STATISTICAL MODELING FOR THE IMPACT OF WEATHER AND SOIL PARAMETERS ON THE YIELD OF PADDY UNDER LONG TERM FERTILIZER EXPERIMENT

by

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(2017-19-003)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Statistical modeling for the impact of weather and soil parameters on the yield of paddy under Long Term Fertilizer Experiment"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any University or Society.

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Certified that this thesis entitled **"Statistical modeling for the impact of weather and soil parameters on the yield of paddy under Long Term Fertilizer Experiment"** is a record of research work done independently by Ms. Dhanya G. (2017-19-003) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

ANOVA	Analysis of Variance
CD	Critical Difference
CV	Coefficient of variation
ha	Hectare
LTFE	Long Term Fertilizer Experiment
IFSRS	Integrated Farming System Research Station
var	Variety
RBD	Randomized Block Design
MANOVA	Multivariate Analysis of Variance
ARIMA	Auto Regressive Integrated Moving Average
ACF	Autocorrelation
PACF	Partial Autocorrelation
AIC	Akaike Information Criteria
BIC	Bayesian Information Criteria
ARCH	Autoregressive Conditional Heteroscedasticity
GARCH	Generalized ARCH
Std	Standard
mm	Millimetre
et al.,	Co-workers
ADF	Augmented Dickey – Fuller
RDF	Recommended dose of fertilizers
SE	Standard Error
MST	Mean Sum of Treatments
MSE	Mean Sum of Error
MaxTem	Maximum Temperature
MinTem	Minimum Temperature
OC	Organic carbon

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N	Nitrogen
P	Phosphorus
K	Potassium
Ave	Average
kg	Kilogram
m	Meter
viz	Namely

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Introduction

1. INTRODUCTION

India is an agrarian country; agriculture is the most important sector of Indian economy. Agriculture sector contributes 18 per cent to the gross domestic product (GDP) and 50 per cent employment of country workforce is engaged in agriculture. India is the world's largest producer of pulses, rice, wheat and spices. There comes the importance of agricultural field experiments for new innovations.

Rice (*Oryza sativa* L.) is an important cereal crop belonging to *Poaceae* family. Rice is the basic food crop and being a tropical plant, it grows easily in hot and humid climate. It is mainly grown in rain fed areas that require heavy annual rainfall. That is why it is basically a kharif crop in India. Rice production in India reached 112.91 million metric tons with an area of 431.94 lakh hectare in 2017-19. However, the production in Kerala was about 5.21 lakh tonnes from a cultivated area of 1.94 lakh hectares, shows a decline of 11.7 per cent as compared to 2008-09 levels (GOI, 2018). A number of factors are responsible for the production of Paddy in Kerala among which increase in cost of cultivation, reduction in rice cultivable area, unexpected climatic change, pest and disease attack and variation in soil properties are the major factors responsible for this decline.

The critical mean temperature during flowering and maturing is important for paddy cultivation. A critical temperature of 16^0C to 20^0C during flowering and 18^0C to 32^0C during maturing may be considered as ideal condition for better yield. Temperature above 35^0C affects grain filling. Low temperature in the range of 15°C to 19°C during the propagative stage harms microspore growth and causes the sterile pollen grains formation that results in poor grain filling and high spikelet sterility which in turn reduce spikelet fertility and it may affect grain quality. Paddy grows well in different soil types. For normal growth, a pH range of 5.0-8.0 is suitable. In general, 18 different nutrients are necessary for normal growth and full development of rice which includes micro and macro nutrients achieved from air and soil. Each element plays its own role in plant growth that cannot be replaced by other. 90: 45: 45 kg NPK/ha is the recommended dose of fertilizer for rice.

Recently there has been drastic change in weather variables all over the world and it adversely affects the crop output. Various statistical models can be used to predict the pattern of change in weather factors overtime. For example annual global temperature has increased by 0.4^0 C since 1980, with larger changes observed in several regions. Many studies have considered the impact of further climate change on food production, the effect of their past changes on agriculture remain unclear. The weather factors also influence the crop growth at various stages

A series of experiments has to be carried out for releasing of a new variety of a crop. Similar is the case for fertilizer, pest or disease management practice, only after several field trials, effective management practice is to be found out. Long-term field experiments are those experiments that test a series of treatments over a period of time and are proposed to assess the sustainability of crop production, and thereby food security. These experiments are managed keenly to identify any treatment that is failing to retain or increase yields. These experiments allow the field resource and samples for study on plant and soil processes and properties, especially those properties where change occurs slowly and affects soil fertility. The observations recorded or generated from these types of experiments always are a time series data.

Time series analysis is a statistical technique that deals with a sequence of numerical data points in successive chronological order and there are a number of methods to study features of the data. The data or observations made out from a long term experiment are there by time series and thus time series modeling can be carried out.

Different parametric methods are used in case of long term experiment analysis. Ordinary analysis of variance (ANOVA), multivariate analysis of variance, pooled analysis, split plot analysis and serial correlation are some of the various parametric methods. In long term experiments year or season can be considered as factors and treatments are taken as second factor to get precise output. Thus, various statistical models can be used to predict the pattern of change in weather parameters over time. In order to study the behavior of maximum temperature, minimum temperature and total rainfall we have to use some statistical models which are specific to time series. Moreover, for predicting the potential effects of weather change and soil nutrients on the crop yield requires a model to understand how crop respond to weather changes. This type of analyses need time series data on weather parameters, soil nutrients and yield from different locations or single location.

1.1 OBJECTIVE OF THE STUDY

The study was based on secondary data collected from a long tern fertilizer trial carried out in Integrated Farming System Research Station (IFSRS), Karamana on rice (variety Aiswarya) for a period from 1985-86 to 2013-14. The field experiment was conducted in a randomized block design with 12 treatments comprising different fertiliser doses (NPK) and four replications during kharif and rabi season. The objectives of the study are:

To develop suitable statistical models to analyse the change in weather variable over time, changes in soil parameters across treatments in Long Term Fertilizer Experiment (LTFE) over the years and to analyse the impact of weather and soil parameters on the yield of paddy across different treatment.

The main items of observation included in the analysis are

1. Data on rainfall, maximum temperature and minimum temperature
2. Soil nutrient status of OC, P, K at the end of kharif and rabi
3. Yield -straw yield and grain yield

1.2 NATURE AND SCOPE OF THE STUDY

Analysis on maximum temperature, minimum temperature and rainfall over a long period provides an idea about their changing pattern. Further this study aims to explore various time series methods to model climate change. Moreover, analysis on soil organic carbon, soil phosphorus and soil potassium after experiments in each season over a period highlight the trends in fertility status of the soil in LTFE. Further, the effect of soil parameters and climatic variables on the yield delineates the importance of these variables on crop productivity.

1.3 FUTURE STUDY

The study has been done as a part of M.Sc. Programme, need more time to proceed with further analysis. The study was conducted in rice, similar study can be carried out in other crops to find out which model fit the best and the impact of weather and soil parameters on their yield.

1.4 ORGANISATION OF THE STUDY

For the proper analysis and clear explanation of the results of the study, the thesis has been arranged in five chapters where introduction is the first chapter which highlights importance, scope, objectives and limitation of the study. The second chapter includes review of the findings related to the study. The materials and methods that are adopted for the study are described third chapter. The results and discussions are explained in fourth chapter followed by summary in fifth chapter.

Review of Literature

2. REVIEW OF LITERATURE

The findings of previous research works pave the way to understand the methodologies that may adopted for the present study. This chapter includes the critical reviews of literature related to the current study. The research works done by many research workers related to different statistical procedures and its practical applications has been critically reviewed under the subheadings given below.

2.1 Modeling of weather parameters

2.1.1 Modeling of temperature

2.1.2 Modeling of rainfall

2.2 Study on Long term Fertilizer Experiment

2.3 Modelling of soil parameters

2.4 Impact of weather and soil parameters on yield

2.1 MODELING OF WEATHER PARAMETERS

2.1.1 Modelling of temperature

Linear autoregressive integrated moving average (ARIMA) model is used in the study by Mishra and Desai (2005) on drought forecasting in West Bengal, India. The study showed that in most time series, there is a serial correlation among observations which is effectively considered by ARIMA model and also provides systematic identification, estimation and diagnostic check for a suitable model. ARIMA (1,0,0)(2,1,1) was found as the best fit model the best fit model and the model developed can help in forecasting drought and drought preparedness plan can be made effective.

In the study by Lobell and Burke (2010) CERES-Maize model was first used to stimulate maize yield variability at 200 sites in Sub Sharan Africa. Statistical models of three types (time series, panel and cross sectional models) were then trained on the simulated historical variability and then used to predict the responses to the future climatic change. Results of the study suggests that statistical models used were a useful tool in projecting the future yield responses. Moreover statistical models continue to play an important role in forecasting impact of climatic change. Time-series models were better suited for predicting response to precipitation than temperature, whereas panel or cross-section models are better suited for temperature.

The five staple crops were used in the study conducted in Sub-Saharan Africa (SSA) by Schlenker and Lobell (2010) were maize, sorghum, millet, groundnuts and cassava. Depending on the crop, different models result in the highest R-square, with nearly all showing significant improvement beyond a model with no weather but for cassava the weather variables do not add much, as it is a root crop with a highly variable growing season and it is hence empirically difficult to match weather data during the growing season to a particular yield.

Shahid (2011) FAO-56 model and GIS model has been carried out to estimate the change of irrigation water demand in dry season in Boro rice field of northwest Bangladesh in the context of global climate change. Climate change modeling software SCENGEN is used to forecast change in rainfall and temperature. The study suggested that there was no significant changes in total irrigation water requirement due to climate change.

Muhammet (2012) used the ARIMA method to predict the temperature and rainfall in Afyonkarahisar Province, Turkey, until the year 2025, and found that there is an increase in trend in temperature according to the quadratic and linear trend models.

ARIMA model (1,0,0) (0,1,1) was found to be the best fit for time series monthly rainfall data for the years 1901–2002 (102 years) of the Mahanadi River Basin of India. Forecasting mean rainfall over the Mahanadi river basin was also done for 12 years which help farmers scheduling field operations accordingly. (Janhabi and Ramakar, 2013).

Khedhiri (2014) studied the statistical properties of time series temperature data in Canada for the period 1913-2013 and determined a seasonal ARIMA model for the series to predict future temperature records as ARIMA modelling is found to be good fit for time series air temperature studies.

To study and forecast the annual temperature at Shiraz Balyani *et al.* (2014) collected data from 1955-2005.ARIMA model was used for fitting of data and found ARIMA (1, 1, 3) as the optimal model for the annual temperature. Temperature forecast was also made using this model and the model predicted a 0.20°C increase in annual temperature in Shiraz.

A study was conducted to analyse the effect of weather variables viz, rainfall, wind velocity and sunshine hours on paddy yield by Pandey *et al.* (2015) in districts of Faizabad, Uttar Pradesh. The multiple regression analysis results of this study suggested that the joint effect of weather variables had played an important role on paddy yield, more important combination is rainfall and wind velocity with 82% followed by rainfall and sunshine hr and wind velocity and sun shine hr 63% and 53.8, respectively.

Annual surface absolute temperature of Libya was studied by El-Mallah *et al.* (2016). Data was collected from 16 stations and was fitted with ARIMA model, ARIMA (3, 1, 2) and ARIMA (3, 2, 3) were found as the best fit model.

Forecasting of monthly temperature based on ARIMA model was done by Goswami *et al* (2017) for long term temperature data of Dibrugarh, Assam. SARIMA(2,1,1)(0,1,1) and SARIMA(2,1,1)(0,1,1) were found as best suited Seasonal ARIMA model for Maximum temperature and minimum temperature respectively.

Study done by Murat *et al.* (2018) on forecasting meteorological time series data, it was found that ARIMA models is best fit for air temperature studies. SARIMA models were found as not answering when time series data for many years is considered. ARIMAF (3,0,1) [K=1], ARIMAF (3,0,2) [K=7], ARIMAF (3,0,3) [K=3] and ARIMAF (2,0,2) [K=4] models for air temperature and ARIMAF (0,0,3) [K=7] and ARIMAF(3,0,1) [K=2] models for precipitation.

Study by Unnikrishnan *et al.* (2018) on forecasting weather parameters showed that ARIMA (011) (011) is the most commonly fitted ARIMA model for seasonal parameters.

Wang *et al.* (2018) studied the effect of climatic changes on the yield of different cereal crops in the world. Regression analysis was carried out and the results showed that climate variation, specially the increase in temperature resulted in yield reduction of major cereal crops. Breeding and irrigation techniques were suggested as solutions to overcome these problems encountered by global warming.

2.1.2 Modelling of rainfall

A binary discrete autoregressive moving average (DARMA) model was used by Chang et al. (1984) for modelling the sequences of wet and dry days which are obtained from daily precipitation data of Indiana. DARMA (1, 1) was found as best fit.

ARIMA (1, 1, 1) model was found as best suitable model for forecasting annual rainfall in all regions of Thailand with adequate precision, which are able to fulfill the requirement for agricultural water allocation planning. (Weesakul and Lowanichchai, 2005).

Naill and Momani (2009) studied on modelling on time series monthly rainfall data collected from Amman airport station for the period from 1922-1999 in Saudi Arabia. ARIMA (1, 0, 0) (0, 1, 1) was found as the best fit model and also forecasted rainfall for 10 years, which help farmers in schedule farm practices accordingly.

A comparison of MLR and ARIMA models were done by Magar and Jothiprakash (2011) using time-series rainfall data collected from the Koyna dam in Maharashtra for predicting the inflow. The study concluded that similar results were given by MLR and ARIMA models for sufficiently longer rainfall data.

Yusof and Kane (2012) studied Volatility modelling for rainfall time series data from Peninsular Malaysia and found GARCH (1,1) model is the best fit for studying volatility in rainfall data.

Modarres and Ouarda (2016) studied the relationship between climate oscillation and drought in Iran for a period of 1954-2000. GARCH modelling was used for the study. GARCH modelling improves the understanding between two time series. The study also showed GARCH approach is best to examine the effect of the time-varying variance of different variables such as rainfall, streamflow, temperature, wind speed, and evaporation on each other.

The Mann-Kendall test was used for trend analysis in the study of rainfall and drought characteristics in Kerala by Thomas and Prasannakumar (2016). The result of the test showed that annual and south-west monsoon followed a weak and insignificant negative trend whereas post monsoon, pre monsoon and winter monsoon showed an increasing trend.

2.2 STUDY ON LONG TERM EXPERIMENTAL TRIALS

Split plot design was chosen in the study by Bellido *et al.* (1996) to determine the effects of tillage, crop rotation nitrogen fertilizer on wheat yield in a rainfed Mediterranean region. Differences in rainfall during the growing season had a marked effect on wheat yield. Amount of rainfall during the vegetative period for wheat was highly correlated with yield because of the high water-retention capacity of Vertisols. In dry years, wheat yield was greater under no tillage than under conventional tillage; the opposite was true in wet years.

The long term effects of rice straw management practices in a wheat-rice rotation in six straw management practices was studied by Verma and Bhagat (1992) from 1984 to 1989. None of the straw management practices had residual effects on the yields and N uptake during the first rice crop whereas the wheat yield and N uptake did not vary significantly under control throughout the experimental period.

Long term experimental trial was conducted on paddy yield trends and changes in soil organic carbon and available NPK in rice – wheat system by Yadav *et al.* (2000) in Ludhiana and Pantnagar. A declining yield trend was observed in all treatments except the one with manure + fertilizer combination, the high significance in annual yield of rice with integrated supply of nutrients through fertilizers and manures on doing the regression analysis states the same.

Zhong and Cai (2002) studied the Long-term effects of inorganic fertilizers on microbial biomass and community functional diversity in a paddy soil derived from Red Soil Ecological Experimental Station of the Chinese Academy of Sciences.

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Studies shows that phosphorus helps in improving growth of rice crops and soil organic carbon can be increased through root turn over. Most microbial parameters were mainly correlated with soil organic carbon content rather than P and N, indicating that the application of P and N did not directly affect microbial parameters in the soil.

Crop rotation long term experiments on rice-wheat-jute, soybean-wheat and sorghum-wheat were carried out by Manna *et al* (2005) in Barrakpure, Ranchi and Akola respectively, least-squares linear regression analysis was done to determine yield trends over the years to test that yield trends during the research period, and the result showed that yield trend is negatively significant in all rice based system.

Seven treatments of various combination of fertilizers in rice –wheat rotation was studied from 1988-2000 by Singh *et al.* (2014) in South Asia. Split plot design with year in main plot and treatments in subplot was followed for the study. Rice yield was found to be decreased by 0.02 to 0.13Mg ha^{-1} yr^{-1} and wheat yield was found to be remained unchanged. Climatic parameter variation and deficiency of soil potassium are assumed to be the reasons for the yield reduction.

2.3 MODELLING OF SOIL PARAMETERS

Hitzl *et al.* (1997) studied on 31 treatments with 3 replication of soils- compost, mixture and pasture. MANOVA was conducted to test the differences between mean vectors among three groups and the result of the analysis showed that there was no significant difference between soil types.

Seven long term experiments were conducted on nine organic soil models using twelve datasets by Smith *et al.* (1997) in USA. RothC, CANDY, DNDC, CENTURY, DAISY and NCSOIL were one group of models and SOMM, ITE and Verberne were the other group of models used for comparision. Comparison of models showed that the model errors of one group of model did not differ significantly from each other.

Rahman (2002) in Bangladesh studied the impact of selected soil fertility parameters on modern rice productivity from survey data of 21 villages in three agroecological regions. A multistage sampling procedure was adopted to select the sample farmers for survey. The general form of Cobb-Douglas stochastic production frontier function was used in the analysis. The soil fertility status in each region was determined by analysis of soil organic carbon, available nitrogen, phosphorus and potassium concentration. Soil fertility significantly affects the parameters of the production function, soil potassium and soil nitrogen significantly increase rice productivity whereas available soil phosphorus has an opposite effect. The soil organic carbon content also has a desirable positive effect but the influence is not significant.

The study by Meena *et al.* (2003) was on influence of nitrogen and phosphorus on the production and economy of hybrid rice, carried out in split-plot design in New Delhi. The result of the split plot experiment with two levels of nitrogen in main plot and two levels of potassium in sub plot suggests that application of 200 $kgha^{-1}$ nitrogen and 65 $kg\ ha^{-1}$ potassium improve the plant characters, productivity and highest benefit cost ratio.

MANOVA was carried out in order to test whether 8 treatments for the conservation of nitrogen content in soils of Bhubaneswar differ significantly by Prasad and Bhar (2005). Results of the analysis showed that 8 treatments differed significantly with a Wilks lambda value of 0.11.

Long-term fertilizer experiments conducted over 30 years by Sharma and Swarup (2005) in different agro- ecological regions involving diversified cropping systems and soil types showed significant responses of crops to K applications. Application of K enhanced its available status in soils and uptake by the crops. The results suggest that in years ahead K will be the most limiting factor affecting sustainability of intensive cropping systems in India.

Clustering of villages based on soil parameters in Panchamahal district of Gujarat was done by Khokhar (2008). ANOVA and MANOVA were used to test the significance of variation in each of the five soil parameters. Three clusters in Godhra, four in Kaalol and Lunawa, six in in Khanpur and Santrampur, seven in Halol, Morava and Kadana talukes and nine in Jambghoda taluks were identified from the study.

French *et al.* (2011) concluded that significant multivariate test should be followed by univariate F test for each variable to interpret the effect of each variable. MANOVA was recommended to avoid the error that may produce due to multiple ANOVAs. MANOVA was also said to be sensitive to outliers.

Meirong *et al.* (2011) considered the impact of long-term fertilization on organic C, nutrients, microbial biomass of soil, and grain yield of paddy in subtropical conditions after 18 years of inorganic and organic fertilizer application to an infertile field under their study. Which shows that organic manure application combined with P fertilizer was needed to make sure sustainable and high productivity. The all soil chemical properties except available K content was significantly correlated with yield, and stepwise regression analysis showed that soil available P content was the limiting factor to rice yield.

