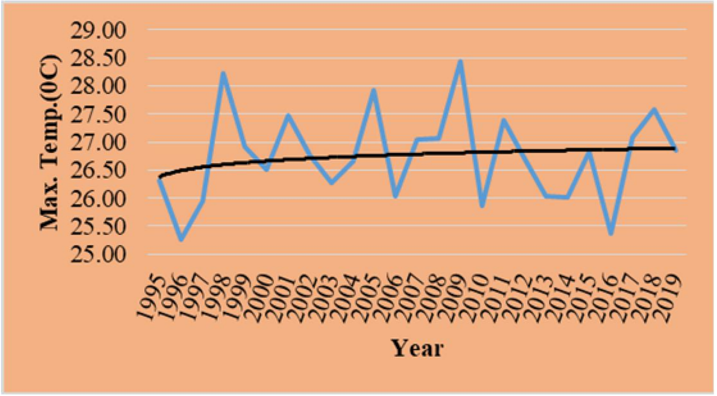

Fig. 4.12: Logarithmic trend of Max. temp for month of Aug.

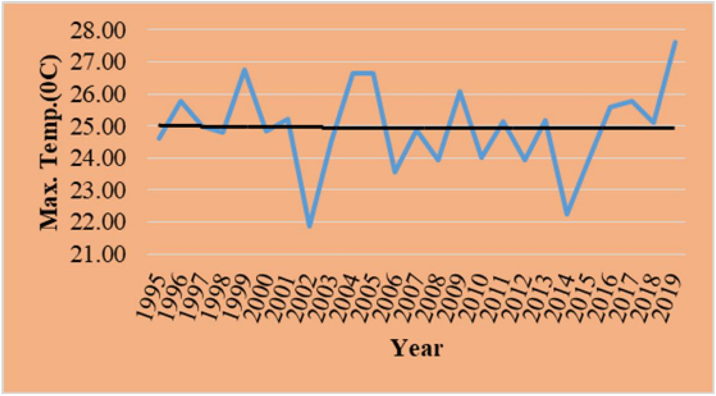

Fig. 4.13: Logarithmic trend of Max. temp for month of Sep.

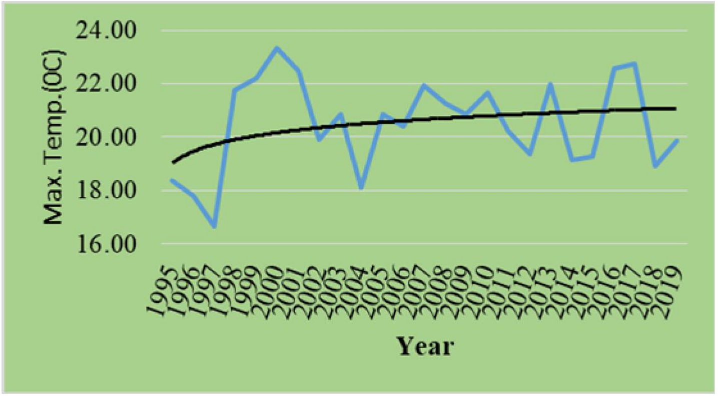

Fig. 4.14: Logarithmic trend of Max. temp for month of Oct.

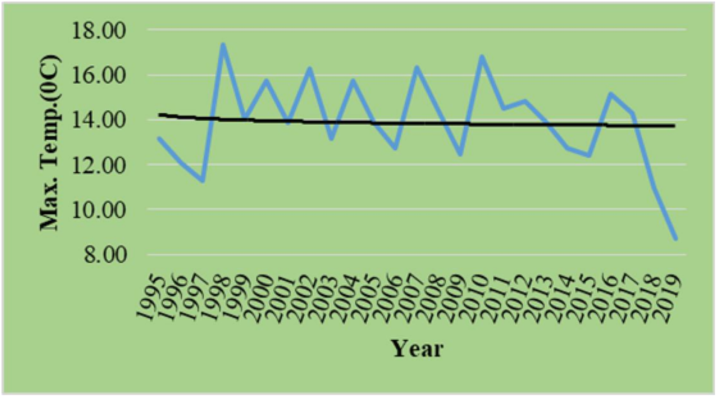

Fig. 4.15: Logarithmic trend of Max. temp for month of Nov.

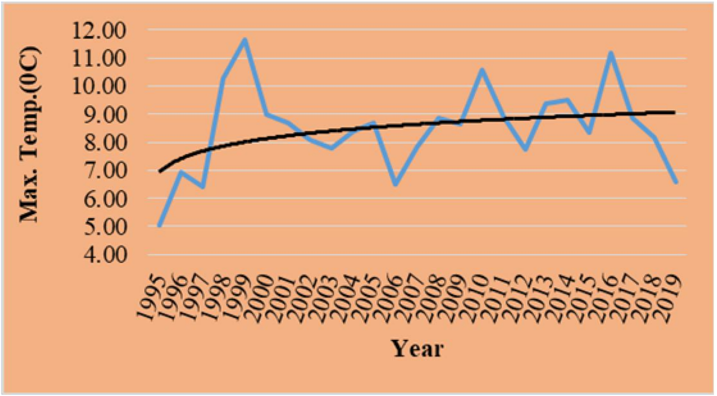

Fig. 4.16: Logarithmic trend of Max. temp for month of Dec.

Minimum

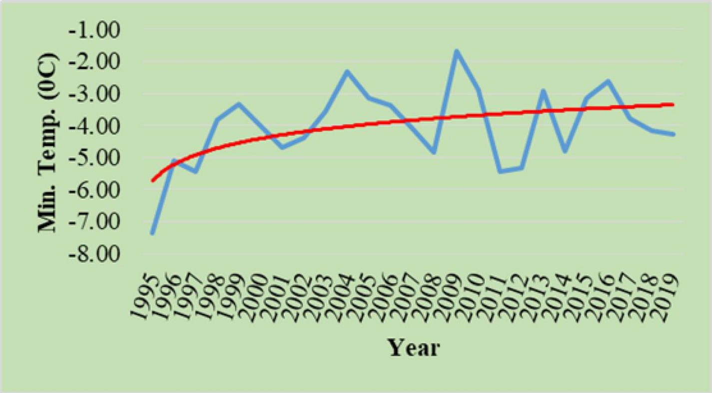

Fig. 4.17: Logarithmic trend of Min. temp for month of Jan.