Effect of different levels of phosphorus on the growth and yield of wheat was studied in Tandojam, Pakistan. One way ANOVA and multiple regression analysis were carried out where phosphorus levels and placement exhibited significant differences to the maturity days, plant height, tiller production, spike length, grains per spike, seed index, harvest index and grain yield ha^{-1}. (Noonari, 2015)

Multivariate analysis for the classification of locations using soil parameters in central districts of Kerala was studied by Muhsina (2018). Ernakulam and Kottayam districts of Kerala were the locations under study, 13 soil fertility parameters were studied using statistical methods like descriptive statistics, MANOVA, PCA, factor analysis and cluster analysis. SPSS and STATA were also used.

2.4 IMPACT OF WEATHER AND SOIL PARAMETERS ON YIELD

The influence of rainfall on the paddy production was studied by Yoshino and Suppiah (1984) for each Districts of Sri Lanka during the period from 1961 to 1980. Regression analysis was carried out and the result showed that there was a significant positive relationship in the dry zone in the second inter-monsoon and northeast monsoon seasons and wet zone have in the southwest monsoon season as their

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principal cropping seasons. Increase in the rain fall didn't increase the paddy production, which implies a negative relationship of paddy production and rainfall.

A salt-sensitive (IR28) and salt-tolerant (Pokkali) variety of rice were chosen by Bohra, and Doerffling (1993) to study the effect of K (0, 25, 50 and 75 mg kg^{-1} K soil) application on their salt tolerance in Institute of General Botany, Hamburg, Germany. The reults of the study showed that Potassium application significantly increased potential photosynthetic activity (Rfd value), percentage of filled spikelets, yield and K concentration in straw.

The CERES-Rice v3 crop simulation model was used for analysing the effect of climate change on rice productivity in Kerala by Saseendran *et al.* (2000). When temperature elevations were taken into consideration, the crop simulations show a decrease of 8 percent in crop maturity period and 6 percent in yield. The temperature sensitivity experiments have shown that for a positive change in temperature up to 5°C, there was a continuous decline in the yield and for every one degree increase the failure in yield is about 6 percent.

Thirty three rice-wheat long term experiment trials in Indo-Gangetic plains of South Asia, non Indo-Gangetic plains of India and China was analysed by Ladha *et al.* (2002) to examine the yield is increasing or decreasing and the probable cause for the same. Linear regression analysis was carried out and the result of the long term experiments shows that there was a decreasing trend in the yield of paddy and wheat, rice yield was declining faster than wheat, decreasing trend in the yield of paddy and wheat depletion of soil potassium seems to be the general cause for this trend.

Long-term soil fertility experiment was carried out by Regmi *et al.* (2002) from1988–1999 at the Regional Agricultural Research Station, Bhairhawa, Nepal to govern how long the yields of rice and wheat can be sustained without potassium (K). Result of regression analysis was both rice and wheat responded to K application but the response of wheat was considerably more, the estimated K balance in soil was highly negative. Reduction of soil K and insufficient K fertilization appears the primary reasons of dropping yield of rice and wheat crop. The study revealed that the existing local fertilizer recommendations, particularly for K, for the rice–rice–wheat system are inadequate. The study also suggested farmers to apply required amount of potassium for higher and sustainable yield.

A study by Alam *et al.* (2006) used descriptive statistics, ordinal regression, and percentile analysis to measure the level of farmers adaptability to climate change as a result of the various existing supports and encouragements provided by the government and other external agencies in Malaysia. The study found that projections of climatic change and its adverse effects on paddy productivity and socioeconomic status of the farmers was disappointing. Study emphasis the need of introducing an adaptation strategy for agriculture and livelihood sustainability in the long run. Moreover to improve the adaptability of the farmers, government and other agencies have to increase the subsidy as well as other supporting measures.

In the paper by Yao *et al.* (2006) eight typical rice stations ranging in latitude, longitude, and elevation that are located in the main rice ecological zones of China are selected for climatic impact assessment. Regional Climate Model (RCM) and Crop Estimation through Resource and Environment Synthesis (CERES)-rice model was the model used for the study and the result was high frequency at low yield and high variances of rice yield made a threat to rice yield at most selected stations in the main rice areas of China.

Variety Naseer 2000 and variety IRRI-6 were used in the study conducted to study the response of wheat and rice to phosphorus respectively by Khan *et al.* (2007) in Punjab. The experiment was carried out in RCB design with three replications. The result of regression analysis showed that Phosphorus application significantly increased the grain yield of wheat and rice, an increase of 22% in wheat and 75% in rice was observed.

A study was conducted to analyse the effect of average climate during the period 1971–2000 to predict the possible effects of the future climate (2081–2100) on agricultural practices in Japan by Ohta and Kimura (2007). Climate projections of the global coupled atmosphere-ocean general circulation model(version 2) (CGCM2) by the Meteorological Research Institute (MRI) was the model used for analysis and the result from the simulations is that the water temperature during the growing season for the future climate increased by approximately 1.6–2.0 °C throughout the country. The agricultural practices and rice cultivars used in these areas had to be altered to prevent the projected heat stress during summer.

A study was conducted to analyses the effect of climate change on wet paddy production in Srilanka by Silva, *et al.* (2007).The results of the analysis has shown that change in climate affect wet paddy production inversely. Reduced rainfall and increased evapotranspiration suggest that earlier planting of short duration varieties rather than on January-February.

Aydinalp and Cresser (2008) studied possible physical effects of climatic change on agriculture. The results of the study emphasis that regional increase and decrease associated with climate change was not expected to result in large changes of food production over the next century.

The role of phosphorus in rice yield was studied by Hossain (2008) along with the role of arsenate and Fe^{2+} on amount and composition of Fe-oxide plaque at the rice-root surface and on the yield and arsenic accumulation in rice in a replicated pot-culture experiment. Principle of F statistics, and the mean values were compared using Duncan's Multiple Range Test in the study and found that higher phosphate application increased the concentration of phosphate in both grain and straw.

Tao *et al.* (2008) studied trends in seasonal climate (maximum and minimum temperatures, diurnal temperature range and precipitation) and their impacts on the yields of major crops (rice, wheat, maize and soybean) in China over few years. The results of the analysis indicated that yield was significantly related to growing season climate for all crops in the main production regions of China and growing season temperature had a general significant warming trend.

According to Kang *et al.* (2009) climatic change affect crop yield differently in different area according to latitude of area and irrigation application. CERES-Maize (Crop Environment Resource Synthesis), CERES-Wheat, SWAP (soil–water–atmosphere–plant), and InFoCrop were the models used for fitting crop growth models used to study climate change impacts on crop yields. As temperature increases and precipitation fluctuates and crop yield will get reduced in forthcoming and the total crop production can be improved by increasing the irrigated area.

CERES-Rice model of DSSAT v4.0 was used to study the impact of climate change on the yield of paddy by Rai *et al.* (2009) at Nepal Agriculture Research Council (NARC) Tarahara during the period 1989-2008. The increase in maximum temperature up to 2 °C and 1 °C in minimum temperature had positive impact on rice yield but beyond that temperature had negative impact on both cases of paddy production. Similar result was observed in case of mean temperature, but had negative impact on rice yield, whereas solar radiation had positive impact on rice yield.

The impact of climate change on yield of crops was studied by Kumar *et al.* (2011) using A1b 2030 scenario derived from the Precis regional climate model (RCM). The result of the study was that areas with higher temperature and reduced rainfall or in areas receiving less rainfall and increased rainfall in already high rainfall zones will give reduced yield for crops. Whereas reduction in rainfall in high rainfall zones benefitted the crops.

Climate trends were large enough in any countries to change a significant portion of the variation in average yields that rose from technology, carbon dioxide fertilization, and other factors. The multiple regression analysis from the study on climate trend in global crop production by Lobell *et al.* (2011) showed statistically significant relation of temperature and precipitation with yield of maize, wheat, rice and soybean. The study also showed that a 1°C rise in temperature resulted in 10 percent yield reduction except in high latitude countries, where in particular rice gains from increase in temperature. Precipitation increases yields for nearly all crops and countries, up to a point at which further rainfall becomes harmful.

Climate change like higher temperatures and changes in precipitation will directly affect crop yields. A study by Prakash *et al.* (2011) assesses the effect of observed climate variables on yield of major food-crops in Nepal, namely rice, wheat, maize, millet, barley and potato based on regression model for time series climatic data and yield data for the period from 1978 to 2008. The yield growth rate of all the food-crops was positive. The result of regression analysis indicated that an increase

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in summer rain and maximum temperature has contributed positively to rice yield and potato yield and negatively on the yield of maize and millet. Increase in wheat and barley yield was explained by current trend of winter rain and temperature.

The daily rainfall and temperature data for a period of 1977 to 2000 of Kharagpur were analyzed by Bhattacharya and Panda (2013) to know seasonal and annual variability. FAO Aquacrop model version 3.1 was the model used for the analysis. The results revealed that there was reduction in yield with each unit increase in temperature and rise in yield with per mm increase in rainfall.

Kim *et al.* (2013) conducted their study on rice in Germany shows that rice production at higher latitudinal regions was increased because of progressive temperature effects. The combined effects of CO2, temperature, precipitation, and solar radiation on yields at different latitudinal regions contribute to yield.

The sensitivity of rice yield to change in climate variables and the magnitude of potential impacts on productivity in Nepal was studied by Karn (2014). The result of the multiple regression analysis carried out has shown that one degree celsius (1°C) rise in day time maximum temperature during the ripening phase of rice resulted an increase of harvest by 27 kg ha^{-1}. The result of analysis also indicated that productivity drops when the day time maximum temperature goes above 29.9°C. Thus rainfall had a potential impact of rice productivity. Rainfall had a strong negative effect on yield, high rainfall on nursery stage affect seedling adversely.

The minimum temperature trend in India was analyzed using 0.5° grid data for annual, kharif and rabi cropping seasons at the district level for the period 1971–2009 by Rao et al. (2014). Annual mean minimum temperature showed an increasing rate of 0.24°C 10 yr^{-1} on all India basis. The scale of rise in seasonal mean temperatures was less during kharif as compared to rabi. Moreover there was a decline in kharif paddy yield ranged between 411 to 859 kg ha^{-1} per 1 °C rise in minimum temperature across regions.

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Materials and Methods

3. MATERIALS AND METHODS

The study entitled 'Permanent plot experiment on integrated nutrient supply system for cereal based crop sequence' was based on a long term field experiment on rice (var. Aiswarya) carried out for the period from 1985-86 to 2013-14 at Integrated Farming System Research Station (IFSRS), Karamana. This chapter includes different procedures applied in analysis of data collected under the following headings.

3.1 Description of experiment

3.2 Collection of secondary data

3.3 Statistical procedures and techniques employed

3.1 DESCRIPTION OF EXPERIMENT

The field experiment was a long term fertilizer trial experiment consisted of twelve different treatment combinations of recommended dose of fertilizers including one control (no fertilizers and no organic matters) and farmers practice. The experiment was carried out during kharif (spacing used was 20 cm × 15 cm, net plot area was 15.2 × 5.7 m^2) and rabi (spacing used was 20 cm × 10 cm, net plot area was 15.2 × 5.9 m^2) seasons based on randomized block design (RBD) with four replications. The twelve different treatments followed during kharif and rabi are shown below, where T_1 represents the control and T_{12} represents the farmers practice.

Twelve different treatment combinations include:

1. T_1: Absolute control.
2. T_2: 50 per cent RDF* of NPK in kharif and rabi.
3. T_3: 50 per cent RDF of NPK in kharif, and 100 percent RDF of NPK in rabi.
4. T_4: 75per cent RDF of NPK in kharif and rabi.
5. T_5: 100 per cent RDF of NPK in kharif and rabi.
6. T_6: 50 per cent RDF of NPK+ 50 percent FYM in kharif and 50 per cent RDF of NPK in rabi.
7. T_7: 75 per cent RDF of NPK+ 25 percent FYM in kharif and 75 per cent RDF of NPK in rabi.

8. T_8: 50 per cent RDF of NPK + 50 per cent through crop residues in kharif and 100 per cent NPK through fertilizers in rabi.
9. T_9:75 per cent RDF of NPK+ 25 per cent through crop residues in kharif and 75 per cent RDF of NPK through fertilizers in rabi.
10. T_{10}: 50per cent RDF of NPK + 50 per cent through green manuring in kharif and 100 per cent RDF of NPK through fertilizers.
11. T_{11}:75 per cent RDF of NPK + 25 per cent through green manuring in kharif and 75 per cent RDF of NPK through fertilizers in rabi.
12. T_{12}: Farmer's practice (3t FYM in kharif, 90:22.5:22.5 kg NPK/ha in rabi).

*RDF: Recommended dose of fertilizers- (90: 45: 45 kg NPK/ha)

3.2 COLLECTION OF SECONDARY DATA

The secondary data on soil and yield parameters were collected from IFSRS, Karamana for a period of 29 years. Data on weather parameters such as maximum temperature, minimum temperature and total rainfall were collected from Department of Meteorology, College of Agriculture, and Vellayani for the period 1985-86 to 2013-14.

3.2.1 Yield parameters

3.2.1.1 Grain Yield

The grain yield from the field experiment was collected from net plot area individually, threshed, cleaned, dried and weighed to express in *kg* ha^{-1}at 14 percent moisture.

3.2.1.2 Straw yield

The straw obtained from net plot was dried under sun to constant weight and expressed in *kg* ha^{-1}.

3.2.2 Soil parameters

3.2.2.1 Soil organic carbon

The soil organic carbon content was measured after cropping and expressed in percentage

3.2.2.2 Soil Phosphorous

The soil phosphorous content was measured after harvest and expressed in *kg ha^{-1}*.

3.2.2.3 Soil Potassium

The soil potassium content was measured after harvest and expressed in *kg ha^{-1}*.

3.2.3 Weather parameters

3.2.3.1 Maximum temperature

Daily maximum temperature was noted and expressed in degree Celsius (^{0}C).

3.2.3.2 Minimum temperature

Daily minimum temperature was noted and expressed in degree Celsius (^{0}C).

3.2.3.3 Rainfall

Rainfall on all rainy days was measured and expressed in mm.

3.3 STATISTICAL PROCEDURES AND TECHNIQUES EMPLOYED

The different statistical procedures used for the analysis in this study is explained below.

3.3.1 Initial data analysis

Data on yield and soil parameters for 29 years (1985-2014) were collected for kharif and rabi seasons, separately. Initial data analysis is the process of examination of data at different identity and remove the data inconsistence present in the data. The purpose is to lessen the risk of incorrect outcomes. In this step we can identify the outliers or extreme values, missing observations, checking the units of observations made similar etc.

3.3.2 Descriptive Statistics

Descriptive statistics provides various characteristics of the variable in the data such as minimum, maximum, average and standard deviation. It is a method of analyzing *data* sets to summarize their main characteristics. Descriptive statistics are brief descriptive coefficients that conclude a given data set, which can either be a symbol of the whole or a part of a population. They provide simple conclusions about the sample and the measures. The descriptive statistics and the usual analysis of variance (ANOVA) for Ramdomised Block Design (RBD). Mean value of maximum and minimum temperature was found for every month from the daily temperature data collected for 29 years.

3.3.3 Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) deals with the variance within classes relative to the overall variance. An ANOVA test is a way to find out if survey or experiment results are significant. It is used to find out if one need to reject the null hypothesis or accept the alternate hypothesis. Testing groups to see if there's a difference between them is done here.

Table 1. ANOVA table for RBD

Source of variance	Degrees of freedom	Sum of square	Mean sum of square	F
Factor A	a-1	SSA	SSA/(a-1)	MSA/MSE
Factor B	b-1	SSB	SSB/(b-1)	MSB/MSE
Interaction AB	(a-1)(b-1)	SSAB	SSAB/(a-1)(b-1)	MSAB/MSE
Error	n-ab	SSE	SSE/n-ab	
Total	n-1	SST		

The null hypothesis is accepted if the calculated F-value is smaller than table F-value, else it is rejected.

3.3.4 Multivariate Analysis of Variance (MANOVA)

Multivariate Analysis of Variance (MANOVA) is similar to Analysis of Variance (ANOVA), it is simply an ANOVA with several dependent variables. ANOVA tests for the difference in means between two or more groups, while MANOVA tests for the difference in two or more vectors of means. For p variables and n samples, n×p matrix can be arranged as

$$X = \begin{bmatrix} X_{11} & X_{12} & \dots X_{1p} \\ X_{21} & X_{22} & \dots X_{2p} \\ \vdots & \vdots & \vdots \\ X_{n1} & X_{n2} & \dots X_{np} \end{bmatrix}$$

X_{ij} is the j[th] variable for i[th] sample value. If the population mean vector of X is μ then,

$$\mu = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \vdots \\ \mu_p \end{bmatrix}$$

If $\sum$ is population variance covariance matrix

$$\Sigma = E[(X - E(X)(X - E(X)'] = E[(X - \mu)(X - \mu)']$$

$$\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \dots \sigma_{1p} \\ \sigma_{21} & \sigma_{22} & \sigma_{2p} \\ \vdots & \vdots & \dots \vdots \\ \sigma_{n1} & \sigma_{n2} & \dots \sigma_{np} \end{bmatrix}$$

$$\Sigma = \begin{bmatrix} var(x_1) & cov(x_1x_2) \dots & cov(x_1x_p) \\ cov(x_2x_1) & var(x_2) \dots & cov(x_1x_2) \\ \vdots & \vdots & \vdots \\ cov(x_px_1) & cov(x_px_2) \dots & var(x_p) \end{bmatrix}$$

As data contains several variables multivariate tests for the mean vector of different groups is done by assuming equal variance- covariance matrix, then this method is known as MANOVA. Single MANOVA is enough of multiple ANOVA for significance study.

If there are k treatments with r replications and B is the matrix of corrected sum of squares and sum of products between treatments and A is the matrix of within sum of squares and sum of products, then model for each observation is

$X_{ki} = \mu + \alpha + \epsilon$

where, $X_{ki} \sim . N_p(\mu_k, \Sigma)$ (Rencher., 2002)

X is the vector of individual responses, μ is the general mean vector, α is the treatment vector and ϵ is the random error vector. MANOVA table is represented in table 2.

Table 2. MANOVA table

Source of variation	Degrees of freedom	Sum of squares of product matrix
Between groups	k-1	B
Within groups	n-k	A
Total	n-1	C

Multivariate tests used in MANOVA includes Wilk's lambda, Hotelling-Lawley's trace, Pillai's trace and Roy's largest root.

If B = T.+.A is treatment + error matrix and A is error matrix then statistic E is explained as,

$$E = \frac{B}{A}$$

3.3.4.1 Wilk's lambda criterion (Λ):

Wilks' lambda is a test statistic used in MANOVA to test whether there are differences between the means of identified groups of subjects on a combination of dependent variables. It is defined from two independent Wishart distributed variables as the ratio distribution of their determinants.

$$A \sim W_p(\Sigma, m) \quad B \sim W_p(\Sigma, n)$$

independent with m≥p

$$\Lambda = \frac{|A|}{|(A+B)|} = \frac{1}{|1+A^{-1}B|} \sim \Lambda(p, m, n)$$

where, p is the number of dimensions m is error degrees of freedom n is hypothesis error degrees of freedom and m+n is total error degrees of freedom.

3.3.4.2 Hotelling-Lawley's trace

Hotelling's T-squared distribution (T^2) is a multivariate distribution proportional to the F-distribution and arises importantly as the distribution of a set of statistics which are natural generalizations of the statistics underlying Student's t-distribution.

Hotelling-Lawley's trace= trace (E)=trace(BA^{-1})=$\sum_{i=1}^{p} \lambda_i$

3.3.4.3 Pillai's trace

Pillai's trace is used as a test statistic in MANOVA and MANCOVA. This is a positive valued statistic ranging from 0 to 1. Increasing values means that effects are contributing more to the model; you should reject the null hypothesis for large values.

Pillai's trace=trace [$B(B+ A^{-1})$] = $\sum_{i=1}^{P} \frac{\lambda_i}{1-\lambda_i}$

Out of four tests Pillai's trace is said to be the powerful. test.

3.3.4.4 Roy's largest root

Roy's largest root is a common test statistic in multivariate analysis, statistical signal processing and allied fields.

Roy's largest root=max(λ_i), where λ_i is the i^{th} eigon value of the matrix E.

3.3.6 Split-split plot analysis

A split plot design is a special case of a factorial treatment structure. Basically a split plot design consists of two experiments with different experimental units of different "size". The restriction on randomization mentioned in the split-plot designs can be extended to more than one factor. For the case where the restriction is on two factors the resulting design is called a split-split-plot design. These designs usually have three different sizes or types of experimental units.

$$y_{ijkh}= \mu+ \tau_i+ \beta_j+(\tau\beta)_{ij}+ \gamma_k+ (\tau\gamma)_{ik}+ (\beta\gamma)_{jk}+ (\tau\beta\gamma)_{ijk}+\delta h+ (\tau\delta)_{ih}+ (\beta\delta)_{jh}+ (\tau\beta\delta)_{ijh}+ (\gamma\delta)_{kh}+ (\tau\gamma\delta)_{ikh}+ (\beta\gamma\delta)_{jkh}+(\tau\beta\gamma\delta)_{ijkh}+\epsilon_{ijkh} \text{ for } i=1,2,\ldots,r;\ j=1,2,\ldots,a;\ k=1,2,\ldots,b;\ h=1,2,\ldots,c$$

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Table 3. ANOVA for split-split plot design

Source of variance	Degrees of freedom	Sum of square	Mean sum of square	F
(Whole plots)				
Block	r – 1		MSR	MSR/Ea
Factor A	a – 1		MST	MST/Ea
Whole plot error	(r - 1)(a - 1)		Ea	
(Sub plots)				
Factor B	b – 1		MSS	MSS/Eb
A × B	(a - 1)(b - 1)		MSI	MSI/Eb
Sub plot error	a(r - 1)(b - 1)		Eb	
(Sub-sub-plots)				
Factor C	c – 1		MSSs	MSSs
A × C	(a - 1)(c - 1)		MSI_1	MSI_1/ Ec
B × C	(b - 1)(c - 1)		MSI_2	MSI_2/ Ec
A × B × C	(a - 1)(b - 1)(c - 1)		MSI_3	MSI_3/ Ec
Sub-sub plot error	ab(r - 1)(c - 1)		Ec	
Total	(rabc) – 1			

3.3.5 Time series data analysis

Time series data usually contain unit root or it is non-stationary in nature that could be spurious, transformation to stationary of a nonstationary time series has to be done to escape such spurious regression. Mean and variance of time series data remain same for stationary data else changes over time with some tendency or pattern can be seen. If the time series has a unit root, the solution to transform them into stationarity series by taking the difference of historical series variable.

To determine the order of integration or to test stationarity Augmented Dickey – Fuller (ADF) test is worked out. The ADF test is comparable with the simple DF test, but is augmented by adding lagged values of the first difference of the dependent variable as additional repressors which are required to account for likely incidence of autocorrelation. The ADF test is based on the relation

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta Y_{t-i} + \varepsilon_t$$

where, Y_t is the variable being tested, $\varepsilon_t \sim$ IID $N(0, \sigma^2)$, $\beta = 1 - \rho$ and $\Delta Y_t = Y_t - Y_{t-1}$, $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$, $\Delta Y_{t-2} = (Y_{t-2} - Y_{t-3})$, etc. α , β and δ_i are parameters to be estimated. The null and alternative hypotheses tested is

H_0: $\beta = 0$ or Y_t is not I(0), against

H_1: $\beta < 0$ or Y_t is I(0)

The test statistic is the conventional t-ratio

$$t = \frac{\hat{\beta}}{SE(\hat{\beta})}$$

Where $\hat{\beta}$ denotes ordinary least square (OLS) estimate of β and $SE(\hat{\beta})$ denotes the coefficient of standard error. But, Dickey and Fuller (1979) showed that under the null hypothesis of a unit root, this statistic does not follow the conventional Student's *t* distribution and it follows the τ (tau) statistic. They also computed the critical values of the *tau statistic* on the basis of Monte Carlo simulations for various sample sizes. More recently, MacKinnon (1991, 1996) had developed more extensive than those tabulated by Dickey and Fuller. In addition, MacKinnon estimates response surfaces for the simulation results, permitting the calculation of Dickey-Fuller critical values and p-values for arbitrary sample sizes.

In general, if the estimate of β is negative and significantly different from zero then reject the null hypothesis, H_0 which shows that series is stationary. It is important to see the critical value of tau statistic from ADF test. If the computed absolute value of tau statistic ($|\tau|$) exceeds the absolute critical value or Mac Kinnon Critical tau value, we reject the hypothesis of $\delta = 1$, which means that the variable is stationary with zero mean. On the other hand, if the computed tau statistic ($|\tau|$) value does not exceed the absolute critical value, we do not reject the null hypothesis, in which case the time series is non stationary. (Gujarati *et al.,* 2012)

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3.3.5.1 ARIMA (Auto Regressive Integrated Moving Average) model

ARIMA model is commonly known as Box- Jenkins Auto Regressive Integrated Moving Average method and is made up of AR, MA and I. AR represents an Autoregressive process which explains the variables regressed on own lagged or prior values, MA is the Moving average process which is the linear combination of error terms of repeated values and I labels the differencing process to make the variables stationary. The process of ARIMA model can be expressed as ARIMA (p, d, and q), where p denotes the number of autoregressive terms, d the number of times the series has to be differenced before it becomes stationary, and q the number of moving average terms. The value of I can be either one (1^{st} differencing was stationary) or 2 (second differencing was stationary).

For example, The ARIMA (1, 1) model can be written as

$$Y_t = \theta + \alpha_1 Y_{t-1} + \beta_0 u_1 + \beta_1 u_{t-1}$$

Where there is one autoregressive and one moving average term. The characteristics of the time series models, i.e., the parameters (p, d, and q) and therefore the estimation of the relevant model can be carried out in a planned approach outlined by Box and Jenkins methodology (Gujarati *et al.,* 2012).

3.3.5.1.1 Box and Jenkins methodology

Box and Jenkins methodology consists of following steps:

1. **Identification**: Identification means fitting by finding proper values of p, d and q.
2. **Estimation**: After finding the suitable ARIMA (p, d, q) model, the next step is to evaluate the parameters of autoregressive and moving average terms included in the equation.
3. **Diagnostic checking**: For examining the chosen model fits the data sensibly or not one simple diagnostic is to obtain the residuals and obtain Autocorrelation (ACF) and Partial Autocorrelation (PACF) function of these residuals. We can accept the model if the residuals estimated from this model are white noise.

4. **Forecasting**: The forecasts found from this method are more consistent than those got from the customary econometric modelling.

3.3.5.1.2 Model Selection Criteria

After fitting the model it is necessary to verify the adequacy of the model. To choose the best model, different techniques are available. AIC (Akaike Information Criterion) is a one of the common diagnostic checking method. It is estimated as

$$AIC = e^{\frac{2k}{n}} \frac{SSR}{n}$$

Where k is the number of parameters in the model, RSS is regression sum of squares and n is the number of observations. For mathematical convenience above equation written as

$$\ln AIC = \left(\frac{2k}{n}\right) + \ln\left(\frac{SSR}{n}\right)$$

Where ln AIC is the natural log of AIC. Many statistical packages define AIC only in. terms of its log transform so there is no need to put *ln* before AIC. In selection of model, the model which has low Akaike Information Criterion (AIC) is selected.

3.3.5.1.3 ARCH-LM Test

The presence of ARCH effect (whether or not volatility varies over time) has to be tested through the squared residuals of the series (Tsay, 2005). The most commonly used method to test for ARCH effect is Lagrange-Multiplier test. In this test first estimate the mean equation using OLS,

$$y_t = \beta_0 + \beta_1 y_{t-1} + ... + \beta_k y_{t-k} + \varepsilon_t$$

Let ε_t be the residual series to test the conditional heteroscedasticity. Then $\{\varepsilon_t^2\}$ is the squared residual series which is used to check for conditional heteroscedasticity, which is also known as the autoregressive conditional heteroscedastic (ARCH) effects. Lagrange's Multiplier (LM) test was used for testing conditional heteroscedasticity, for testing H_0: $\gamma_1 = 0$ and $\gamma_2 = 0$ and $\gamma_3 = 0$ and ... and $\gamma_q = 0$ in the linear regression where squared residuals were regressed them on *q* own lags to test for ARCH of order *q*

$$\varepsilon_t^2 = \gamma_0 + \gamma_1 \varepsilon_{t-1}^2 + \gamma_2 \varepsilon_{t-2}^2 + ... + \gamma_q \varepsilon_{t-q}^2 + e_t$$

Obtained $R^2$from this regression and the test statistic is defined as $n.R^2$ (the number of observation multiplied by the coefficient of multiple correlation) from the last regression, and is distributed as a χ^2 with q degrees of freedom. If the value of the test statistic is greater than the critical value of χ^2distribution with α level of significance, then reject the null hypothesis which indicates presence of ARCH effect.

3.3.5.2 ARCH Model

The Autoregressive Conditional Heteroscedasticity (ARCH) type models are defined in terms of the distribution of errors of a linear regression model by taking dependent variable as commodity price which is considered as an autoregressive process. That means

$$y_t = \beta_0 + \beta_1 y_{t-1} + \ldots\ldots. + \beta_k y_{t-k} + u_t \quad \text{where } u_t = \sigma_t \varepsilon_t, \quad \epsilon_t \sim iid\ \mathrm{N}(0, 1), \sum \alpha_i \leq 1$$

Engle (1982) developed a model for σ_t^2 based on past squared errors (u_t) of above equation known as conditional variance. The conditional variance depends on the previous q lagged innovations is denoted as ARCH (q) and is represented as

$$\sigma_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \ldots + \alpha_q u_{t-q}^2 \qquad \text{where } \alpha_0 > 0 \text{ and } \alpha_i \geq 0 \text{ for } i > 0.$$

In the equation it can be seen that large values of the innovation of price has a bigger impact on the conditional variance because they are squared, which means that a large shock have tendency to follow the other large shock and this behaviour is named as the clusters of the volatility.

3.3.5.2.1 GARCH Model

In the ARCH model there are several restrictions that have to be fulfilled so that the model can sufficiently estimate the volatility, which can be a problem. And in ARCH model, the conditional variance of the error term depends on the previous error term of different lags. But the problem of this model is that, at higher lag the model comprises of several parameters which makes the estimation difficult and lengthy. Therefore, Bollerslev (1986) recommend a transformation of the ARCH model, to a generalized ARCH model (GARCH), where conditional variance of error term depends not only on the previous squared errors but also on its conditional variances in the previous time periods. GARCH (p, q) model has two equations named as mean equation and variance equation

$$y_t = \beta_0 + \beta_1 y_{t-1} + \dots\dots + \beta_k y_{t-k} + u_t \qquad\qquad u_t = \sigma_t \varepsilon_t$$

$$\sigma^2{}_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i u_{t-i}^2 + \sum_{j=1}^{p} \beta_j \sigma_{t-j}^2$$

where $\epsilon_t \sim iid\ N(0,1)$, the parameters α_i are the ARCH parameters and β_j are the GARCH parameters where i= 1, 2,…p, j=1, 2,…q and $\alpha_0 > 0$, $\alpha_i \geq 0$, $\beta_j \geq 0$ and $\sum_{i=1}^{\max(p,q)} (\alpha_i + \beta_j) < 1$. A simple form GARCH (p, q) is GARCH (1, 1), given as

$$\sigma^2{}_t = \alpha_0 + \alpha_1 u_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

The restriction on the ARCH and GARCH parameters (α_i, β_j) suggests that the volatility (u_t) is finite and that the conditional standard deviation increases (σ_t).If the sum of $(\alpha_i + \beta_j)$ i.e. ARCH and GARCH coefficients close to 1, it indicates that volatility shocks are quite persistent in the prices series and greater is the tendency of price volatility to persist for longer time in the variable under consideration.

3.3.6 Regression Analysis

Regression is the measure of relationship between two or more variables. The relationship between variables can be identified by fitting with several regression models. A linear function in univariate case can be defined as

logY= a+bX

In the multivariate case, when there is more than one independent variable, the regression line cannot be visualized in the two dimensional space the multiple regression model is

$\log Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n$

where, logY is the log of dependent variable, a is the constant and X in univariate case and $X_1, X_2, \dots, X_n$ in multivariate case represents the independent variable.

R value got from the analysis is the pearson product moment correlation coefficient. It is the correlation between the observed and predicted values of dependent variable.

R-square is the ratio of variance in dependent variable to the independent variable, this measures the overall strength of the association.

Table 4. ANOVA for regression analysis

Source of variance	Degrees of freedom	Sum of square	Mean sum of square	F
Regression	k-1	SSR	SSR/(k-1)	MSR/MSE
Error	n-k	SSE	SSE/(n-k)	
Total	n-1	SS		

3.3.7 Statistical packages used in the study

In the present study, SPSS 16.0 package was used for plotting trend of parameters throughout the years of observation. The open source software 'Gretl' was used for ARIMA and GARCH analysis. STATA 12.0 was used for multiple linear regressions analysis.

Results and Discussion

4. RESULTS AND DISCUSSIONS

The data on weather and soil parameters collected from IFSRS, Karamana and College of Agriculture, Vellayani were subjected to different statistical analysis. This chapter presents the results obtained from the study in line with the objectives specified under the following headlines.

4.1 Initial data analysis

4.2 Yield parameters

4.3. Weather parameters

4.4 Soil parameters

4.5 Impact of soil and weather parameters over yield

4.1 INITIAL DATA ANALYSIS

4.1.1 Rice production

Rice is the most important food crop grown in India as well as in Kerala. It occupies 7.46 per cent of the total cropped area of Kerala. But, the productivity of the crop is very low in the State (2790 kg/ha), though it is higher than the national average (2424 kg/ha). There has only been a marginal increase in the productivity of rice in the past four decades (GOI, 2017).

4.1.2 Data collection

'Permanent plot experiment on integrated nutrient system for a cereal based crop sequence' was carried out at Integrated Farming System Research Station (IFSRS), Karamana on rice (var. Aiswarya) from 1985-86 to 2013-14. Data on yield and soil parameters data was collected from IFSRS based on the Long Term Fertilizer Experiment (LTFE) on rice involving twelve treatments in four replications. The weather parameters were collected from Department of Agricultural Meteorology from College of Agriculture, Vellayani.

4.2 YIELD PARAMETERS

The Long Term Fertilizer Experiment (LTFE) carried out by using randomized block design consisted of twelve treatments in four replications at IFSRS, Karamana. ANOVA was carried out to test the significant difference of treatments based on grain yield and straw yield. The results of ANOVA are discussed in the following sections.

4.2.1 Results of ANOVA on Grain Yield

ANOVA was performed to study the significant difference of the treatments in every year. The results of ANOVA on grain yield for some selected years in kharif and rabi are shown in Table 5 and 6.

Table 5. ANOVA details for kharif grain yield

Year	**1985-86**	**1990-91**	**1995-96**	**2000-01**	**2005-06**	**2010-11**	**2013-14**
T_1	28.66	24.34	29.98	27.35	23.25	19.88	27.12
T_2	30.26	30.21	25.83	31.73	28.75	30.25	36.21
T_3	30.48	29.27	27.25	35.13	32.38	29.38	38.37
T_4	29.38	31.79	31.69	33.25	32.63	32.38	39.81
T_5	31.02	30.98	29.36	31.75	38.25	35.75	42.7
T_6	32.17	33.83	31.81	31.55	41.5	39.5	47.03
T_7	29.57	32.61	28.16	33	40.5	39.8	47.6
T_8	30.22	29.36	28.94	32.13	41.25	43	47.03
T_9	30.41	31.39	29.34	37	40.13	38.5	47.46
T_{10}	30.05	30.08	25.56	43.13	41.25	40.88	44.28
T_{11}	26.15	29.81	26.31	35.13	40.75	41.75	46.16
T_{12}	29.51	33.69	30.13	34	37.5	36.63	40.39
MST	8.49	25.35	17.95	58.05	141.47	177.60	149.18
MSE	13.99	8.55	5.52	26.81	2.39	4.70	0.43
F	0.61	2.96	3.25	2.16	58.99	37.78	346.98
p-value	0.81	0.007	0.004	0.043	0.000	0.000	0.000
	NS	S	S	S	S	S	S
CD	-	4.22	3.39	7.48	2.23	3.13	0.95
SEM	1.87	1.462	1.17	2.59	0.77	1.08	0.33

It is evident from the table 5 that, treatments were significant in all years (1990-91, 1995-5-96, 2000-01, 2005-06, 2010-11 1nd 2013-14) except 1985-86. On comparing with the critical difference of respective the years, treatments T_2, T_4, T_5, T_6, T_7, T_9, T_{10} and T_{12} were found to be on par with T_6 which recorded maximum mean yield in 1990-91. T_6 was the best treatment which gave maximum yield in 1995-96 and it was on par with T_1, T_4, T_6 and T_9. However, T_{10} was found as best treatment during 2000-01 as it was significantly different from all other treatments and was on par with T_9. T_6 recorded highest yield in 2005-06 and was on par with T_{10}, T_9, T_7, and T11. T_8 was found to be best treatment in 2011 and it was on par with T_{10} and T_{11} .T_7 recorded highest yield in 2013-14 and T_6, T_7, T_8 and T_9 were on par with T_7.

The results of ANOVA for some years in rabi grain yield are shown Table 6. It is evident from the table that, treatments were significant in all years (1985-86, 1990-91, 1995-5-96, 2005-06, 2010-11 1nd 2013-14) except 2000-01. On comparing with the critical difference of respective years T_3, T_4, T_5, T_6, T_7, T_8 and T_9 were on par in 1985-86with T_8 as highest mean. T_7 was the treatment recorded with highest mean grain yield in 1985-86 which was on par withT_2, T_3, T_4, T_5, T_6, T_7, T_8, T_{10} and T_{11}. T_6 was the treatment with highest mean yield in 1995-96 which was on par with T_7. Highest mean yield in 2005-06 was recorded for T_9 which was on par with T_5, T_6, T_7, T_9 and T_{10}. T_8, T_9 and T_{10} were on par with T_6 which was the treatment with highest mean yield in 2010. T_7 was found as best treatment during 2013-14, it was significantly different from all other treatments.

Table 6. ANOVA details for rabi grain yield

Year	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2013-14
T_1	25	17.69	16.88	12.88	16.13	22.44	22.16
T_2	28.94	21.25	24.31	15.75	23.13	34.57	34.43
T_3	33.53	22.10	24.88	14.62	24.75	43.35	36.52
T_4	31.38	21.46	23.19	14.38	26.13	42.09	37.77
T_5	31.5	20.62	21.25	14.25	29.63	36.59	42.65
T_6	33.05	22.26	27.94	12.13	29.5	47.53	44.88
T_7	32.21	23.38	26.19	11.00	30.36	45.3	50.46
T_8	34.78	20.51	24.13	12.63	29.76	46.14	45.3
T_9	31.63	19.77	24.5	15.25	30.44	44.42	42.93
T_{10}	30.75	23.11	24	12.75	29.44	44.33	47.53
T_{11}	30.13	21.68	22.63	14.63	28.75	43.91	46.97
T_{12}	28.31	18.65	24.5	14.5	24.88	36.8	40.14
MST	27.39	11.64	3.18	8.08	71.42	198.80	231.68
MSE	6.68	4.83	1.09	15.43	1.18	3.43	0.33
F	4.10	2.41	9.19	0.52	60.53	57.97	707.47
P	0.0007	0.03	0.00	0.87	0.00	0.00	0.00
	S	S	S	NS	S	S	S
CD	3.73	3.17	2.59	-	1.57	2.68	0.83
SEM	1.29	1.09	0.89	1.96	0.54	0.93	0.29

The results of ANOVA for some years in kharif straw yield are shown Table 7. It is obvious from the table that, treatments were significant in 1985-86, 2005-06, 2010-11 and 2013-14 but not significant in 1990-91, 1995-96 and 2000-01. T_2, T_3, T_5, T_8, T_9, T_{10} and T_{12} were on par with T_7 which was the treatment with highest mean yield in 1985-86. T_{10} has highest mean yield in 2005-06 which was on par with T_6, T_8, T_9 and T_{11}. T_7 recorded highest mean yield in 2010-11 which was on par with T_6, T_8, T_9, T_{10} and T_{11}. T_9 obtained highest mean in 2013-14 and was on par with T_{10}.