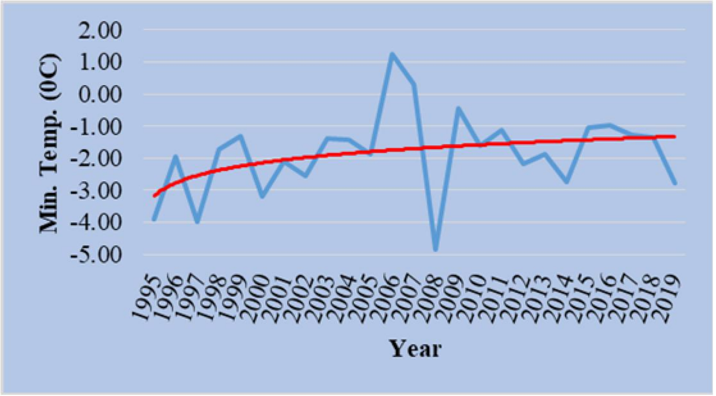

Fig. 4.18: Logarithmic trend of Min. temp for month of Feb.

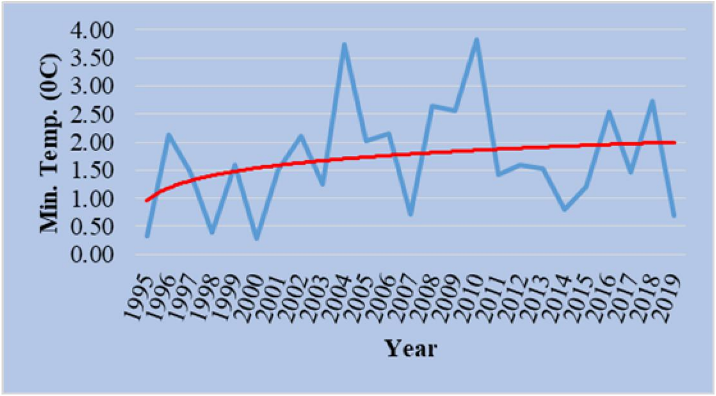

Fig. 4.19: Logarithmic trend of Min. temp for month of Mar.

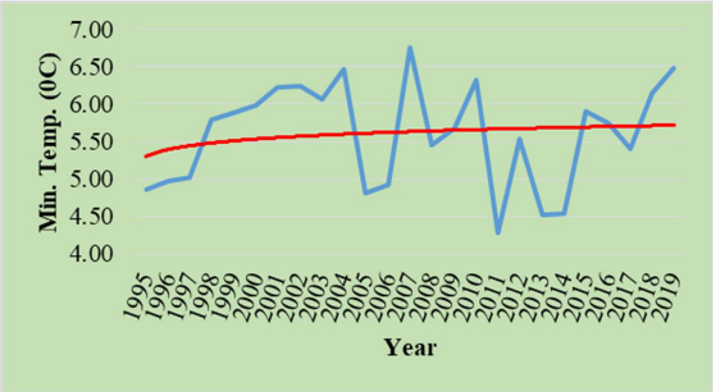

Fig. 4.20: Logarithmic trend of Min. temp for month of Apr.

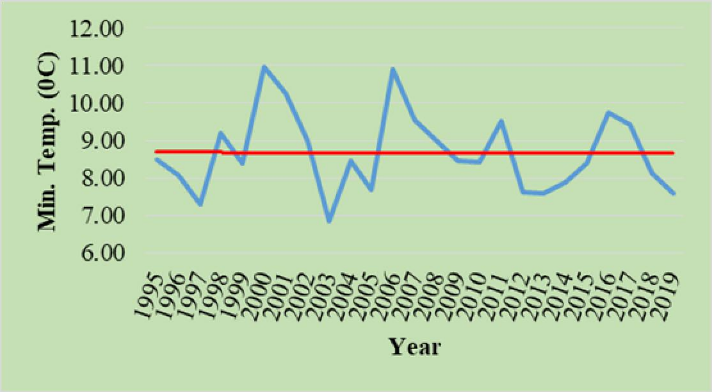

Fig. 4.21: Logarithmic trend of Min. temp for month of May.

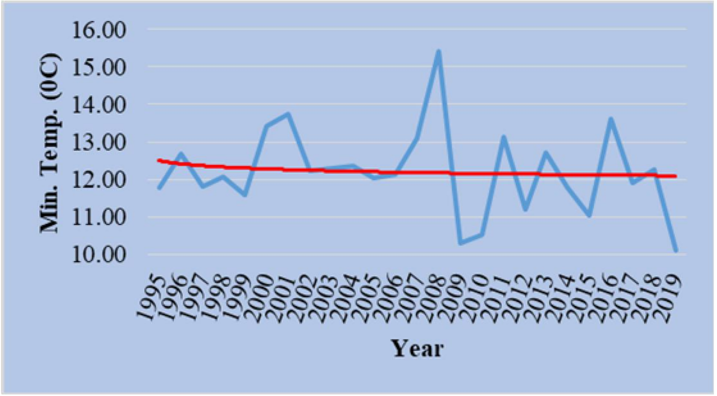

Fig. 4.22: Logarithmic trend of Min. temp for month of Jun.

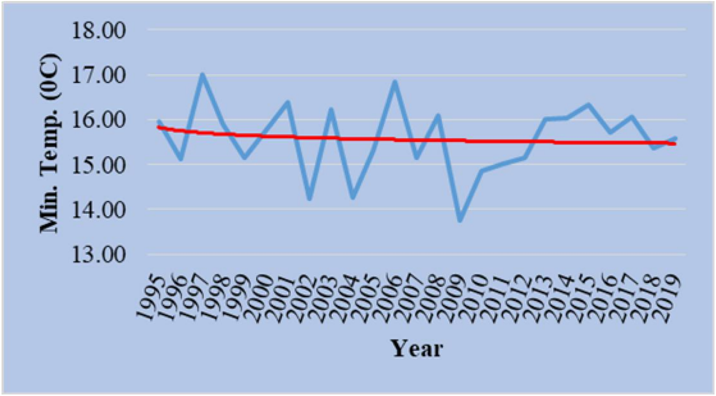

Fig. 4.23: Logarithmic trend of Min. temp for month of Jul.