Table 7. ANOVA results for kharif straw yield

Year	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2013-14
T_1	48.62	35.06	83.03	55.65	36.75	29.5	44.86
T_2	63.85	46.42	63.685	68.15	43.5	46	63.04
T_3	64.49	50.79	71.5	86.75	49	44	60.3
T_4	73.27	56.8	67.59	77	48.25	46.25	52.07
T_5	64.25	67.35	66.64	78.13	56.5	49.5	52.07
T_6	74.72	47.67	68.06	76.08	59.75	53.25	57.27
T_7	81.37	46.19	59.59	80.5	57.75	56.25	56.55
T_8	64.06	59.74	171.31	88	60	54.5	57.7
T_9	64.99	61.48	59.66	93	59.5	51.75	64.77
T_{10}	72.79	41.56	55.18	99.75	60.25	53.75	62.75
T_{11}	77.45	46.67	65.94	77.38	59.75	54.5	64.05
T_{12}	69.54	57.56	69	84.25	57.13	51.5	45.01
MST	294.24	343.57	3868.12	528.47	242.68	214.15	192.71
MSE	67.63	202.21	4156.13	296.64	5.57	6.81	0.14
F	4.35	1.69	0.931	1.78	43.50	31.45	1359.15
P	0.0004	0.12	0.52	0.09	0.000	0.000	0.000
	S	NS	NS	NS	S	S	S
CD	11.88	-	-	-	3.41	3.77	0.54
SEM	4.11	7.11	32.23	8.61	1.18	1.31	0.18

The results of ANOVA for some years in rabi straw yield are shown Table 8. It is evident from the table that, treatments were significant in 1985-86, 2005-06 and 2010-11 but not significant in 1990-91, 1995-96, 2000-01 and 2013-14. T_8 was recorded with highest mean yield in 1985-86 and was on par with T_3, T_5, T_6, T_9, T_{10}, T_{11} and T_{12}. T_8 had highest mean yield in 2005-06 and it was on par with T_5, T_9, T_{10} and T_{11}. T_6 had highest mean yield in 2010-11, which was significantly different from all treatments.

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during kharif season. Trends in average straw yield was similar for all the treatment except T_8 and T_{11} which have shown a decreasing trend in 1997-98 and 1998-99 respectively. Figure 4 shows the trend in mean straw yield of 12 treatments during rabi season. T_4, T_5, T_6, T_7 and T_{11} showed a decreasing trend in 1996-97 while others had shown an increasing trend. T_6 recorded the highest straw yield among the treatments in 2009-10. T_1 recorded the lowest straw yield throughout the years. The graph for yield parameters was highly fluctuating but all treatments followed similar trend throughout the years.

Table 8. ANOVA results for rabi straw yield

Year	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2013-14
T_1	22.65	17.72	32.06	38.63	30	22.72	35.4
T_2	33.88	21.13	47.88	50	38.88	37.63	55.89
T_3	43.86	25.07	48.69	54.13	42.63	41.96	46.97
T_4	37.77	23.81	45.44	44.63	43	53.38	57.71
T_5	46.43	20.86	43.75	39.75	46	42.1	54.64
T_6	40.13	23.188	56.81	50.13	44	52.83	57.01
T_7	38.65	24.06	53.91	51.13	44.81	46.83	68.16
T_8	50.35	20.63	52.88	45.63	47.63	50.18	61.19
T_9	42.15	22.38	50	56.63	46.63	46.97	53.66
T_{10}	41.89	27.72	47.86	56.00	45.88	42.93	66.07
T_{11}	43.28	22.06	48.69	49.25	46.61	48.93	66.07
T_{12}	40.88	19.16	47.25	46.25	41.25	41.40	60.49
MST	192.01	29.21	152.91	134.06	93.89	274.32	328.87
MSE	59.78	19.55	9.86	167.96	3.24	0.77	0.17
F	3.21	1.49	15.49	0.79	28.96	357.16	1884.94
P	0.004	0.18	0.000	0.64	0.000	0.000	0.000
	S	NS	NS	NS	S	S	NS
CD	11.17	-	4.54	-	2.60	1.27	0.60
SEM	3.86	2.21	1.57	6.48	0.90	0.44	0.21

4.2.2 Trends in Grain Yield across treatment

Average grain and straw yield of 12 treatments for 29 years were calculated and it was plotted using a line graph for kharif and rabi seasons separately (Figure 1, 2, 3 and 4). Figure 1 shows the trend in mean grain yield in kharif season of 12 treatments. Trend in grain yield of 12 treatments were similar till 2004-05 but slight fluctuation was noticed for T_5 and T_8 after 2004. Among the treatments T_6 had given maximum grain yield in most of the years and least was recorded T_1. The trend in mean grain yield of 12 treatments during rabi season was similar to that of kharif season (Figure 2). Figure 3 shows the trend in mean straw yield of 12 treatments

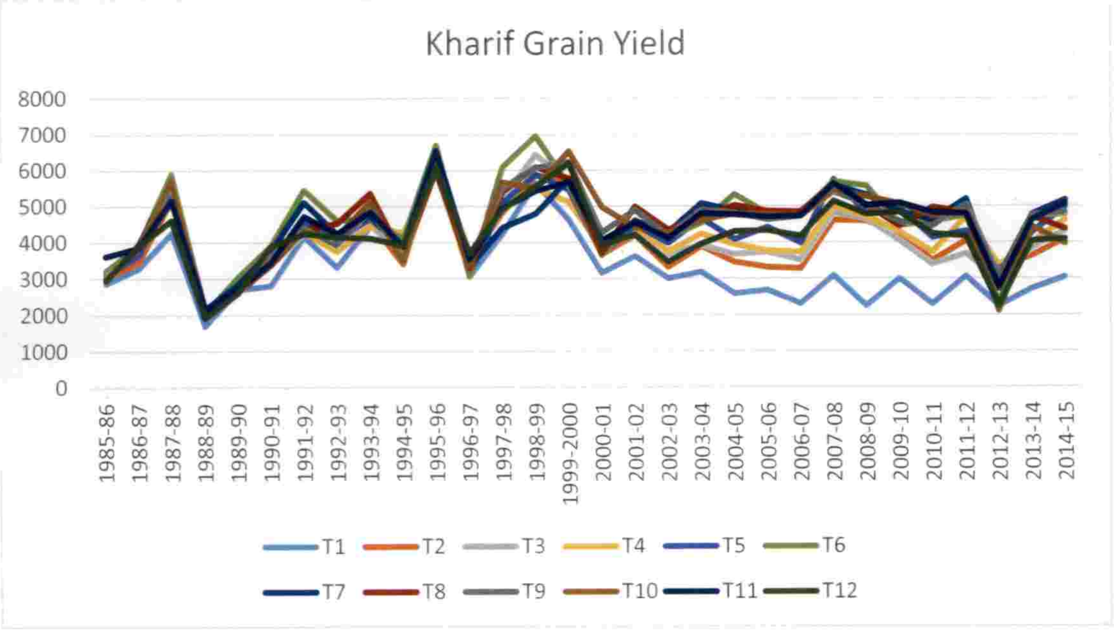

Figure 1. Trends in grain yield (*kg ha*$^{-1}$) during kharif over different years

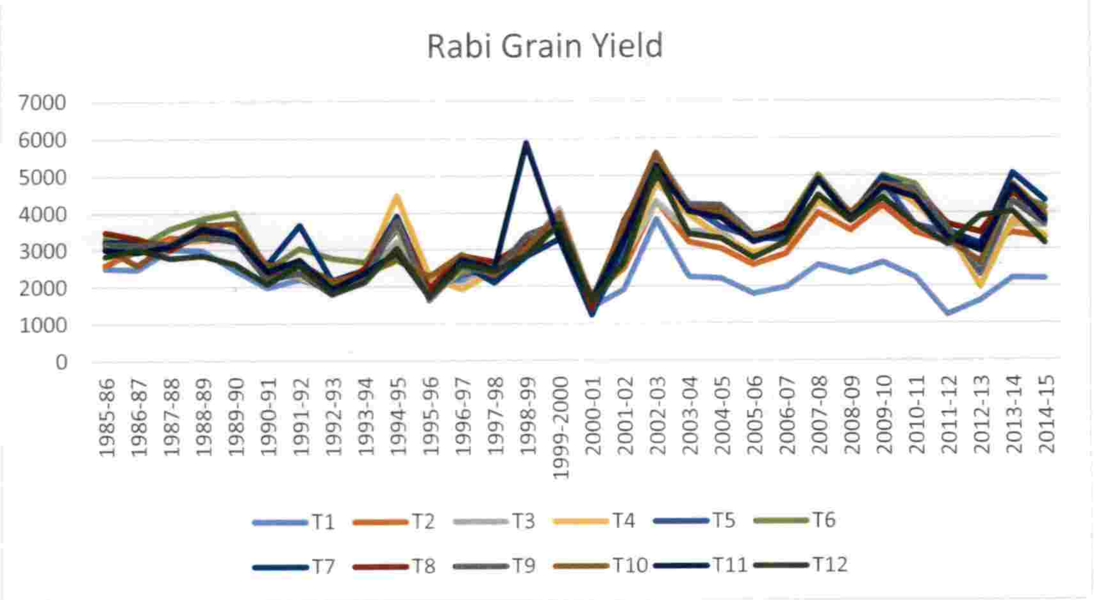

Figure 2. Trends in grain yield (*kg ha*$^{-1}$) during rabi over different years

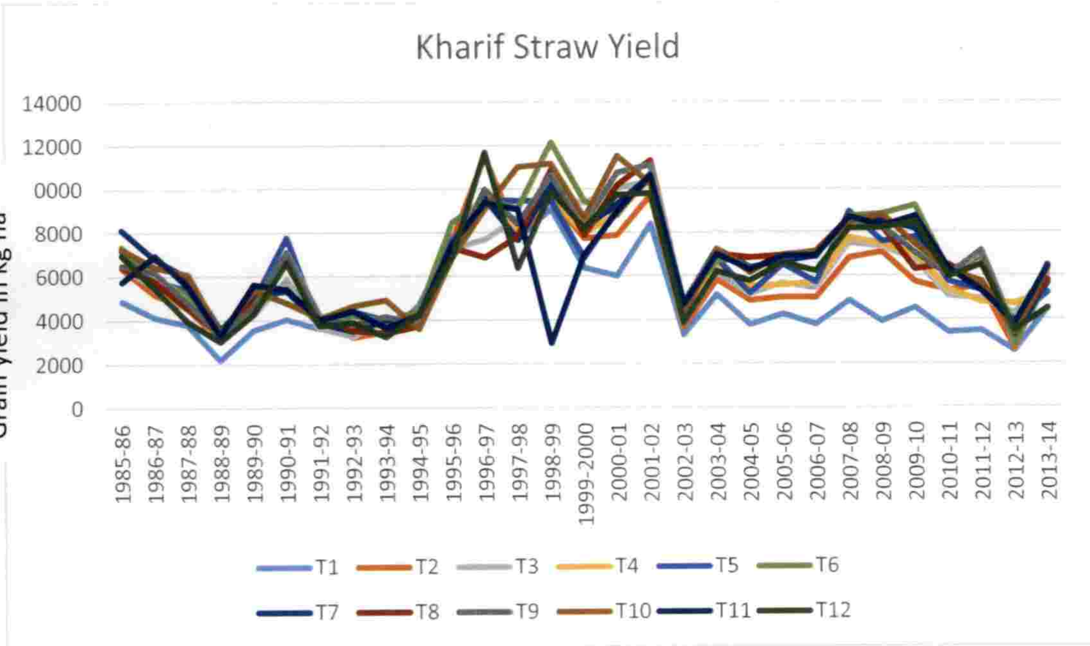

Figure 3. Trends in straw yield (*kg ha*$^{-1}$) during kharif over different years

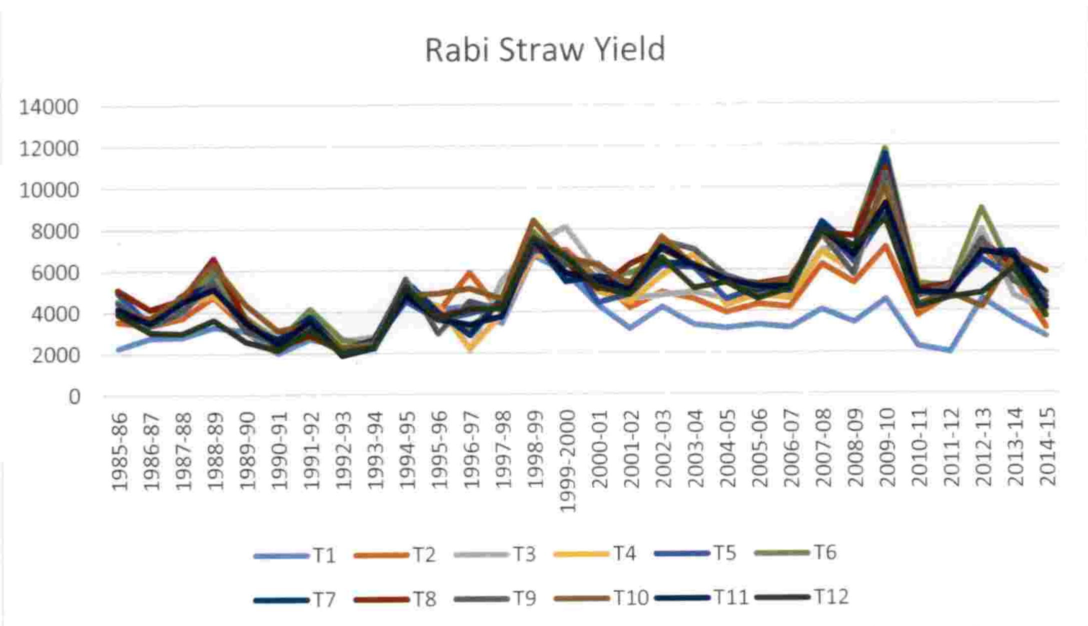

Figure 4. Trends in straw yield (*kg ha*$^{-1}$) during rabi over different years

4.2.3 Split-split plot analysis

In order to analyse the interaction effect of treatments with seasons and years, a split-split plot analysis was conducted by taking years in the main plots seasons in the sub plot and treatments in sub-sub plot. The results of the analysis are shown in table 9.

Table 9. ANOVA of Split-split plot analysis for grain yield

Source of variance	Degrees of freedom	F-value	P-value
Main plot			
Year	6	185.74	<0.0001
Main plot error	18		
Sub plot			
Season	1	373.67	<0.0001
Year×Season	6	128.57	<0.0001
Sub plot error	21		
Sub-sub plot			
Treatment	11	41.79	<0.0001
Year×Treatment	66	5.59	<0.0001
Season×Treatment	11	1.51	0.12
Year×Season×Treatment	66	1.29	0.07
Sub-sub plot error	462		

The result of the analysis (table 9) suggest that there was significant difference between the treatments over the years. The interactions year×season and year×treatment were found to be significant, but season×Treatments and year×season×treatment interactions were not significant.

Table 10. Split-split plot analysis for Straw yield

Source of variance	Degrees of freedom	F-value	P-value
Main plot			
Year	6	22.37	<0.0001
Main plot error	18		
Sub plot			
Season	1	168.94	<0.0001
Year×Season	6	11.76	<0.0001
Sub plot error	21		
Sub-sub plot			
Treatment	11	5.28	<0.0001
Year×Treatment	66	1.11	0.28
Season×Treatment	11	0.82	0.62
Year×Season×Treatment	66	1.11	0.26
Sub-sub plot error	462		

Split-split plot analysis on straw yield (table 10) indicated that there was significant difference between treatments, seasons and years. All the interaction effect except year × season were found to be not significant.

Split plot design was chosen in the study by Bellido *et al.* (1996) to determine the effects of tillage, crop rotation nitrogen fertilizer on wheat yield in a rain fed Mediterranean region and concluded differences in rainfall during the growing season had a marked effect on wheat yield. Jones (2009) in his study observe that the assumption of split plot analysis is the response of the observations in the subplot within each main plot is correlated. So to represent season or year as subplot in a long term experiment split plot analysis can be used. In this study to find the interaction effect of treatment on season and year we have to take year as main plot, season as its sub plot and treatment as its sub-sub plot.

4.3 WEATHER PARAMETERS

Descriptive statistics including average, standard deviation and coefficient of variance of maximum temperature, minimum temperature and total rainfall for years were carried out for the period 1985-86 to 2013-14. The results of descriptive statistics are shown in table 11.

Table 11. Descriptive statistics of weather variables

Year	Max tem	SD	CV	Min tem	SD	CV	Total rainfall	SD	CV
1985	30.99	1.26	4.05	23.00	0.64	2.78	1510.4	159.77	126.93
1986	31.61	1.36	4.30	22.14	1.04	4.70	1536.5	101.89	79.57
1987	31.71	1.15	3.61	23.35	1.69	7.26	1490.3	112.96	90.96
1988	31.57	1.01	3.20	23.50	1.26	5.36	1190.3	113.09	114.02
1989	30.96	1.31	4.24	23.20	1.14	4.94	1454.7	277.22	74.68
1990	31.13	1.23	3.96	23.55	1.16	4.94	1299.2	135.94	125.56
1991	31.00	1.27	4.10	23.56	1.30	5.52	1802.8	187.89	125.07
1992	30.58	1.10	3.60	23.14	1.36	5.89	1858.5	195.08	125.96
1993	30.67	1.11	3.61	23.20	1.25	5.41	1995.1	170.80	102.73
1994	30.81	0.83	2.70	23.49	0.87	3.72	1593.7	119.86	90.25
1995	31.25	0.97	3.11	23.65	1.35	5.69	1410.8	118.21	100.55
1996	30.58	1.08	3.52	22.06	1.11	5.02	1307.1	92.81	85.21
1997	30.68	1.65	5.36	21.60	0.75	3.48	1536.5	117.09	91.45
1998	31.18	1.63	5.23	24.16	1.04	4.32	2038.9	145.63	85.71
1999	30.47	1.09	3.58	23.44	0.93	3.95	2311.8	233.02	120.95
2000	30.52	1.14	3.74	22.39	1.26	5.63	1205.8	87.92	87.50
2001	31.13	1.08	3.45	22.00	1.27	5.78	1160	120.53	124.69
2002	31.13	1.08	3.45	23.23	1.05	4.50	1160	120.53	124.69
2003	31.48	0.83	2.65	23.58	1.18	5.00	1767.8	139.07	94.40
2004	31.15	1.19	3.81	23.18	1.04	4.50	1804.4	141.46	94.07
2005	31.61	1.02	3.22	23.61	1.06	4.49	1724	120.43	83.82
2006	31.10	1.03	3.32	23.64	1.19	5.03	2013.05	179.61	107.07
2007	31.17	0.94	3.00	23.06	0.98	4.26	1953.6	126.52	77.71
2008	30.93	0.91	2.93	23.26	0.98	4.20	1881.4	109.16	81.88
2009	31.01	1.42	4.57	24.23	1.14	4.69	1216.7	128.94	127.17
2010	31.52	1.55	4.92	23.40	1.06	4.55	1980.2	148.12	89.76
2011	30.88	1.10	3.57	24.25	0.71	2.93	1046.4	64.62	74.11
2012	30.59	0.82	2.69	23.63	1.28	5.44	878.95	54.53	74.45
2013	30.66	1.38	4.49	23.36	1.12	4.80	1902.41	137.43	86.69

The range of average maximum temperature varied from 30.47 to 31.61 with a coefficient of variation (CV) less than 6. The minimum temperature varied from 22.00 to 24.25 with CV less than 6. However, the range of total rain fall was very high (878.95-2311.80) with very high and fluctuating CV. Coefficient of variation (CV) is used to categorize the degree of variability of data as less when CV<20, moderate when 20<CV<30 and high when CV>30 (Hare, 2003). CV range for maximum temperature was 2.69-5.36, for minimum temperature was 2.78-7.26 but for rainfall it was 74.11-127.17, which shows that there was less CV for maximum and minimum temperature and a high CV for total rainfall. It is evident from the table that was high variation in total rainfall.