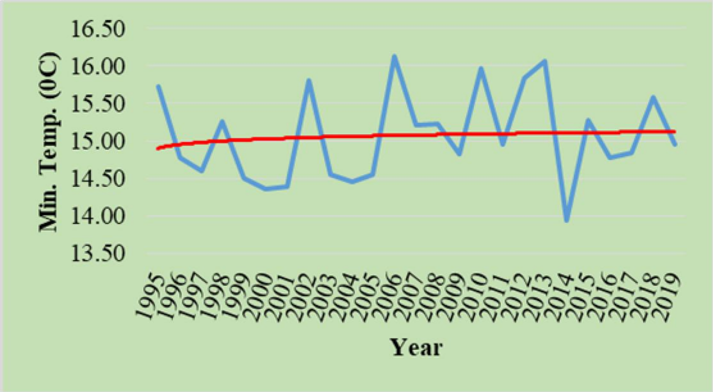

Fig. 4.24: Logarithmic trend of Min. temp for month of Aug.

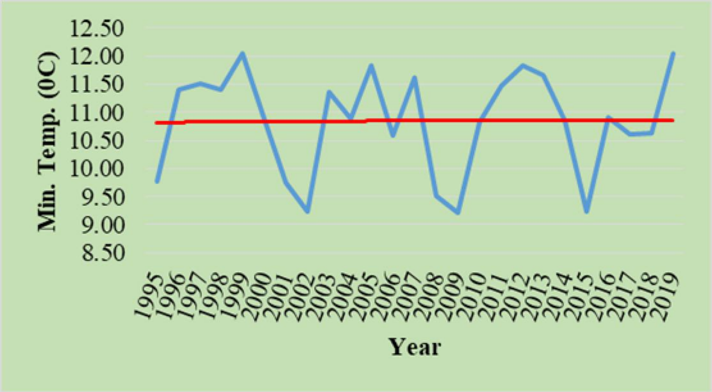

Fig. 4.25: Logarithmic trend of Min. temp for month of Sep.

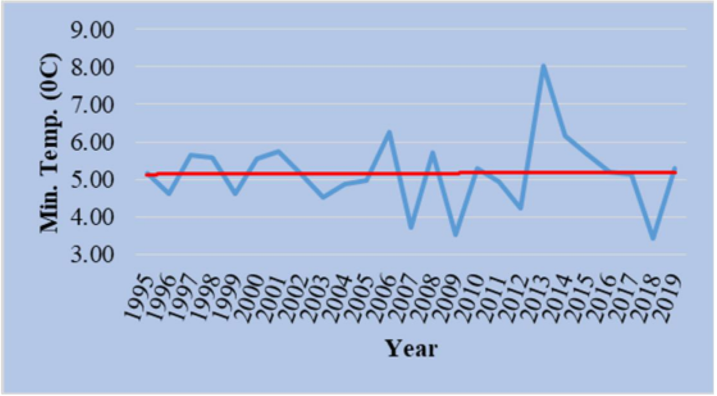

Fig. 4.26: Logarithmic trend of Min. temp for month of Oct.

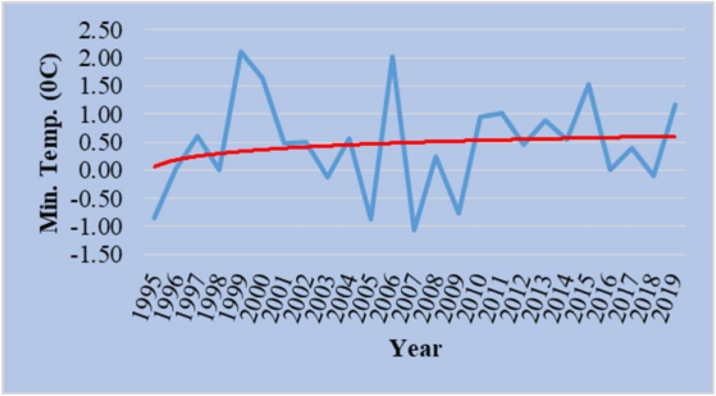

Fig. 4.27: Logarithmic trend of Min. temp for month of Nov.

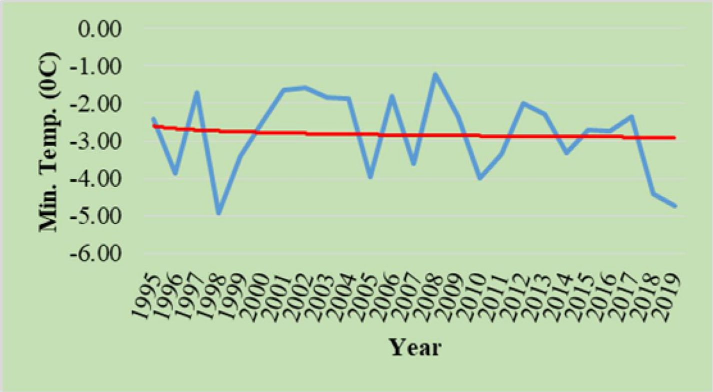

Fig. 4.28: Logarithmic trend of Min. temp for month of Dec.

Rainfall

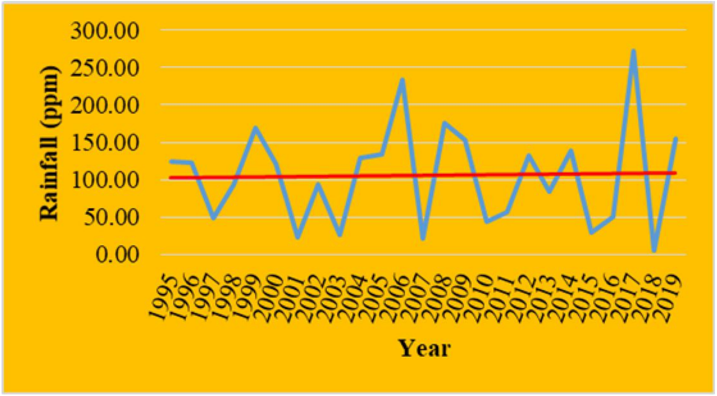

Fig. 4.29: Linear trend of Rainfall for month of Jan.

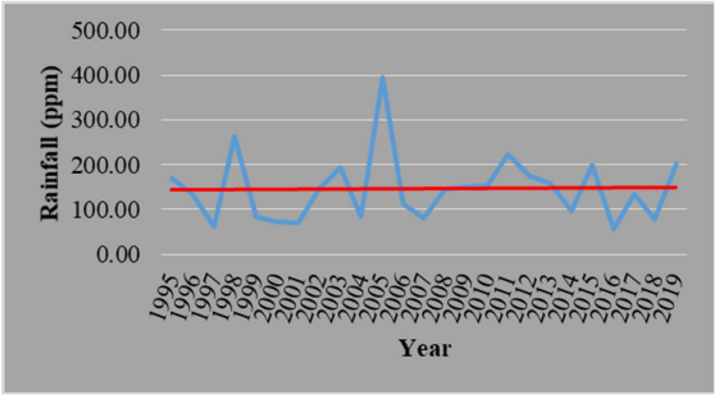

Fig. 4.30: Linear trend of Rainfall for month of Feb.