Monthly distribution of rainfall for 29 years was represented using boxplot as shown in figure 5. Average rainfall in the month of January ranged from 0-28.25mm, with high rainfall was noticed for years 1985 and 1991. Average rainfall in February ranged from 0-78.6 mm and highest rainfall was reported in 1999.However, 0-86.3 mm was the average rainfall in the month of March wherein 2013 has received the highest rainfall of 86.3. Average rainfall in April was in the range of 31.2 to 182.00 mm with a maximum on 182 mm 1989. Average rainfall in may was 12-369 mm where 1999 and 1989 were the years which received highest rainfall. 72-397.4 mm was the average rainfall received in june and 1991, 1992 and 2013 were the outlier years with very high value. 46.5to 321.4 mm was the average rainfall range in July and in 1989 highest rainfall was received. Average rainfall marked in August was 32.6-234 mm and highest rainfall was noticed in 1987 and 1989. Average rainfall marked in September was 0-390.6 mm and highest rainfall was noticed in 1986. Average rainfall marked in October was 64.5-611.6 mm. Average rainfall marked in November was 90.2-477.6 mm and highest rainfall was noticed in 1989 and the average rainfall marked in December was 0-233 mm where heavy rainfall was received in 1986.

4.3.1. Trends in weather parameters.

Trend in maximum temperature, minimum temperature and total rainfall was studied graphically (figure6, figure 9 and figure12). It is evident from the graph that a seasonal effect was present for maximum temperature, minimum temperature and total rainfall. Figure 6 shows the trend in maximum temperature over the years. Similar trend of increasing and decreasing pattern can be observed from the graph. Figure 7, figure 10 and figure 12 shows the change in maximum temperature, change in minimum temperature and change in total rainfall throughout the years.

Seasonal effect of a variable can be removed from original time series data by deseasonalising. To deseasonalise the data seasonality index has to be found out, and it is removed from the original data. Deseasonalised trends of maximum temperature, minimum temperature and total rainfall is shown in figure 8, figure11 and figure14 respectively. More fluctuations is seen in the period 1995-2010 for deseasonalised temperature variables. For deseasonalised total rainfall high fluctuation was shown in the period 1999-2001.

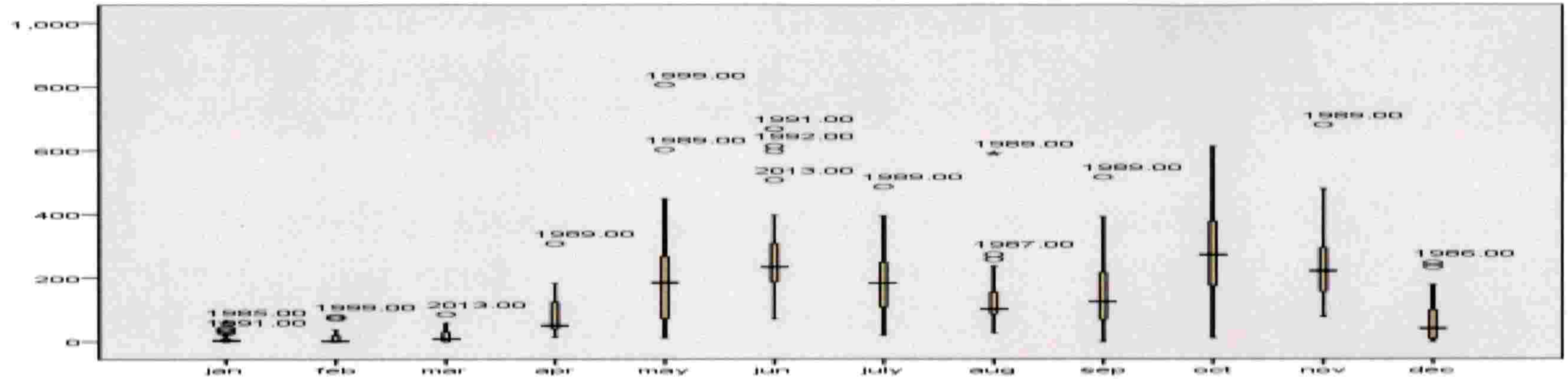

Figure 5: Boxplot on total rainfall

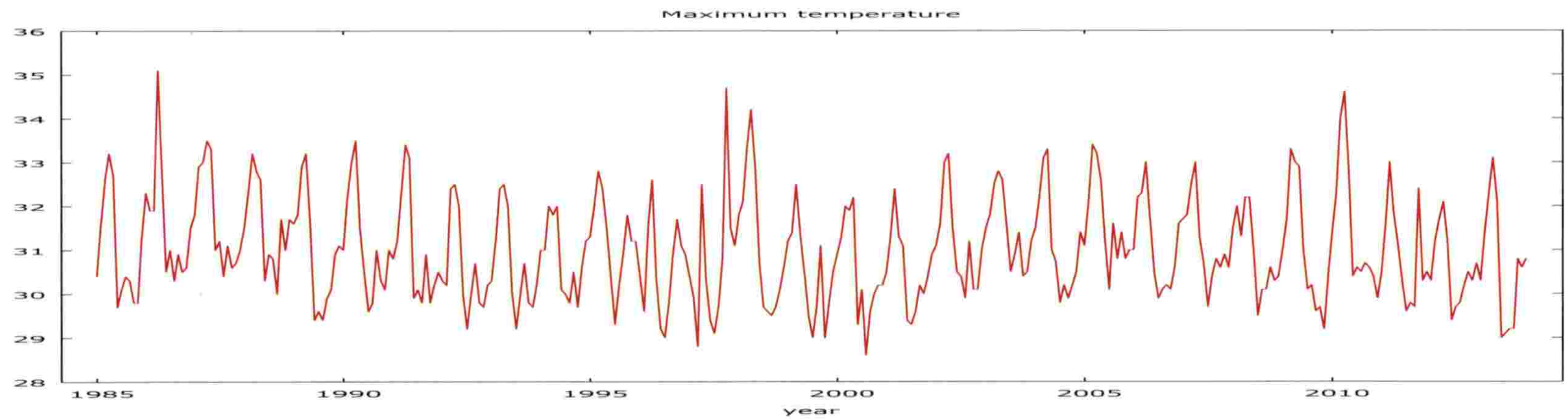

Figure 6. Trend in maximum temperature over different years.

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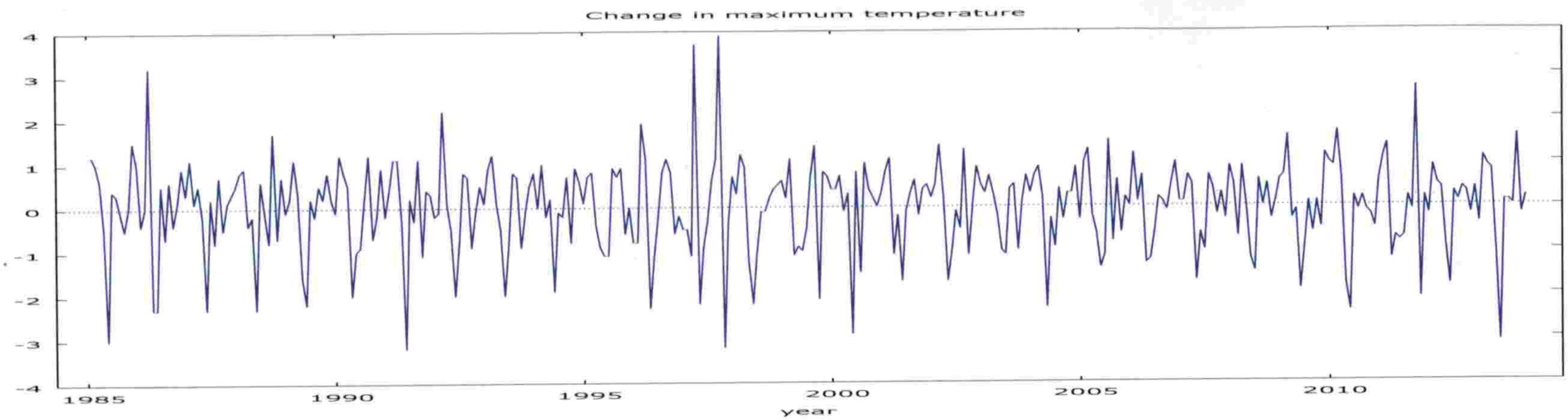

Figure 7: Trend of change in maximum temperature over different years.

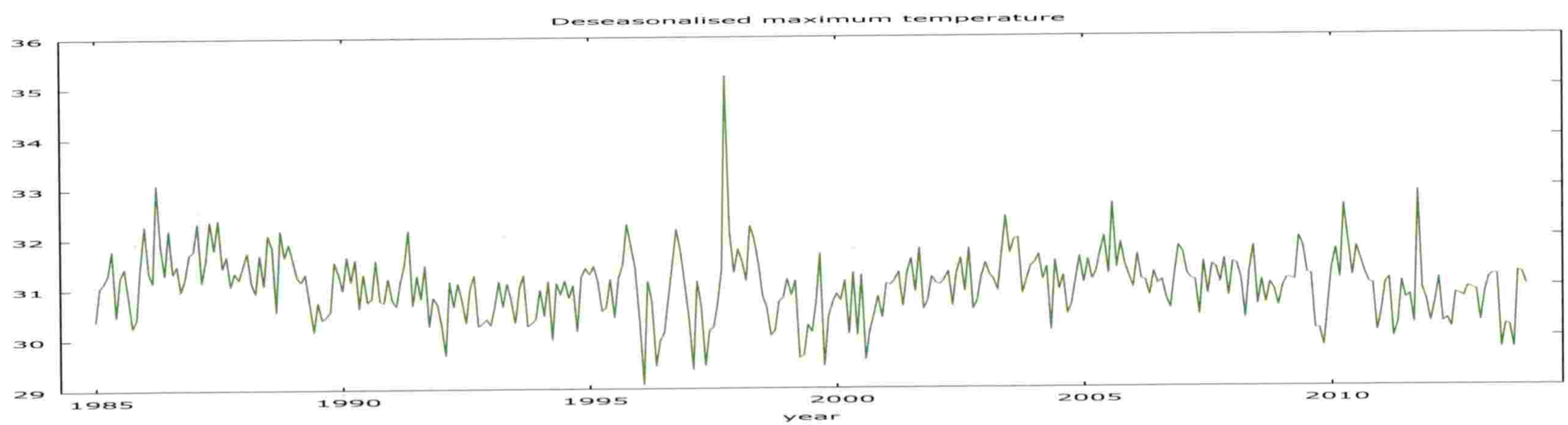

Figure 8: Trend of deseasonalised maximum temperature over different years.

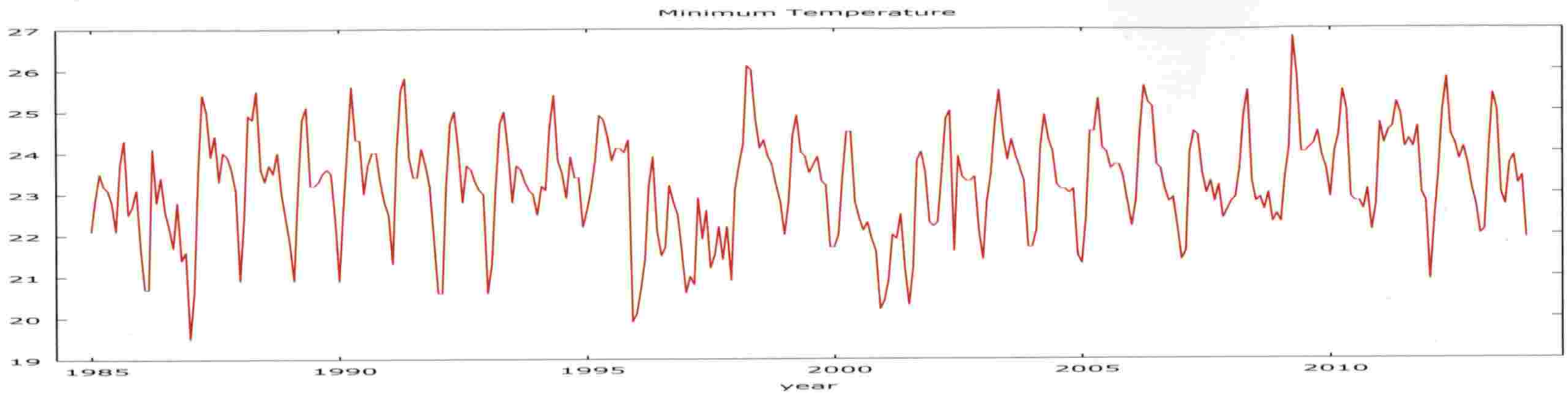

Figure 9: Trend in minimum temperature over different years.

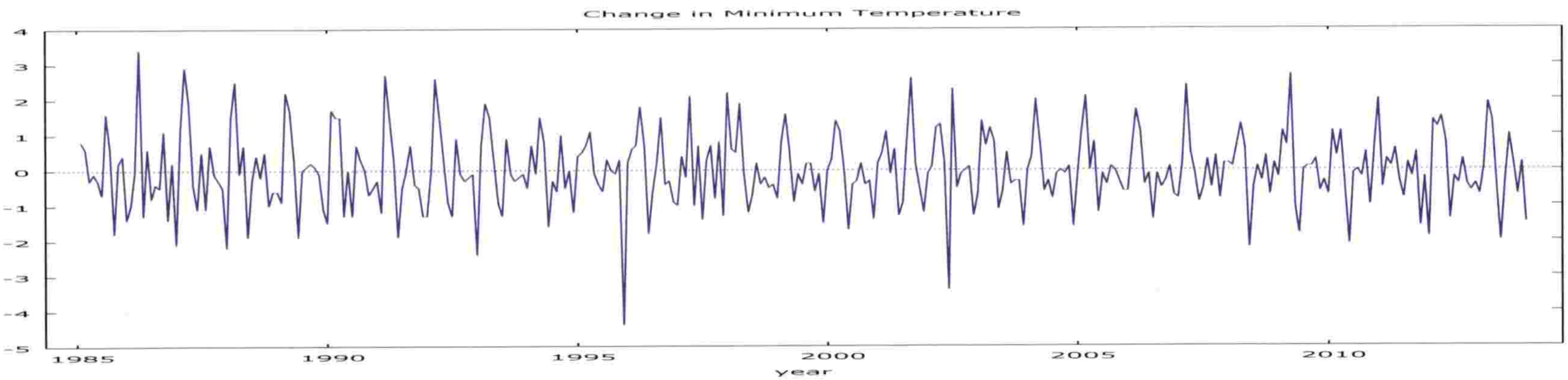

Figure 10: Trend in change in minimum temperature over different years.

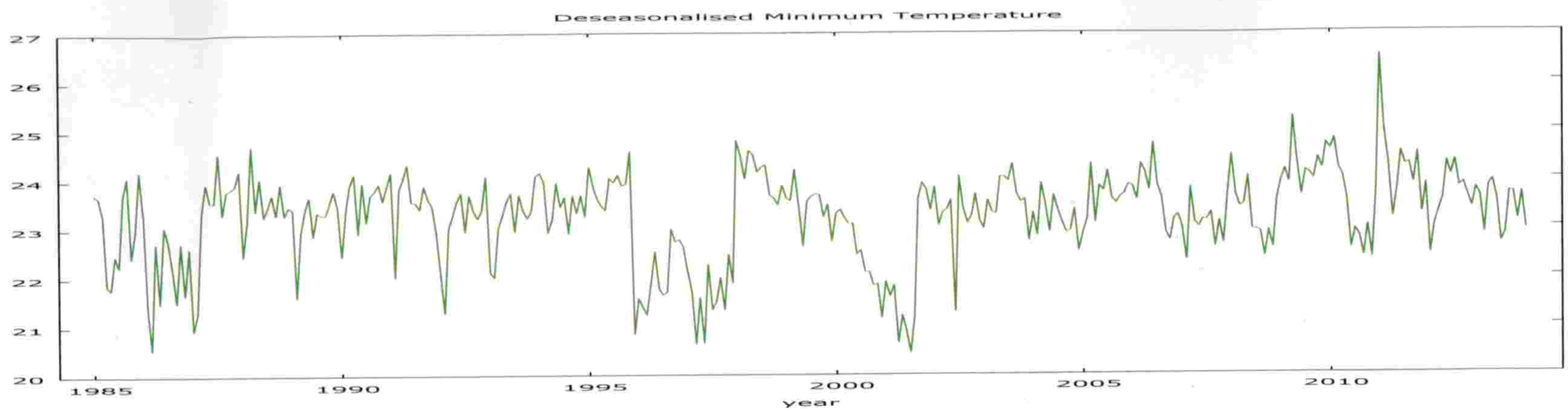

Figure 11.Trend of deseasonalised minimum temperature over different years.

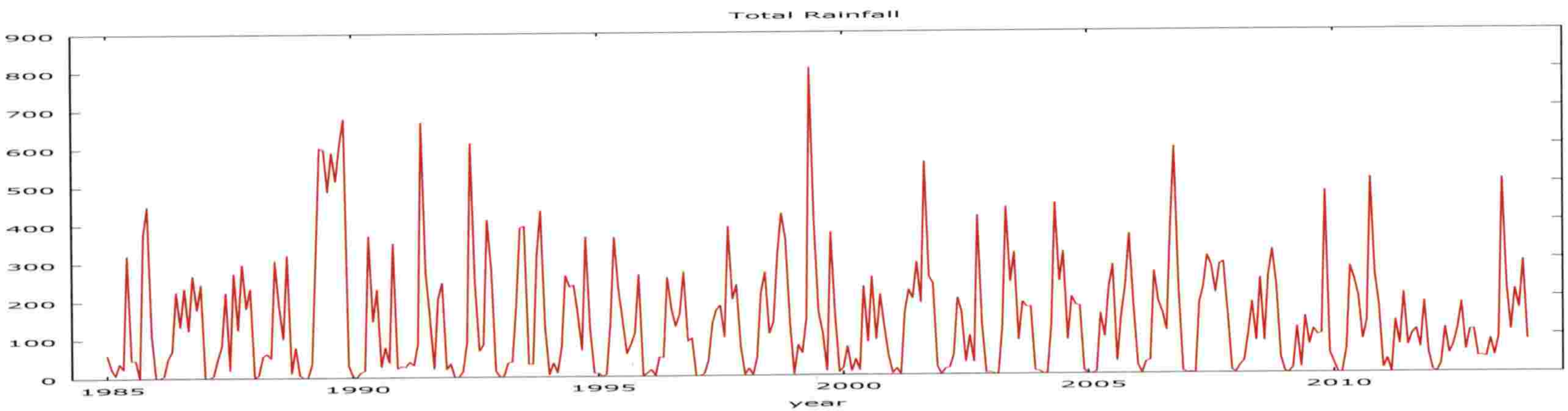

Figure 12: Trend in total rain fall over different years.