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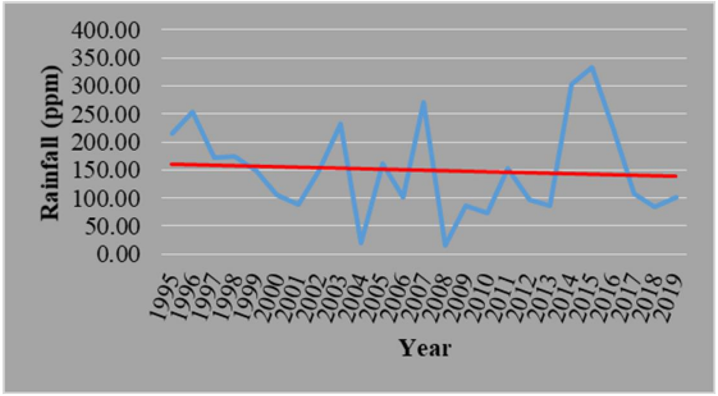

Fig. 4.31: Linear trend of Rainfall for month of Mar.

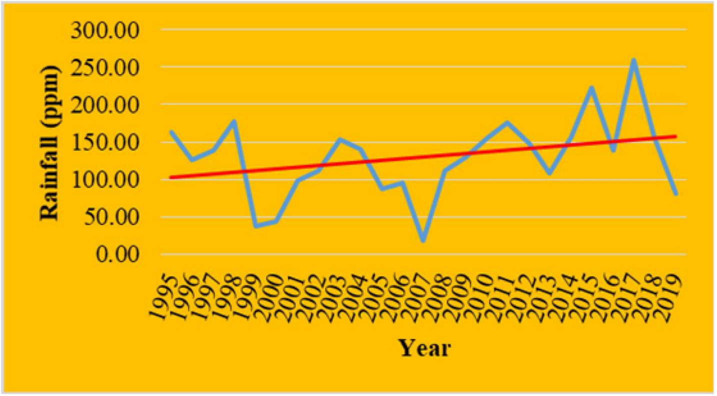

Fig. 4.32: Linear trend of Rainfall for month of Apr.

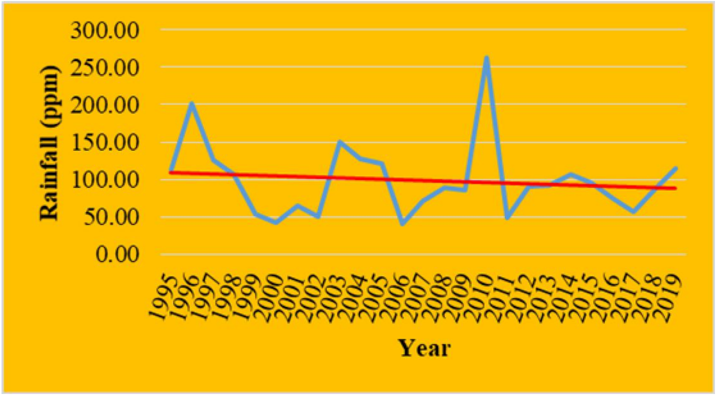

Fig. 4.33: Linear trend of Rainfall for month of May.

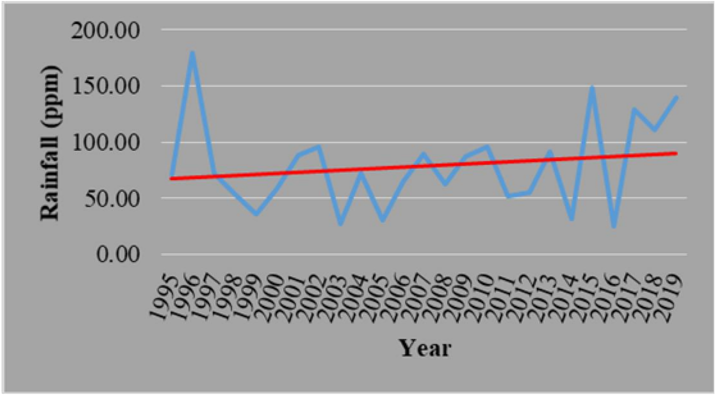

Fig. 4.34: Linear trend of Rainfall for month of Jun.

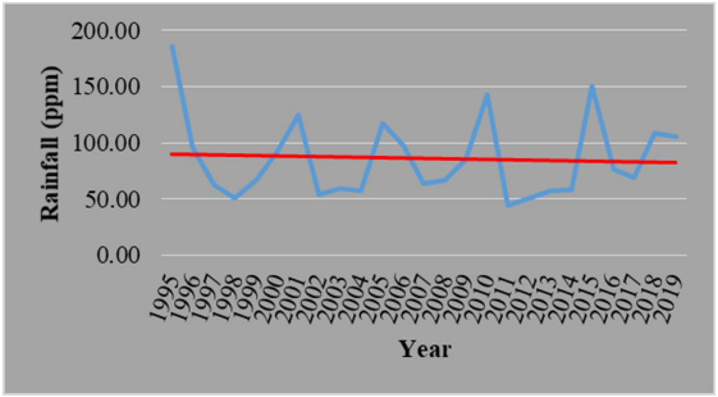

Fig. 4.35: Linear trend of Rainfall for month of Jul.

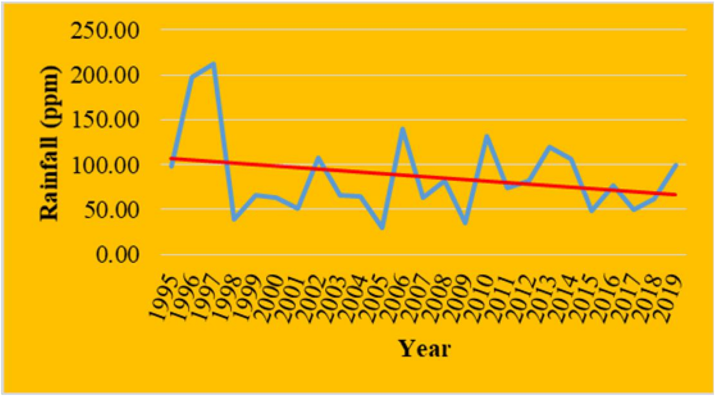

Fig. 4.36: Linear trend of Rainfall for month of Aug.