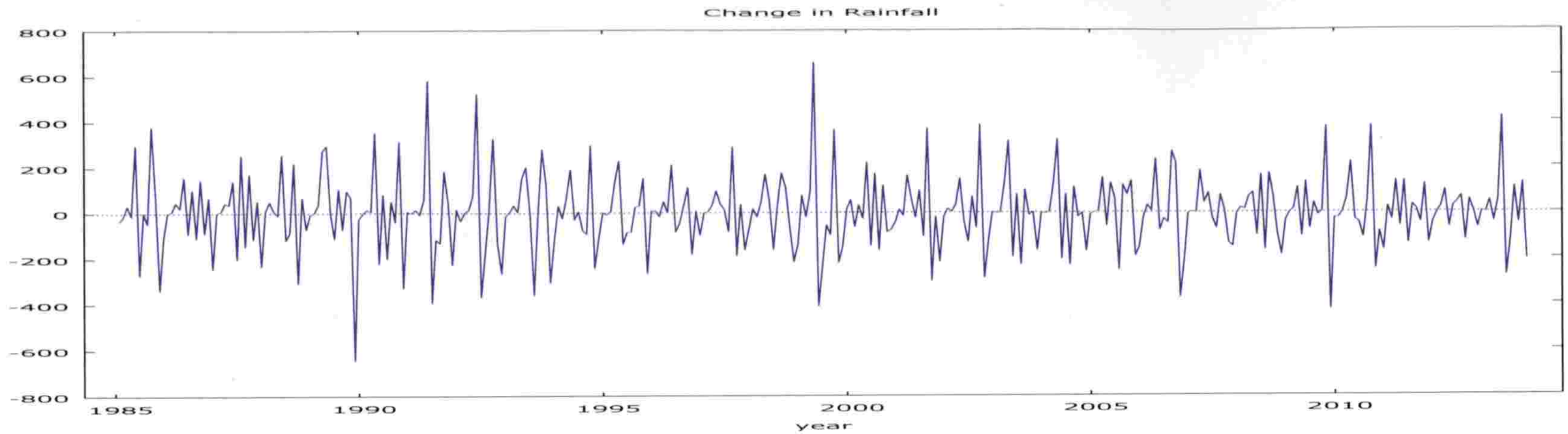

Figure 13.Trend in change in total rainfall over different years

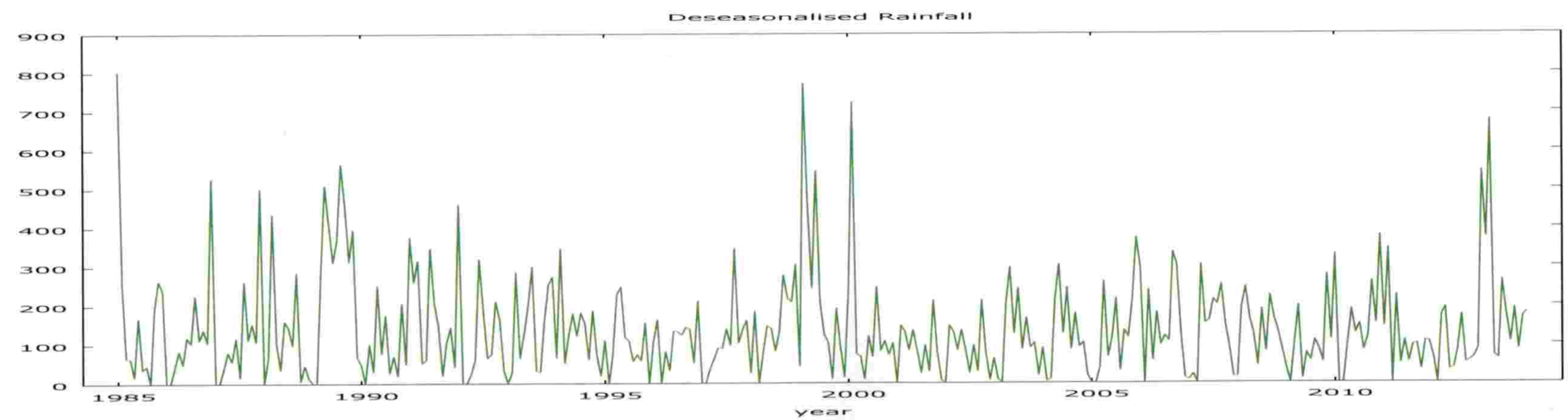

Figure 14: Trend in deseasonalised total rain fall over different years.

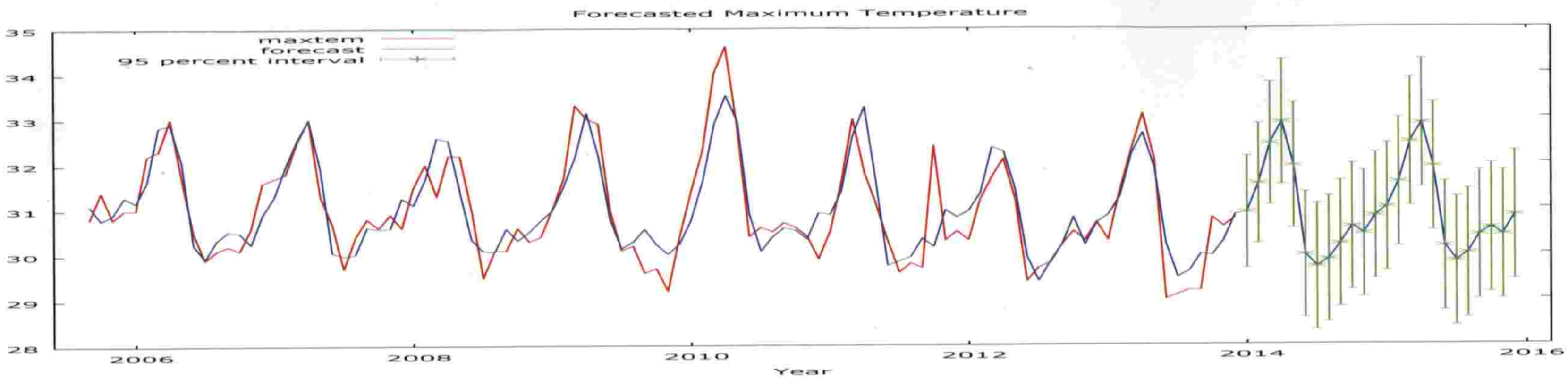

Figure 15.Trend of forecasted maximum temperature

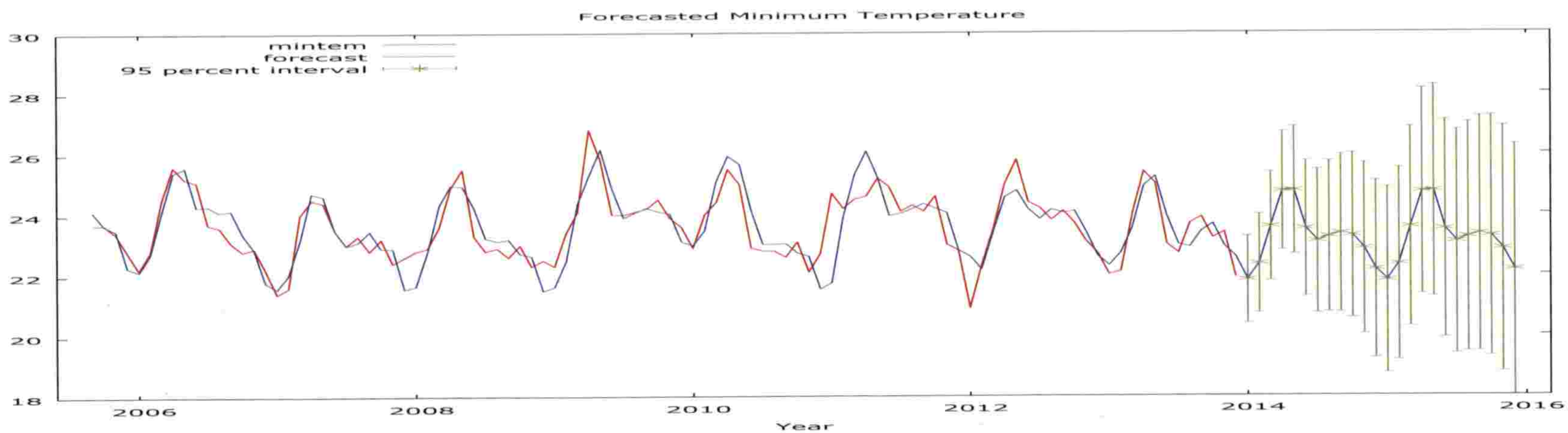

Figure 16.Trend of forecasted minimum temperature

4.3.2 Models for weather parameters

4.3.2.1 Models for maximum temperature

The change in temperature was initially discussed in the previous sections. However, there are various time series models that are able to capture the trends of the data. Autoregressive Integrated Moving Average (ARIMA), Seasonal ARIMA are some of these models. The present study used ARIMA model to estimate trend in maximum temperature and minimum temperature and further it is used for prediction. In any time series models, stationarity is the hard concept of the data. ADF suggest that maximum temperature, minimum temperature and total rainfall were stationary on the level form. ARIMA model can be represented as (p,d,q)(P,D,Q) p, d, q, P, D and Q are the parameters in ARIMA, where p and P denotes the number of autoregressive terms, d and D the number of times the series has to be differenced before it becomes stationary, and q and Q the number of moving average terms. p, d, and q represents parameters of original data whereas, P, D, and Q represents the parameters of deseasonalised data.

Model with least Akaike Information Criteria (AIC) and least Bayesian Information Criteria (BIC) and least Hannan-Quinn value will be best fit. ARMA model was used in the study by Mishra and Desai (2005), Their study showed that in most time series, there is a serial correlation among observations which is effectively considered by ARIMA model and it also provides systematic identification, estimation and diagnostic check for a suitable model.

Table 12. ARIMA model for maximum temperature

ARIMA model		coefficient	P-value	AIC	BIC	Hannan-Quinn
(001)(111)	Phi-1 theta-1 Theta-1	0.22 0.33 −1.00	7.63e-05 *** 4.48e-014 *** 4.54e-071 ***	717.24	732.51	723.32
(010)(111)	Phi-1 Theta-1	0.16 −0.98	0.01 ** 6.08e-011 ***	804.67	816.11	809.23
(100)(111)	phi-1 Phi-1 Theta-1	0.43 0.19 −1.00	1.66e-018 *** 0.001 *** 2.08e-046 ***	697.64	712.91	703.72
(110)(111)	phi-1 Phi-1 Theta-1	−0.38 0.16 −1.00	2.59e-014 *** 0.004 *** 3.19e-017 ***	753.22	768.48	759.30
(101)(111)	phi-1 Phi-1 theta-1 Theta-1	0.69 0.19 −0.32 −1.00	7.52e-018 *** 0.001 *** 0.002 *** 1.26e-048 ***	692.19	711.28	699.80
(011)(111)	Phi-1 theta-1 Theta-1	0.18 −0.63 −1.00	0.001 *** 1.15e-020 *** 1.09e-061 ***	724.75	740.00	730.83
(011)(011)	theta-1 Theta-1	−0.46 −0.91	1.09e-021 *** 1.01e-128 ***	768.10	779.54	772.66
(011)(101)	Phi-1 theta-1 Theta-1	0.99 −0.45 −0.908	0.00*** 2.11e-020 *** 3.46e-125 ***	800.74	816.13	806.87

Table 12 shows the different estimated ARIMA models using open source software Gretl for maximum temperature and along with AIC, BIC and Hannan-Quinn values are shown by model (101)(111). Therefore best fit model for maximum temperature is ARIMA (101) (111).

Forecasting of time series data is another feature of ARIMA modelling. Based on the selected model ARIMA (101) (111) maximum temperature was forecasted for the period 2014. Table 13 shows the forecasted maximum temperature based on ARIMA (101) (111). There was not much variation between observed and forecasted maximum temperature. Mean absolute error for the forecasted maximum temperature was estimated as 0.034, which shows that forecasted value and original value differ the least. The forecasted temperature trend is shown in figure 15. The forecasted temperature and original temperature shows similar trend.

Table 13. Forecast of maximum temperature based on ARIMA (101) (111)

Month	Forecasted maximum temperature	Std error	Maximum temperature	Variation from predicted value
January	30.9	0.63	30.62	0.28
February	31.5	0.67	31.34	0.16
March	32.4	0.69	32.44	-0.04
April	32.8	0.70	32.40	0.4
May	31.9	0.70	31.88	0.02
June	29.9	0.70	30.76	-0.86
July	29.6	0.71	29.99	-0.39
August	29.8	0.71	29.55	0.25
September	30.1	0.71	30.21	-0.11
October	30.5	0.71	30.53	-0.03
November	30.4	0.71	30.18	0.22
December	30.7	0.71	30.19	0.51

4.3.2.2 Models for minimum temperature

ARIMA modelling was carried out for minimum temperature. By trial and error method the best model was chosen on the basis of model selection criteria. Model with least Akaike Information Criteria (AIC) and least Baesian Information Criteria (BIC) and least Hannan-Quinn value will be best fit.

Table 14. ARIMA model for minimum temperature

ARIMA model		coefficient	p-value	AIC	BIC	Hannan-Quinn
(001)(111)	Phi-1	0.07	0.29	827.75	843.02	833.84
	theta-1	0.44	2.48e-031 ***			
	Theta-1	−0.92	9.61e-072 ***			
(010)(111)	Phi-1	0.07	0.29	827.75	843.02	833.84
	theta-1	0.45	2.48e-31 ***			
	Theta-1	−0.93	9.61e-72 ***			
(100)(111)	phi-1	0.63	4.89e-51 ***	759.32	774.589	765.41
	Phi-1	0.03	0.62			
	Theta-1	−0.93	4.45e-60 ***			
(110)(111)	phi-1	−0.34	3.80e-11 ***	783.51	798.76	789.59
	Phi-1	0.01	0.87			
	Theta-1	−0.91	3.21e-71 ***			
(011)(011)	theta-1	−0.46	9.35e-16 ***	768.10	779.54	772.66
	Theta-1	−0.91	1.23e-108 ***			
(011)(111)	Phi-1	0.02	0.82	770.05	785.31	776.13
	theta-1	−0.46	1.17e-21 ***			
	Theta-1	−0.92	1.10e-99 ***			
(111)(111)	phi-1	0.41	2.91e-7 ***	768.59	784.67	773.19
	Phi-1	0.001	0.98			
	theta-1	−0.82	4.27e-58 ***			
	Theta-1	−0.93	3.45e-87 ***			

Estimated values of the different ARIMA models for minimum temperature are presented in Table 14. The model with least AIC, BIC and Hannan-Quinn values was ARIMA (011) (011). Therefore the best fitted model for minimum temperature was ARIMA (011) (011).

Based on the best fitted model ARIMA (011) (011) minimum temperature was forecasted for the period 2014. Table 15 shows the forecasted minimum temperature based on ARIMA (011) (011). Mean absolute error for the forecasted minimum temperature was only 0.14, which shows the forecasted value and original value were very close together. The forecasted temperature trend is shown in figure 16. The forecasted temperature and original temperature produced similar trend.

Table 15. Forecast of maximum temperature based on ARIMA (011) (011)

2014-Month	Forecasted minimum temperature	Std error	Minimum temperature	Variation from the forecasted value
January	21.8	0.73	21.53	0.27
February	22.4	0.83	22.33	0.07
March	23.6	0.92	22.88	0.72
April	24.8	1.00	24.47	0.33
May	24.8	1.07	24.73	0.07
June	23.5	1.14	23.21	0.29
July	23.1	1.21	23.31	-0.21
August	23.2	1.27	23.74	-0.54
September	23.4	1.33	24.01	-0.61
October	23.3	1.39	23.82	-0.52
November	22.9	1.44	23.38	-0.48
December	22.2	1.49	23.29	-1.09

Similar results were obtained in the study by Unnikrishnan *et al.* (2018) on forecasting weather parameters and also showed that ARIMA (011)(011) is the most commonly fitted ARIMA model for seasonal parameters.

Similar results were reported by Murat *et al.* (2018) on forecasting meteorological time series data, it was found that ARIMA models was the best fit for air temperature studies. Further SARIMA models were found as not answering when time series data for many years is considered.

Another study on time series by El-Mallah and Elsharkawy (2016) reported that modelling and forecasting short term yearly temperature disclosed that the quadratic ARIMA model and linear ARIMA model had the best overall performance in making short-term forecasts of yearly total temperature.

4.3.2.3 Modelling of total rainfall

Two important characteristics within the rainfall time series are highly skewed and volatility clustering (Villarini et al. 2010). Change of variation for total rainfall over the years was very high and for total rainfall. Generalized Autoregressive Conditional Heteroscedasticity (GARCH) is the best suited model for studying the variation of such type of data. Before, estimating the GARCH models ARCH LM test was performed to present volatility clustering. By trial and error method the best model was chosen on the basis of model selection criteria. Model with least Akaike Information Criteria (AIC) and least Bayesian Information Criteria (BIC) and least Hannan-Quinn value will be best fit. Table 16 shows GARCH models estimated to study the volatility in rainfall overtime. GARCH (1,1) with 1 lag was found to be the best fitted model to explain volatility in rainfall with least AIC and BIC value, 4396.19 4415.44 respectively. α and β are coefficients of ARCH and GARCH effect for the given series where 'α'-alpha is called as ARCH parameter and 'β'-beta is called as GARCH parameter. On comparing different models, the model with $\alpha + \beta$ value approaching 1 is the best fitted model. The sum of α and β coefficients represent the degree of persistence of volatility. GARCH (1,1) with 1 lag had highest value for α and β and the sum of the coefficients was 0.943. The sum of alpha and beta parameters was approaching unity indicating that high volatility and persistence of volatility in total rainfall.

Table 16. GARCH modelling of total rainfall

Garch model	lag	omega	alpha	Beta	p-value	AIC	BIC
0,1	0	17779.3	0.173	-	ω: 5.57e-012 *** α:0.0067 ***	4454.439	4465.996
0,1	1	17696.8	0.025	-	ω: 2.10e–010 *** α: 0.7301	4395.280	4410.680
0,2	0	18143.2	0.199 -0.034	-	ω: 8.16e-012 *** $\alpha1$: 0.0020 $\alpha2$: 0.2302	4455.947	4471.356
1,1	0	21235.5	0.195	-0.175	ω:0.0056 *** α: 0.0049 *** β: 0.5828	4456.072	4471.481
1,1	1	984.910	0.013	0.933	ω: 0.3630 α: 0.3984 β:1.37e-060 ***	4396.197	4415.444
1,2	0	1.04356e-08	0.175 -0.171	0.996	ω: 1.0000 $\alpha1$:0.0027*** $\alpha2$:0.0031 *** β: 0.0000 ***	4456.924	4476.185
1,2	1	990.189	0.011 0.001	0.933	ω: 0.4031 $\alpha1$: 0.8997$\alpha2$: 0.9944 β:3.19e-049 ***	4398.197	4421.293
2,1	0	23586.2	0.211	-0.104 -0.182	ω: 2.08e–05 *** α:0.0012 *** $\beta1$: 0.2745 $\beta2$: 0.0130 **	4456.012	4475.273
2,1	1	279.455	0.003	1.804 -0.824	ω: 0.636 α: 0.493 $\beta1$: 2.21e-035 *** $\beta2$: 6.26e-011 ***	4397.396	4420.492

Conditional standard deviation graph was plotted based on GARCH (1, 1) model with one lag for total rainfall. Figure 17 shows the trend of Conditional standard deviation of GARCH (1,1) model with one lag. There was seen a high fluctuation in total rainfall in 1999-2001 period.

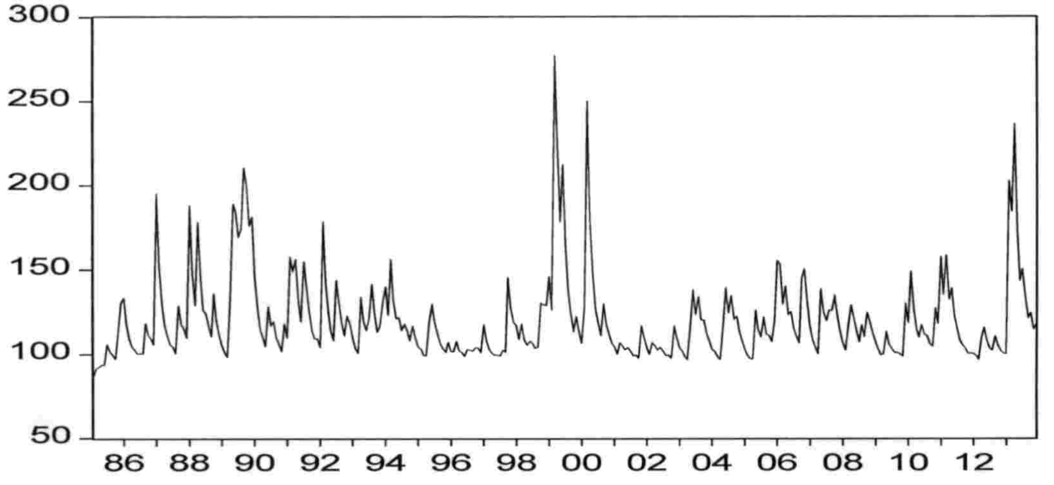

Figure 17. Conditional standard deviation graph of total rainfall based on GARCH (1,1)

GARCH modelling was done for deseasonalised total rainfall. As deseasonalised values are free from seasonality component the result gives more precise value. Table 17 shows GARCH modelling of deseasonalised total rainfall and GARCH (2,1) with 1 lag and E-GARCH (1,1) with 1 lag were found to be the best fit. The 'α'-alpha and 'β'-beta terms indicates the ARCH and GARCH effect for the given series where α is called as ARCH parameter and β is called as GARCH parameter. The sum (α+β) of their coefficients represents the degree of persistence of volatility. The sum of alpha and beta parameters of GARCH (2,1) with 1 lag is approaching one which shows high volatility of total rainfall. E- GARCH parameter 'γ'-gamma, if it is greater than zero it shows positive shock and if it is less than zero then indicate negative shock. Here the γ value is greater than zero which shows positive shock. That means as rainfall increases variability also increases.