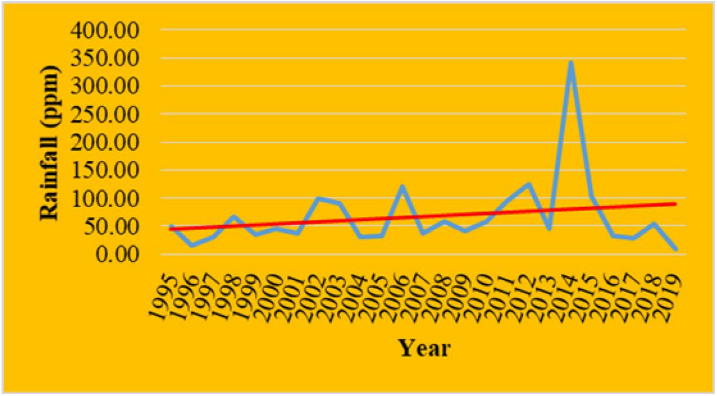

Fig. 4.37: Linear trend of Rainfall for month of Sep.

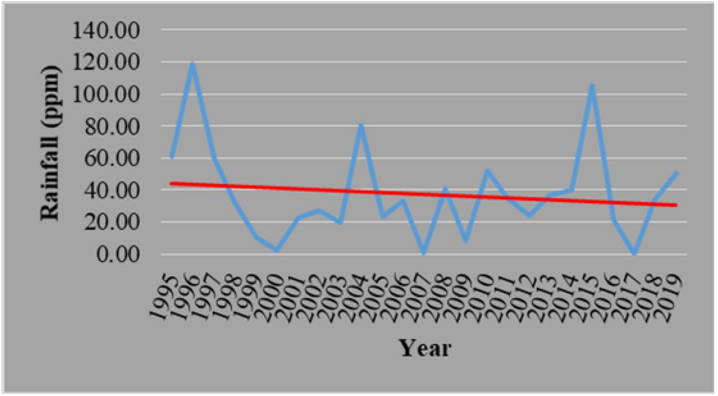

Fig. 4.38: Linear trend of Rainfall for month of Oct.

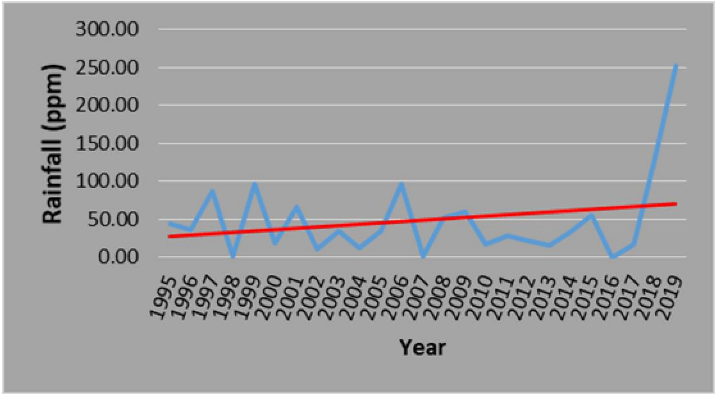

Fig. 4.39: Linear trend of Rainfall for month of Nov.

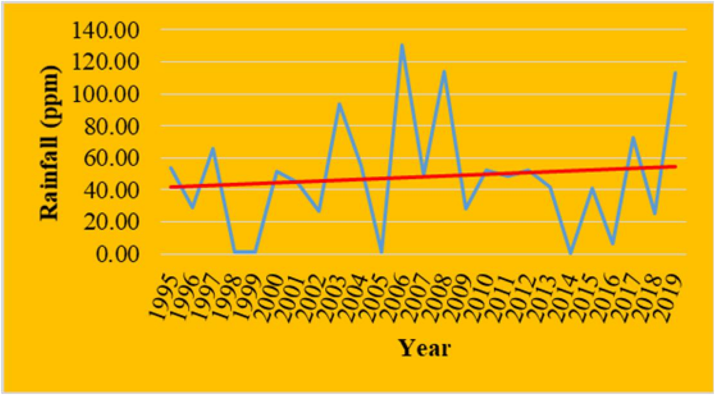

Fig. 4.40: Linear trend of Rainfall for month of Dec,

negative trend for majority of months excepts February, April, September and December months (Table. 4.1.3.2). It was observed that linear regression be best fit model for rainfall trend as compared to logarithmic and exponential model. Linear model has grater R^2 value (Fig. 29 to Fig. 40).

4.1.3.2 Result of Man-Kendal trend test & Sen-Slope estimator

The trend for particular weather parameters was found by Mann-Kenda trend test for monthly data and result are shown in table 4.9, 4.10 and 4.11.

4.1.3.2.1 Mann-Kendall trend test and Sen-Slope estimate of Maximum temperature during the period (1995-2019)

It was found that maximum temperature exhibits insignificant trend for all the month shown in table (4.9). Increasing trend exhibits for all the months except May, June, September October and December which shows decreasing trend with Sen-Slope estimate (-0.012, -0.025, -0.002, -0.003, -0.035) respectively and the month July not show any monotonic trend.

Table 4.9: Mann-Kendall trend test and Sen-Slope estimate of Maximum temperature

Month	Mann-Kendall Test		Sen-Slope Estimate
	Test Z	**Significant**	**S**
Jan.	1.19	NS	0.048
Feb.	1.33	NS	0.038
Mar.	0.72	NS	0.020
Apr.	0.63	NS	0.018
May.	-0.75	NS	-0.012
Jun.	-0.61	NS	-0.025
Jul.	0.00	NS	-0.001
Aug.	1.07	NS	0.018
Sep.	-0.12	NS	-0.002
Oct.	-0.14	NS	-0.003
Nov.	0.37	NS	0.017
Dec.	-1.07	NS	-0.035

4.1.3.2.2 Mann-Kendall trend test and Sen-slope estimate of Minimum temperature during the period (1995-2019)

In minimum temperature it was found that all the months showing insignificant trend (Table 4.10).