Table 17. GARCH modelling of deseasonalised total rainfall

Garch model	lag	omega	alpha	gamma	beta	p-value	AIC	BIC
0,1	0	1.15	0.44	-	-	ω: 1.90e-06 *** α: 0.13	1159.24	1170.80
0,1	1	1.18	0.26	-	-	ω: 1.35e-07 *** α: 0.23	1124.53	1139.93
1,1	0	0.69	0.28	-	0.33	ω: 0.0002 *** α: 0.11 β: 0.002 ***	1154.13	1169.53
1,1	1	0.63	0.24	-	0.36	ω: 0.0001 *** α: 0.102 β: 0.001 ***	1116.59	1135.84
2,1	0	0.52	0.19	-	0.83 -0.37	ω:1.67e-07 *** α: 0.05 β1:1.09e-011 *** β2:8.71e-05 ***	1146.05	1165.31
2,1	1	0.42	0.07	-	1.22 -0.59	ω: 3.39e-06 *** α: 0.25 β1:2.26e-07 *** β2: 0.01 ***	1110.42	1133.52
E-Garch 1,1	0	0.002	0.18	0.1794	0.60	ω: 0.98 α: 0.1527 γ: 0.0301** β: 7.67e-07 ***	1151.54	1170.80
E-Garch 1,1	1	0.01	0.15	0.1963	0.64	ω: 0.9388 α: 0.3999 γ: 0.0227 ** β: 3.91e-06 ***	1114.34	1137.43

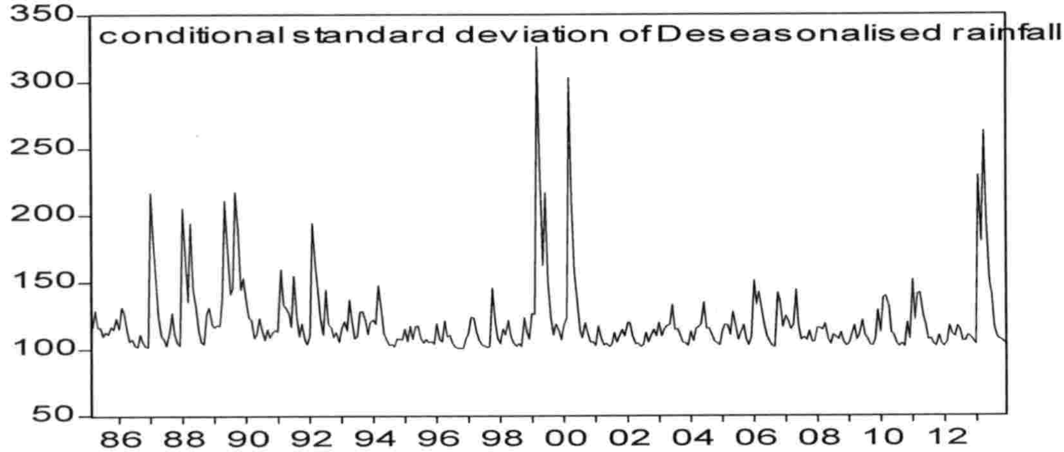

Figure 18. Conditional standard deviation graph for deseasonalised rainfall.

4.4 SOIL PARAMETERS

Soil parameters chosen in the study were organic carbon, phosphorus and potassium. To test whether there is any significant difference between 12 treatments based on soil parameters, MANOVA was carried out. The results of MANOVA for kahrif and rabi are presented in table 18 and Table 19. In MANOVA, we have three test statistic such as Wilks lambda, Roys largest root and Lawley-Hotelling trace. There was no significant difference between treatment means in 1985 based on three test statistics. However, the estimated p values of all the test statistic values were very smaller than 0.05, suggesting the presence of significant difference between treatments with respect to soil parameters in kharif season. Thus soil parameter differs significantly among 12 treatments, the soil organic carbon, phosphorus and potassium varies among treatments. Similar results were derived from the study by Tsai and Chen (2009).

In order to identify the best treatment ANOVA was carried out for soil organic carbo, soil phosphorus and soil potassium separately for both seasons in respective years. Comparison between treatment was made using CD value.

Table 18. MANOVA of soil parameters for kharif season

	1985		1990		1995		2000		2005		2010		2013	
	statistic	**P**	**Statistic**	**P**	**statistic**	**P**	**statistic**	**P**	**statistic**	**P**	**Statistic**	**P**	**statistic**	**P**
Wilks' lambda	0.48	0.66	0.16	0.0002	0.25	0.01	0.26	0.01	0.0002	0.000	0.001	0.000	0.000	0.000
Pillai's trace	0.63	0.66	1.34	0.0001	0.99	0.03	0.98	0.04	1.89	0.000	2.238	0.000	2.38	0.000
Lawley-Hotelling trace	0.88	0.66	2.54	0.0003	2.11	0.003	2.04	0.002	947.07	0.000	98.83	0.000	2247.00	0.000
Roy's largest root	0.53	0.10	1.20	0.001	1.63	0.001	1.56	0.0001	944.19	0.000	86.55	0.000	2220.79	0.000

Table 19. MANOVA of soil parameters for rabi season

	1985		1990		1995		2000		2005		2010		2013	
	statistic	**P**	**statistic**	**P**	**statistic**	**P**	**statistic**	**P**	**statistic**	**P**	**statistic**	**P**	**statistic**	**P**
Wilks' lambda	0.58	0.94	0.22	0.004	0.22	0.004	0.19	0.001	0.00	0.000	0.000	0.000	0.000	0.000
Pillai's trace	0.49	0.93	0.22	0.03	1.03	0.02	1.12	0.001	2.19	0.000	2.18	0.000	2.39	0.000
Lawley-Hotelling trace	0.63	0.93	2.48	0.000	2.43	0.001	2.88	0.00	3667.05	0.000	1966.34	0.000	3594.55	0.000
Roy's largest root	0.41	0.24	2.05	0.000	1.98	0.000	2.35	0.00	3659.44	0.000	1677.66	0.000	3565.59	0.000

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Table 20. ANOVA for organic carbon for kharif and rabi seasons

	KHARIF							RABI						
Year	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**
T_1	1.27	1.08	1.23	1.33	0.69	0.91	1.23	1.193	1.37	1.33	1.35	0.58	0.70	1.13
T_2	1.13	1.49	1.31	1.30	0.86	0.86	1.18	1.203	1.27	1.27	1.24	0.84	0.89	1.09
T_3	1.13	1.35	1.28	1.28	0.80	0.95	1.30	1.078	1.24	1.22	1.23	0.90	0.89	1.22
T_4	1.24	1.23	1.22	1.22	0.85	1.09	1.42	1.260	1.18	1.16	1.35	0.86	0.95	1.42
T_5	1.19	1.39	1.42	1.42	0.81	0.91	1.17	1.228	1.38	1.30	1.43	0.82	0.92	1.29
T_6	1.16	1.54	1.40	1.40	0.91	1.01	1.41	1.190	1.37	1.30	1.19	0.94	0.90	1.45
T_7	1.19	1.56	1.40	1.40	0.80	0.81	1.32	1.195	1.37	1.51	1.53	0.91	0.85	1.50
T_8	1.173	1.16	1.59	1.59	0.94	1.14	1.79	1.135	1.57	1.59	1.69	0.94	0.96	1.72
T_9	1.29	1.43	1.38	1.383	0.82	0.69	1.61	1.308	1.33	1.37	1.50	0.86	0.86	1.63
T_{10}	1.17	1.36	1.48	1.48	0.83	0.75	1.32	1.128	1.43	1.46	1.38	0.93	0.90	1.40
T_{11}	1.12	1.19	1.43	1.43	0.83	0.90	1.30	1.100	1.38	1.38	1.43	0.86	0.85	1.35
T_{12}	1.15	1.10	1.30	1.30	0.69	0.87	1.24	1.145	1.26	1.39	1.43	0.74	0.79	1.34
MST	0.01	0.11	0.05	0.04	0.02	0.06	0.13	0.01	0.04	0.08	0.04	0.04	0.02	0.13
MSE	0.01	0.04	0.05	0.05	0.01	0.02	0.03	0.02	0.05	0.06	0.004	0.004	0.01	0.05
F	0.83	2.39	1.02	0.87	1.19	2.72	3.72	0.653	0.43	0.61	1.11	11.56	1.30	2.72
p-value	0.61	0.02	0.45	0.58	0.33	0.01	0.002	0.77	0.93	0.81	0.38	8.5×10^{-09}	0.26	0.01
	NS	S	NS	NS	NS	S	S	NS	NS	NS	NS	S	NS	S
C.D.	N/A	0.312	N/A	N/A	N/A	0.227	0.272	N/A	N/A	N/A	N/A	0.087	N/A	0.328
SEM	0.06	0.11	0.11	0.11	0.07	0.08	0.09	0.081	0.12	0.12	0.13	0.03	0.06	0.11
C.V.	10.02	16.28	15.88	15.8	16.48	17.31	13.87	13.65	17.32	18.44	18.83	7.07	14.56	16.49

Table 21. ANOVA for phosphorous for kharif and rabi seasons

	KHARIF							RABI						
Year	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**
T_1	18.83	19.06	24.04	24.3	10.67	5.46	8.58	18.12	23.28	23.46	23.40	11.70	6.720	18.62
T_2	16.25	23.06	28.61	28.67	11.61	5.88	9.92	18.97	28.17	28.37	28.62	12.68	10.75	20.26
T_3	20.60	25.20	31.51	31.49	11.76	10.53	15.19	24.92	31.22	31.44	31.55	12.73	18.98	23.15
T_4	18.78	22.95	27.36	27.38	11.54	8.71	15.07	19.1	26.71	27.19	27.40	12.51	10.50	21.32
T_5	20.08	24.00	29.31	29.31	12.74	8.19	10.66	19.9	28.97	29.16	29.48	12.78	12.22	20.58
T_6	19.41	30.03	24.96	25.10	12.61	11.19	12.62	22.03	24.69	24.93	25.35	12.98	14.22	24.75
T_7	18.17	27.17	30.73	30.85	12.49	9.41	13.72	18.21	30.33	30.33	30.85	12.80	14.56	22.54
T_8	22.28	26.45	30.37	30.58	11.67	6.75	15.31	23.68	30.1	30.73	31.18	12.32	10.47	21.56
T_9	19.52	29.35	31.15	31.21	12.05	7.81	9.80	20.91	30.29	30.49	30.70	12.75	13.03	20.34
T_{10}	19.61	26.92	29.43	29.48	12.90	7.97	10.90	19.53	28.91	29.18	29.28	12.03	10.59	23.82
T_{11}	18.51	27.65	31.25	31.36	11.91	7.00	13.23	19.53	30.84	31.05	31.30	12.24	10.88	23.77
T_{12}	20.51	27.89	23.88	23.95	12.13	8.50	13.48	21.49	23.53	23.72	24.03	11.79	11.41	21.56
MST	8.89	38.67	32.25	31.60	1.56	11.89	21.74	18.41	32.77	32.99	33.92	0.71	1122.12	12.89
MSE	5.33	12.92	12.45	12.39	1.18	0.33	0.22	19.49	12.85	12.92	13.17	0.16	0.22	0.12
F	1.67	2.992	2.59	2.551	8.835	35.55	86.6	1.01	2.13	2.08	2.14	4.17	5365.45	9.65
p-value	0.13	0.01	0.02	0.02	2.59×10^{-07}	4.07×10^{-16}	1.73×10^{-22}	0.45	0.04	0.05	0.04	0.001	2.16×10^{-54}	9.6×10^{-23}
	NS	S	S	S	S	S	S	NS	S	S	S	S	S	S
C.D.	N/A	5.19	5.09	5.09	0.61	0.84	0.68	N/A	5.18	5.19	5.24	0.58	0.69	0.49
SE(m)	1.15	1.79	1.76	1.76	0.21	0.29	0.24	2.21	1.79	1.79	1.81	0.20	0.24	0.17
SE(d)	1.63	2.54	2.49	2.489	0.29	0.41	0.33	3.12	2.53	2.54	2.56	0.29	0.34	0.24
C.V.	11.92	13.93	12.36	12.29	3.50	7.13	3.81	21.50	12.76	12.68	12.69	3.23	2.94	1.57

Table 22. ANOVA for potassium for kharif and rabi seasons

	KHARIF							RABI						
Year	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**	**1985**	**1990**	**1995**	**2000**	**2005**	**2010**	**2013**
T_1	122.6	116.7	105.9	106.10	73.63	95.20	122.10	125.60	101.20	101.6	101.9	91.56	101.1	122.1
T_2	119.2	106.1	111.0	111.21	75.32	83.44	161.56	121.40	106.20	106.6	106.8	113.1	119.5	161.6
T_3	140.0	117.03	116.5	116.61	90.16	97.72	136.92	119.92	111.92	112.16	112.2	99.845	112.75	136.92
T_4	131.7	133.02	127.2	127.29	100.2	115.64	147.37	128.77	123.35	123.61	123.8	109.84	116.48	136.08
T_5	105.8	115.9	112	112.50	89.60	75.9	133.60	135.20	107.90	108.1	107.9	107.8	119.6	167.4
T_6	121.9	109.74	121.4	121.47	87.64	67.48	87.36	114.00	116.00	116.4	116.6	94.75	99.56	115.9
T_7	125.2	122.3	123	123.20	80.64	75.30	178.90	116.70	120.40	120.7	120.7	75.88	112.0	171.9
T_8	118.7	125.7	131.7	131.70	93.24	128.24	82.60	124.00	125.30	125.7	125.8	139.7	121.2	110.6
T_9	121.2	133.3	131	130.80	91.28	80.40	164.40	120.20	131.70	131.8	132.1	106.7	116.5	164.4
T_{10}	126.9	126.1	125	125.10	79.46	102.00	133.00	129.30	121.70	121.9	122.1	69.16	110.0	163.8
T_{11}	138.6	130.9	115	115.50	77.00	94.40	131.90	121.50	118.20	118.5	118.8	80.92	105.0	182.3
T_{12}	136.2	110.4	106.6	106.63	61.32	66.36	151.76	125.80	100.20	100.7	100.9	82.88	102.5	179.8
MST	382.00	350.26	316.34	317.29	457.08	1448.7	3316.8	136.65	92.25	389.30	390.5	1518.7	237.41	2577.18
MSE	1253	125.98	100.50	100.46	0.128	5.63	0.49	535.88	393.62	94.32	92.95	0.34	0.27	0.26
F	0.304	2.07	3.28	3.29	2821	248.47	7221.9	0.27	4.52	4.376	4.42	4664.2	957.88	10723.2
p-value	0.98	0.007	0.003	0.003	2.26×10^{-49}	1.7×10^{-30}	1.03×10^{-56}	0.99	0.0003	0.0004	0.003	2.68×10^{-53}	5.97×10^{-41}	8.39×10^{-60}
	NS	S	S	S	S	S	S	NS	S	S	S	S	S	S
C.D.	N/A	16.22	14.5	14.48	0.51	3.43	1.01	N/A	13.88	14.03	13.93	0.85	0.75	0.73
SE(m)	17.7	5.61	5.01	5.01	0.18	1.19	0.35	11.57	4.80	4.86	4.821	0.29	0.26	0.25
SE(d)	25.03	7.94	7.09	7.09	0.23	1.68	0.49	16.37	6.79	6.87	6.82	0.42	0.37	0.36
C.V.	28.17	9.31	8.43	8.42	0.43	2.63	0.52	18.74	8.32	8.39	8.33	0.60	0.46	0.34

4.4.1 Soil organic carbon

The results of ANOVA for organic carbon is showed in table 20 indicated significant difference between treatments only in 1990-91, 2010-11 and 2013-14 during kharif season. T_7 recorded highest soil organic carbon in 1990-91 and it was on par with T_2, T_3, T_5, T_6 and T_9 whereas T_8 showed highest soil organic carbon in 2010-11 and was on par with T_3 and T_4. T_8 recorded maximum in 2013-14 and it was on par T_9. In Rabi season 2005-06 and 2013-14 was found significant and T_8 and T_6 recorded maximum in 2005-06 and was on par in T_3, T_4, T_9, T_{10} and T_{11}; T_8 was recorded maximum in 2013-14 and was on par with T_4, T_6, T_7, T_9 and T_{10}. T_8 recorded maximum soil organic carbon in most of the years. Figure 19 and 20 shows the trends in soil organic carbon during kharif and rabi season respectively. It is evident from the graph that fluctuations in all the treatments were similar throughout the years.

4.4.2 Soil phosphorus

Table 21 shows the ANOVA results for soil phosphorus for kharif and rabi seasons. The ANOVA of all years except for 1985-86 shown that there is significant difference between treatments for both seasons. During kharif season, T_6 recorded maximum soil phosphorus in 1990-91 and was on par with T_3, T_7, T_8, T_9, T_{11} and T_{12}. T_{11} recorded maximum value in 1995-96 and was on par with T_2, T_3, T_4, T_5, T_7, T_8, T_9, T_{10}, T_{11} and T_{12}. T_3 showed maximum value in 2000-01 and was on par with T_2, T_3, T_4, T_5, T_7, T_8, T_9, T_{10} and T_{11}. T_{10} recorded maximum value in 2010 and was on par with T_5 and T_6.T_6 showed maximum value in 2010-11 which was on par with T_3 and T_8 recorded maximum value in 2013-2014 which was on par with T_3 and T_4. In case of rabi season T_{11} recorded maximum in 1990-91 and was on par with T_2, T_3, T_4, T_5, T_7, T_8, T_9 and T_{10}. T_3 recorded highest mean value in 1995-96 and 2000-01 which was on par with T_2, T_4, T_5, T_7, T_8, T_9, T_{10} and T_{11}. T_2, T_3, T_4, T_5 and T_7 was on par with T_6 which recorded highest mean value in 2005-06. T3 and T_6 showed maximum mean value in 2010-11 and 2013-14 respectively which were significantly different from other treatments. T_3 and T_6 showed maximum soil phosphorus value in most of the years. Figure 21 and 22 shows the trend analysis of soil organic carbon in kharif and rabi season respectively. It is evident from the graph that fluctuations in all the treatments were similar throughout the years.

4.4.3 Soil potassium

Table 22 shows the ANOVA results for soil potassium for kharif and rabi seasons. In potassium no treatments were found significant in 1985 in both seasons. During kharif season T_9 recorded highest mean soil potassium value and was on par with T_4, T_7, T_8, T_{10} and T_{11}. T_8 recorded highest mean value in 1995 and 2000and it was on par with T_4, T_6, T_7, T_8, T_9 and T_{10}. T_4, T_8 and T_7 was the treatments with highest soil potassium value during 2005, 2010 and 2013 respectively and were significantly different from other treatments. In rabi season T_9 performed well in 1990 and 1995 and were on par with T_4, T_7, T_8, T_{10} and T_{11}. T_9 recorded highest mean value in 2000 and was on par with T_4, T_8 and T_{10}. T_8 showed maximum mean value in 2005-06 which was significantly different from other treatments. T_5 showed highest mean value in 2010 and was on par with T_2.T_{11} showed maximum mean value in 2013-14 which was significantly different from other treatments. T_8 and T_9 showed maximum soil potassium value in most of the years. Figure 23 and 24 shows the trend analysis of soil organic carbon in kharif and rabi season respectively. It is evident from the graph that fluctuations in all the treatments were similar throughout the years.