Table 4.10: Mann-Kendall trend test and Sen-slope estimate of Minimum temperature

Month	Mann-Kendall Test		Sen-Slope Estimate
	Test Z	Significant	S
Jan.	1.19	NS	0.048
Feb.	1.18	NS	0.039
Mar.	0.72	NS	0.020
Apr.	0.63	NS	0.018
May.	-0.77	NS	-0.012
Jun.	-0.60	NS	-0.023
Jul.	0.00	NS	-0.001
Aug.	1.05	NS	0.018
Sep.	-0.62	NS	-0.002
Oct.	-0.11	NS	-0.003
Nov.	0.39	NS	0.017
Dec.	-1.07	NS	-0.035

It was observed that six month showing monotonic decreasing trend namely May, June, July, September, October and December and rest of the months are showing increasing trend. The high magnitude was recorded for month January, February which is 0.05, 0.4 respectively.

4.1.3.2.2 Mann-Kendall trend test and Sen-Slope estimate of Rainfall during the period (1995-2019)

The result of monthly rainfall revealed the insignificant trend for all the month in table (4.11). It was observed that all the months shows slightly increasing trend except April and June which shows highly increasing trend as compare to others months with magnitude (2.053) (1.339) respectively and the months March, May, August, October and November shows decreasing trend (Fig.61 to Fig.72).

Table 4.11: **Mann-Kendall trend test and Sen-slope estimate of rainfall during the period (1995-2019)**

Month	Mann-Kendall Test		Sen-Slope Estimate
	Test Z	Significant	S
Jan.	0.16	NS	0.329
Feb.	0.77	NS	1.279
Mar.	-0.96	NS	-1.893
Apr.	1.37	NS	2.053
May.	-0.39	NS	-0.616
Jun.	1.00	NS	1.339
Jul.	0.21	NS	0.186
Aug.	-0.49	NS	-0.271
Sep.	0.67	NS	0.756
Oct.	-0.16	NS	-0.123
Nov.	-0.02	NS	-0.070
Dec.	0.09	NS	0.040

4.2 Impact of weather parameters on the productivity of rice crop by path coefficient analyses.

Rice yield was considered as dependent variable and weather parameters (maximum temperature, minimum temperature and rainfall) were regarded as independent variables. Further statistical study conducted using path coefficient analysis to determine the direct and indirect effect of above chosen weather parameters on rice yield. The path analysis outcomes for the data during period of 1995-2019 are shown below.

4.2.1 Correlations matrix between rice yield and weather parameters during period of 1995-2019.

The correlation coefficient was determined for different pairs of variable and described in Table 4.12. The rice yield shows positive significant correlation with minimum temperature (0.614) and showing positive in-significant correlation with maximum temperature (0.271) and rainfall (0.374). The interrelationship demonstrated between these components. This illustrates how significant are these components as factors which assign to rice yield.

Table 4.12: Correlation between weather parameters and rice yield

z	**Rice Yield**	**Max. Temp.**	**Min. Temp.**	**Rainfall**
Rice Yield	1.000			
Max. Temp.	0.271	1.000		
Min. Temp.	0.614**	-0.039	1.000	
Rainfall	0.374	-0.139	0.197	1.000

**Significant at 0.001 level, others insignificant

4.2.2 Path coefficients exhibiting direct and indirect impact of weather parameters on the rice yield during period of 1995-2019

The analysis exhibit that diagonal elements show direct effect and off-diagonal elements shows indirect effect (Table 4.13). It was noticed that the minimum temperature has high positive direct effect (0.566) followed by maximum temperature (0.336) and rainfall (0.309). The combined effects of maximum temperature with minimum temperature and rainfall shows negative effects on rice yield which is (-0.022 and -0.043) respectively, indirect effect of minimum temperature on rice yield due to rainfall contribution was positive (0.061) and rainfall indirect effect on rice yield due to contribution of minimum temperature and maximum temperature was (0.112 and -0.0467) respectively. The diagram representing direct and indirect effect on rice yield has been conferred in fig. 41.

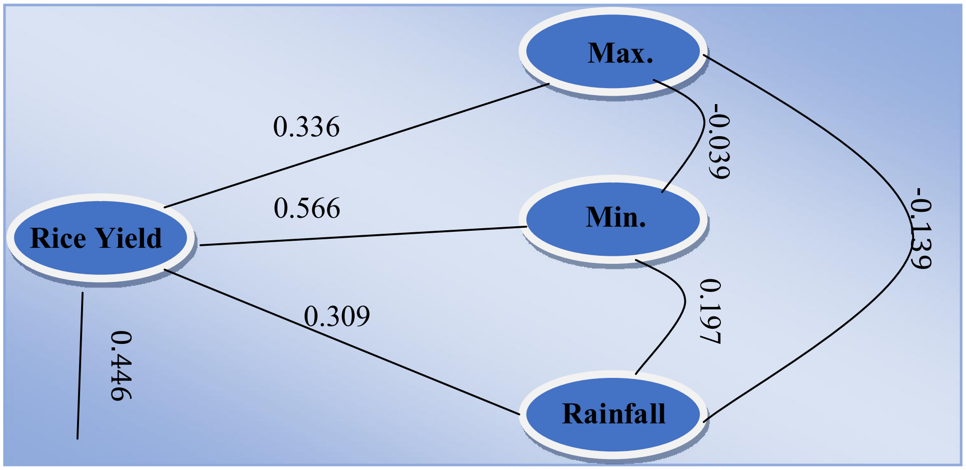

Fig.4.41. Path diagram for rice yield

Table 4.13: Path coefficient analyses of selected weather parameters and rice yield

Parameter	Max. Temp.	Min. Temp.	Rainfall
High. Tem	**0.3360**	-0.0221	-0.0429
Min. Temp.	-0.0131	**0.5660**	0.0609
Rainfall	-0.0467	0.1115	**0.3090**

4.2.3 Direct and indirect contribution of maximum temperature on rice yield during 1995-2019

It was noticed that the direct contribution of maximum temperature on rice yield found to be (0.336) and indirect contribution was found to be negative mixed with minimum temperature (0.022) and due to rainfall effect it was also negative (0.065) as shown in Table 4.14. The contribution of maximum temperature on rice yield was found to be less as compare to minimum temperature and rainfall while, the total contribution of maximum temperature was (0.116).

Table 4.14: Maximum temperature and rice yield

Effects	Parameter	Contribution	
		Positive	Negative
Direct Effect (DE)	Max. Temp.	0.3360	
Indirect Effects (IE)	Min. Temp.		0.0221
	Rainfall		0.0429
Total (IE)		0.3360	0.0650
Total (DE+IE)		0.2710	

4.2.4 Direct and indirect contribution of minimum temperature on rice yield during 1995-2019

The total contribution of minimum temperature was found to be (0.614) which was grater as compare to maximum temperature and rainfall. The direct effect of minimum temperature on rice yield was found to be (0.566) and indirect contribution with rainfall was found to be positive (0.061) and indirect contribution with maximum temperature was negative (0.013) shown in Table

4.15.

Table 4.15: Minimum temperature and rice yield

Effects	Parameter	Contribution	
		Positive	Negative
Direct Effect (DE)	Min. Temp.	0.5660	
Indirect Effects (IE)	Max. Temp.		0.0131
	Rainfall	0.0609	
Total (IE)		0.6269	0.0131
Total (DE+IE)		0.6138	

4.2.5 Direct and indirect contribution of rainfall on rice yield during 1995-2019

The direct effect of rainfall on rice yield was found to be positive 0.309. It was noticed that rainfall shows negative indirect effect combined with maximum temperature and positive combine with minimum temperature on rice yield (0.047 and 0.112) respectively.

Table 4.16: Rainfall and rice yield

Effects	Parameter	Contribution	
		Positive	Negative
Direct Effect (DE)	Rainfall	0.3090	
Indirect Effects (IE)	Max. Temp.		0.0467
	Min. Temp.	0.1115	
Total (IE)		0.4205	0.0467
Total (DE+IE)		0.3738	

Chapter- 5

DISCUSSION

A collection of agro-meteorological parameters derived from climate parameters that are capable of showing the effects of climate change on crop production should be specified in order to assess the risk of climate change in the agricultural sector. One of the most significant limiting factors for agricultural development is the atmosphere. During the growing season, frost risk and low and erratic precipitation with high drought risk during growing period are common issues in agriculture.

Via technical and weather instability, crop yield is substantially more impacted. Technological advances include the influence of enhanced fertilizer applications, better management methods and control of pests, advance seed genetics characteristics and other human-controlled variables intended to increase production. The dependent variable (yield) is affected by seasonal and intra-seasonal fluctuations in weather parameters which are uncontrolled experimental variables.

The findings obtained which were based on the methodologies presented in chapter III, for each of the objective of the study were presented in chapter VI and the same were discussed in this chapter as 'A Study on Climate Change Trend and its Impact on Productivity of Paddy Crop under Temperate Conditions of Kashmir' on under following objectives.

- To study the trend in the weather parameter over the study period.
- Analysis of the impact of weather parameters on the productivity of rice crops.

5.1 To study the trend in the weather parameter over the study period.

Descriptive statistics is valuable statistical instruments used during the study period to explain the variability of weather parameters for the Kashmir valley.

The overall temperature fluctuation over the sample period was observed and it was considered to be optimum in the month of April and extended to October. The deviation coefficient is on the higher hand during the winter. Small change in temperature mean that the high increase in the probability of temperature extremes (Folland *et al*., 1999).

Over a sample period, the maximum temperature and minimum temperature demonstrate more or less equal variation (both have high coefficient of variation in winter season). The minimum temperature was observed to be lower relative to the maximum temperature during the summer season. Similar results for Ludhiana, developed by Prabhjyot *et al*. (2006), with greater variability and uneven temperature distribution over time. It is expected that a rise, even a mild temperature, would result in the frequency of extreme weather conditions including drought, severe flooding and hurricanes.

It was found that the average rainfall was found to be more during January, extended to April, during these months rainfall is more as compare to other months. The variation in rainfall is high for all months, where September and November month showing highest variation. Tiny increase in precipitation indicates a relatively high rise in the probability of rainfall extremes (Waggoner, 1989; Grosiman *et al*., 1999).

5.1.1 Test for normality and Randomness (Run test) of Error terms

Run test was used for testing the randomness of error terms and findings demonstrate that the residuals are randomly distributed for fitted models. Q-Q plot Anderson-Darling test and Shapiro-Wilk test were used for testing the normality of residuals; points lie on straight line of chart and non-significant test statistics of Anderson-Darling and Shapiro-Wilk test revealed that residual were normally distributed.

5.1.2 Trend Analysis

a.) By Parametric method

The maximum temperature has aired an insignificant trend over the study period for all months except July in Linear and Exponential models also January, March and December month in Logarithmic model shows significant trend. All month airs positive trend except June, July and November month which exhibits negative trend in all three models. Beside this, May and October month shows negative trend in Linear and Logarithmic model respectively. It was found that the Logarithmic model was found to be best fit; it had greater R^2 value compared to Exponential and Linear model. The monthly average maximum temperature shows statistically in-significant trend with respect to time for most of the month (Latief Ahmad *et al.*, 2017).

The minimum temperature exhibits insignificant trend during most of the months in all the three models except March month which shows significant increase in logarithmic model and exponential as well as logarithmic model also shows significant trend for January month. Most of the month exhibits positive trend except May, June, July which shows negative trend in all three models and October month also shows negative trend in both logarithmic and exponential model. The minimum temperature in Mandya district shows a non-significant trend over a period of time for all months (Lakshmi, 2014).

It was observed that the rainfall exhibited insignificant trend throughout the study period for all months for all three models (linear, exponential and logarithmic). Exponential model and logarithmic model also shows negative trend for majority of months except February, April, September and December month. Negative trend exhibits for March, May, July, August and October months in linear model. It was observed that linear regression fit best for rainfall trend as compared to logarithmic and exponential model.

b.) By non-parametric method (Mann Kendal trend test)

The maximum temperature had non-significant trend for all the month. It was found that an increasing trend were present for all the months except May, June, September October and December whereas Sen-Slope estimate was found to be negative which indicate decreasing trend. It was noticed that July month not show any monotonic trend. Same result of monthly temperature for Srinagar was developed by Latief Ahmad (2017).

It was found that the minimum temperature showing insignificant trend for all the months. It also shown that six month showing decreasing trend namely May, June, July, September, October and December rest are showing increasing trend. The high magnitude was recorded for month January, February by Sen-Slope estimator.

In rainfall it was seen that there was non-significant trend present for all the month. The majority of months showing slightly increasing trend except March, May, August, October and November shows decreasing trend. Rainfall during summer and winter seasons showed non-significant growing trend (Krishna *et al*., 2009).

5.2 Impact of weather parameters on the rice yield by Path coefficient analysis

5.2.1 The results obtain from correlation analysis

The rice yield positively correlated with minimum temperature, maximum temperature and rainfall. It was observed that minimum temperature shows significant correlation with rice yield where maximum temperature and rainfall have insignificant relationship with rice yield because rice yield in Kashmir mainly dependent on minimum temperature and it is also important to prevent it from pest and disease incidence. The interrelationship demonstrated between these components. This illustrates how significant are these components as factors which assign rice yield. Same result for Kashmir developed by Sheraz (2013).

5.2.2 Path coefficients analysis

The rice yield is more affected by minimum temperature as compare to maximum temperature and rainfall; which was positive direct effect of (0.566). The inter-relation between rice yield and minimum temperature (0.614) was high and positive followed by rainfall and maximum temperature. This shows that rice yield is more depends on mean minimum temperature.

The error value obtained was 0.446. It reveals that 44.6% of variation in rice yield was due to other factors and 55.4% of variation in rice yield was due to three weather parameters.

5.2.3 Direct and indirect effect of weather parameters on rice yield

Minimum temperature

The total contribution of minimum temperature on rice yield was (0.614). The direct contribution of minimum temperature on rice yield was found to be positive (0.566) and indirect contribution mixed with rainfall was found to be positive (0.061) and negative with maximum temperature (0.013). The total contribution of minimum temperature on rice yield is greater followed by rainfall and maximum temperature.

Maximum temperature

It was noticed that the direct contribution of maximum temperature on rice yield found to be (0.336) and indirect contribution was found to be negative due to combined effect of minimum temperature and rainfall (0.022, 0.065) respectively. The total contribution of maximum temperature was (0.116). The contribution of maximum temperature on rice yield was found to be less as compare to minimum temperature and rainfall.

Rainfall

The rainfall had a positive direct effect of 0.309 and indirect effect was found to be negative 0.047 and positive 0.112. The total contribution of rainfall on rice yield 0.371 which was grater then maximum temperature.

Chapter- 6

SUMMARY AND CONCLUSION

Agriculture is a particular phenomenon whose production is primarily dependent on environmental factors. Climate change and agricultural activities are interrelated phenomenon, all of which take place on a global basis relative to various other sectors of the economy. To a great extent, the degree of success of agricultural production and its economy is dictated by how effectively the environmental conditions corresponding to the optimum requirements of the crop are better utilized in order to grow the crops. In addition, how effectively extreme weather conditions that cause thermal, moisture, radiation, biotic stress and wind that hinder crop growth and production are controlled to mitigate their adversity.

As such, the effect of climate change on agriculture must be analyzed and recognized both internationally and at the regional level. There is a lot of study and analysis going on to measure the real effect of climate change in each and every region. The first step is to proceed to the regional level to mark the global level scenario. In this regard the current research objective is to study the pattern of weather parameters and their effect on the rice yield in Kashmir valley (temperate zone). The present study offers sufficient information on climate change and its effect on crop production in the Kashmir.

The weather parameter data sets were used to define climate change and its effects on rice yield. The secondary of weather parameter for the analysis was collected from the Division of Agronomy, SKUAST-K, Wadoora for the period from 1995 to 2019. The weather parameters take into account *viz*., maximum temperature, minimum temperature, rainfall and rice yield. In order to analyze the trend and effect of weather parameters on rice yield, various statistical techniques such as descriptive statistics, trend analysis, correlation analysis, path coefficient analysis were applied to the data sets.

Silent feature of study:

Variability in climatic factors at Kashmir

The more variability was noticed in rainfall whereas less variability was found in minimum temperature and maximum temperature and rainfall were found to be more or less uniform during the study period of 25 years.

Trend analysis

By Parametric Method

The trend analysis was performed over a study period to define the trend pattern in the weather parameters. The findings found that the maximum temperature showing a positive non-significant trend for majority of months over a time period and logarithmic model was found to be best fit trend for maximum temperature whereas, the minimum temperature exhibit a insignificant positive trend for most of the month except May, June, July and October and logarithmic was found to be best fit trend for minimum temperature. Rainfall exhibit irregular non-significant trend for all months during the study period and linear model was found to be best fit trend for rainfall.

By Non-parametric method

Mann-Kendall trend test was used to analyze the trend pattern in weather parameters over a time period. The results indicate that the monthly maximum temperature, minimum temperature and rainfall showing non-significant trend with respect to time for all months. It was found that the maximum temperature exhibit growing trend for majority of month whereas, in minimum temperature six month showing increasing trend and another six month showing decreasing trend. In rainfall it was found that slightly growing trend for majority of months where the magnitude of April month trend is grater as compare to other month.

Inter relationship between rice yield and weather parameters

To know the strength of relationship between rice yield and weather parameters, the correlation analysis was done. The positive correlation was found between rice yield and all three weather parameters namely; maximum temperature, minimum temperature and rainfall whereas, minimum temperature shown significantly high correlation with rice yield followed by rainfall and maximum temperature.

Path analysis to know the Direct and Indirect Effect of Weather Parameters on Rice

Direct effect

It was found that all three weather parameter had positive direct effect on rice yield whereas, minimum temperature had high direct effect followed by maximum temperature and rainfall. It indicates that rice yield is more depends on minimum temperature in Kashmir. The error value obtained was 0.446; which indicates that 55% variation in rice yield was due to these three weather parameters and 45% variation was accounted by unknown factors.

Indirect effect

Both weather parameter (minimum temperature and rainfall) had negative indirect effect via maximum temperature. Rainfall had positive indirect effect and maximum temperature had negative indirect effect via minimum temperature whereas, maximum temperature showing negative and minimum temperature showing positive effect via rainfall.

Total contribution (indirect + direct)

All three weather parameters had positive effect whereas; minimum temperature had high contribution followed by rainfall and maximum temperature on the rice yield in Kashmir.

CONCLUSION:

The variability for the Kashmir Valley showed in-significant variation for all the three weather parameters. Both parametric and non-parametric test for the selected weather parameters during the period under study showed same results. According to these tests there was not time dependent trend for selected weather parameters; in-significant trend for all weather parameters for majority of months.

The present study indicates minimum temperature showed large impact on rice yield as compare to maximum temperature and rainfall. It indicates that lower the temperature leads to increase in rice yield in Kashmir valley.

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CERTIFICATE

Certified that all the corrections/amendments as suggested by External Examiner Dr. Hukum Chandra during Viva-Voce examination held on 03-04-2021 have been incorporated in the manuscript entitled **"A Study on Climate Change Trend and its Impact on Productivity of Paddy Crop under Temperate Conditions of Kashmir"** submitted by **Mr. Rohit Godara (Regd. No. MSSt-2018-22).**

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