There was a sudden decline in soil parameter values during the period of 2000-2005 and the reason for the decline in values is due to the flooding occurred in the field due to heavy rainfall in those years.

Similar study was carried out by Khokhar (2008) where ANOVA and MANOVA were used to test the significance of variation in each of the five soil parameters and clusted villages based on soil parameters in Panchamahal district of Gujarath.

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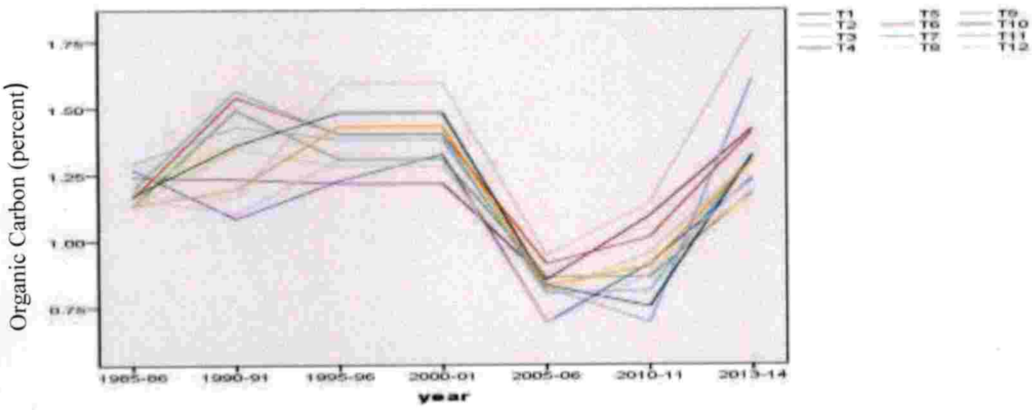

Figure 19. Trends in soil organic carbon in kharif season

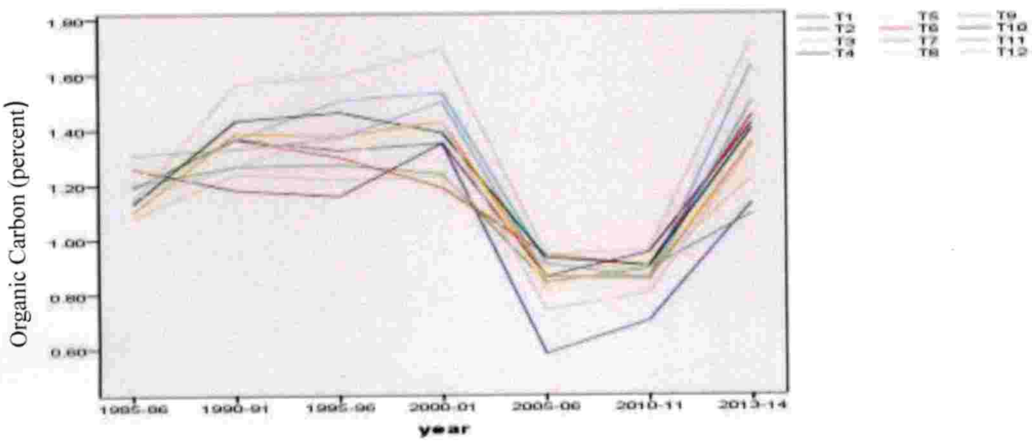

Figure 20. Trends in soil organic carbon in rabi season

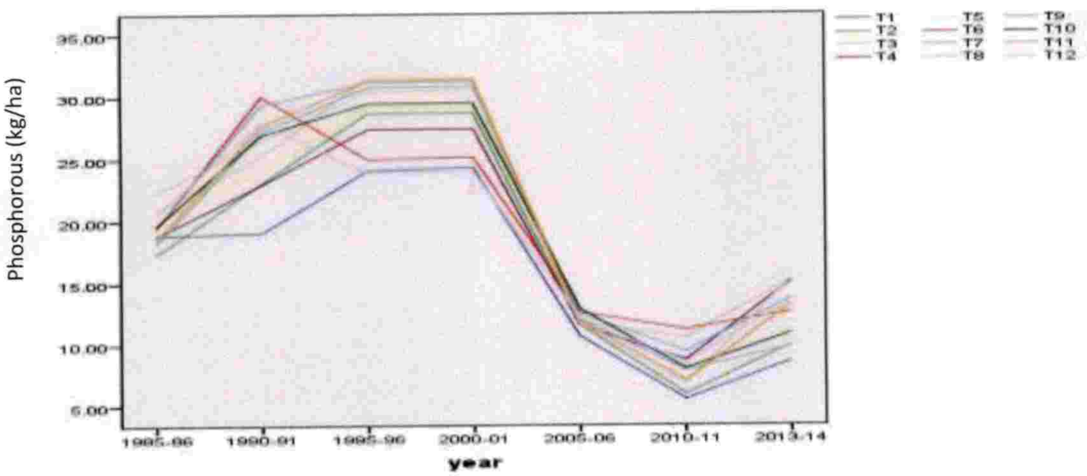

Figure 21. Trends in soil phosphorus in kharif season

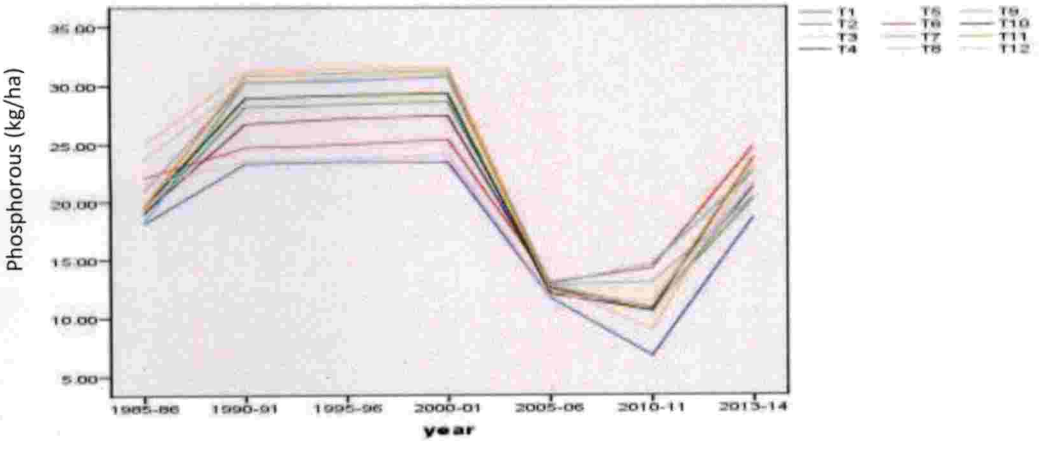

Figure 22. Trends in soil phosphorus in rabi season

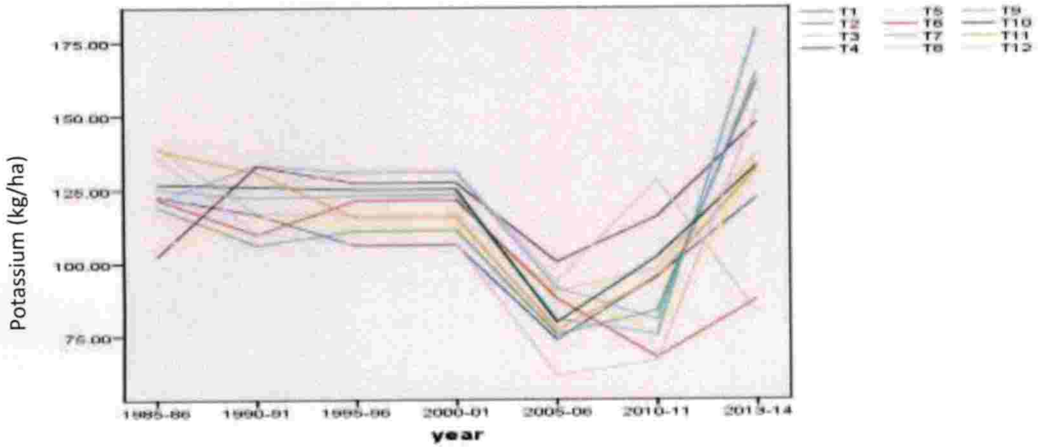

Figure 23. Trends in soil potassium in kharif season

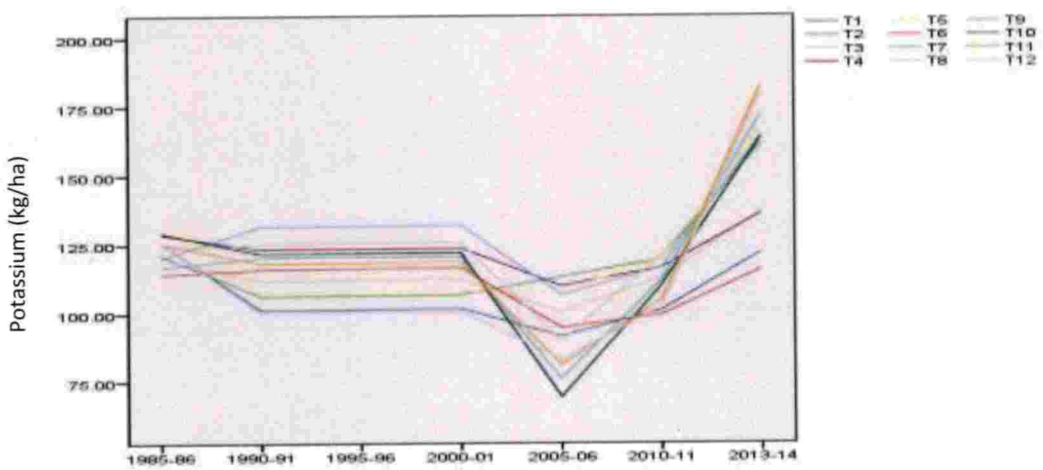

Figure 24. Trends in soil potassium in rabi season

4.4.4 Split-split plot design

In order to analyse the interaction effect of soil parameters with season and years a split-split plot analysis was conducted by taking years in the main plot seasons in the sub plot and treatments in sub-sub plot and the result is shown in Table 23.

Table 23. Split-split plot design for soil parameters

Source of variance	Degrees of freedom	Soil organic carbon		Soil phosphorus		Soil potassium	
		F-value	p-value	F-value	p-value	F-value	p-value
Main plot							
Year	6	36.03	<.0001	235.58	<0.0001	164.26	<0.0001
Main plot error	18						
Sub plot							
Season	1	0.04	0.84	211.41	<0.0001	27.75	<0.0001
Year×Season	6	0.17	0.98	53.89	<0.0001	17.74	<0.0001
Sub plot error	21						
Sub-sub plot							
Treatment	11	7.43	<.0001	38.92	<0.0001	13.15	<0.0001
Year×Treatment	66	1.74	0.001	13.10	<0.0001	7.62	<0.0001
Season× Treatment	11	0.70	0.74	13.11	<0.0001	2.33	0.0085
Year×Season× Treatment	66	0.68	0.97	10.35	<0.0001	1.96	<0.0001
Sub-sub plot error	462						

Treatment effect was found significant. Year x treatment interaction, year x season, and year x season x treatment interactions were also found significant for soil organic carbon. However, main plot factor, subplot factor and sub-sub plot factor and the interactions year×treatment, season×treatment and year ×season× treatment interactions were found significant in case of soil phosphorus and potassium. This suggests that, treatments are not consistent in with respect to seasons and year for these two soil parameters.

4.5 IMPACT OF SOIL AND WEATHER PARAMETERS OVER YIELD

4.5.1 Regression analysis

To find out the impact of weather parameters and soil parameters on grain yield, regression was performed by taking yield as the dependent variable and soil and weather parameters as independent variables.

Regression analysis was carried out by taking grain yield of all treatments separately with soil and weather parameters to find out the impact of soil and weather parameters on each treatments.

Table 24 shows the regression result of soil and weather parameters on all treatments. The estimated coefficients for phosphorus (5% level of significance), rainfall, maximum and minimum temperature (1 % level of significant) were found to be positive and significant effect of grain yield based on T_1. None of the parameter effects were found significant in case of T_2. Effect of rainfall was found positively significant on T_3, T_4, T_5, T_6, T_8, T_9, T_{10} and T_{11} at 5 per cent level of significance and T_1 and T_{12} at 1 percent level of significance. T_6 at 5 per cent level of significance and minimum temperature at 1 per cent level of significance. Effect of minimum temperature was found positively significant on T_7 and T_7 at 1 per cent level of significance. Effect of phosphorus and maximum temperature was found positively significant with grain yield of T_1 at 5 per cent level of significance.

Similar result of regression analysis found in the study by Prakash *et al.* (2011) indicated that an increase in summer rain and maximum temperature had contributed positively to rice yield.

Study by Karn (2014) has shown that one degree Celsius (1°C) rise in day time maximum temperature during the ripening phase of rice resulted an increased in yield during harvest. At the same time the result of analysis also indicated that productivity drops when the day time maximum temperature goes above 29.9°C.

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Table 24. Treatment wise regression analysis

Treatment	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}
Intercept	-0.31	2.80	2.52	1.51	0.53	-0.28	0.85	1.21	1.98	2.98	2.004	2.51
OC	0.06	0.01	0.03	0.04	0.07	0.10	0.09	0.04	0.04	0.04	0.04	0.05
P	0.01**	0.002	0.002	0.004	0.002	0.001	-0.003	-0.01	-0.003	-0.003	-0.003	-0.003
K	0.00	0.001	0.001	0.002	0.001	0.002	0.0004	0.00	0.0005	-3×10^{-5}	0.0003	4.3×10^{-5}
Rainfall	0.001*	0.001	0.001**	0.001**	0.001**	0.001**	0.001*	0.001**	0.001**	0.001**	0.001**	0.001*
Max temp	0.06*	0.001	0.003	0.01	0.03	0.04	0.006	0.02	0.01	-0.005	0.001	-0.004
Min temp	0.07	0.03	0.03	0.06	0.09	0.10*	0.09*	0.06	0.04	0.02	0.06	0.04

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Regression analysis was carried out by taking grain yield of all treatments together of each season separately with soil and weather parameters. Weather parameter values for June, July and august for kharif and September, October and November for rabi were chosen for the multiple regression analysis. The result of regression analysis for kharif season is shown in Table 25. The results of regression analysis in kharif season suggest a significant and negative and significant influence of maximum temperature and soil potassium on grain yield and a positive and significant influence of total rainfall on grain yield.

Table 25. Regression table for kharif grain yield

Yield	Coef.	SE.	t	p-value	[95% Conf. Interval]	
OC	-0.15	0.10	-1.43	0.189	-0.39	0.09
P	0.004	0.004	0.91	0.388	-0.006	0.01
K	-0.006	0.002	-3.10	0.015	-0.01	-0.001
MaxTem	-0.177	0.07	-2.41	0.043	-0.34	-0.01
MinTem	0.002	0.04	0.06	0.953	-0.09	0.09
TotalRain	0.0008	0.0003	2.28	0.052	-9.02×10^{-6}	0.002
Cons	9.57	1.98	4.84	0.001	5.01	14.13

Table 26 shows the regression analysis for grain yield of all treatments together of rabi separately with soil and weather parameters in rabi season. The results of regression analysis in rabi season showed that total rainfall was influencing positively and significantly on grain yield whereas potassium and maximum temperature contributing was negatively (significant) to grain yield.

Table 26. Regression table for rabi grain yield

Yield	Coef.	SE	t	p-value	[95% Conf. Interval]	
OC	0.06	0.12	0.52	0.62	-0.20	0.33
P	-0.005	0.005	-1.03	0.33	-0.02	0.006
K	-0.0003	0.002	-0.14	0.89	-0.004	0.004
MaxTem	0.03	0.05	0.56	0.59	-0.09	0.14
MinTem	0.14	0.05	2.62	0.03	0.02	0.27
TotalRain	0.001	0.0005	1.39	0.20	-0.0004	0.002
Cons	-0.69	2.29	-0.30	0.77	-5.97	4.58

This finding is reliable with that of the study by Welch *et al.* (2010) on impact of climate change on rice where it was indicated that maximum temperature increases yield but at a decreasing rate during the ripening phase. Similar result for potassium was found in the study by Ladha *et al.* (2002) where in the long term experiments that there was a decreasing trend in the yield of paddy and wheat due to depletion of soil potassium which seems to be the general cause for this trend.

Summary

5. SUMMARY

The present research study entitled "Statistical modeling for the impact of weather and soil parameters on the yield of paddy under Long Term Fertilizer Experiment" was formulated with the following objective.

To develop suitable statistical models to analyse the change in weather variable over time, changes in soil parameters across treatments in Long Term Fertilizer Experiment (LTFE) over the years and to analyse the impact of weather and soil parameters on the yield of paddy across different treatment.

This study is based on data collected from long term fertilizer experiment on rice (var. Aiswarya) conducted at Integrated Farming System Research Station (IFSRS), Karamana namely, 'Permanent plot experiment on integrated nutrient supply system for cereal based crop sequence' carried out for the period from 1985-86 to 2013-14. The field experiment was a long term fertilizer trial experiment consisted of twelve different treatments on recommended dose of fertilizers including a control (no fertilizers and no organic matters) and farmers practice where T_1 represents the control and T_{12} represents the farmers practice. It was conducted a randomized block design with four replications. The main items of observation include weather parameters (maximum temperature, minimum temperature and total rain fall), soil parameters (organic carbon, phosphorus and potassium) and yield parameters (grain yield and straw yield) for the period from 1985-86 to 2013-14. The yield and soil parameters were collected from IFSRS, Karamana and the weather parameters were collected from Department of Agricultural Meteorology from College of Agriculture, Vellayani for the period from 1985-86 to 2013-14.

The salient findings of the study are given below.

ANOVA was performed to study the significant difference of the treatments used in the design based on grain and straw yield. The results of ANOVA on grain yield for some selected years in kharif and rabi seasons revealed that, treatments were significant in all years (1990-91, 1995-5-96, 2000-01, 2005-06, 2010-11 1nd 2013-14) except 1985-

86 in kharif and treatments were significant in all years (1985-86, 1990-91, 1995-5-96, 2005-06, 2010-11 1nd 2013-14) except 2000-01. Among the treatments T_6 has given maximum grain yield in most of the years and least was recorded for T_1. The trend in mean grain yield of 12 treatments during rabi season was similar to that of kharif season. Trend in grain yield of 12 treatments were similar till 2004-05 but slight fluctuation was noticed for T_5 and T_8 after 2004 in rabi season.

Results of ANOVA for straw yield showed that treatments were significant in 1985-86, 2005-06, 2010-11 and 2013-14 but not significant in 1990-91, 1995-96 and 2000-01 in kharif and treatments were significant in 1985-86, 2005-06 and 2010-11 but not significant in 1990-91, 1995-96, 2000-01 and 2013-14 in rabi season.

Split-split plot analysis was carried out for grain yield and straw yield to understand the effect of treatments over the year and over the treatments. The factors such as treatments, season, and year factors were significant and year × treatment interaction, year × season interaction and year × season × treatment interactions were found significant for grain yield. Treatments, season, and year were significant for straw yield. Year × season interaction was also found to be significant for straw yield.

Trends in yield parameters were carried out graphically for 29 years separately for kharif and rabi seasons. The graphs showed high fluctuation but all the treatments followed similar trend throughout the period. T_1 has shown least result in all the years in both kharif and rabi seasons for grain and straw yield. T_6 has given maximum grain yield in most of the years in kharif season. In rabi season T_{11} has given the maximum grain yield. For straw yield T_6 and T_3 in kharif and rabi respectively gave highest yield.

Descriptive statistics, seasonality index and deseasonalisation were carried out for maximum temperature, minimum temperature and total rainfall. Similar trends of increasing and decreasing pattern can be observed from the graph. The range of average maximum temperature varied from 30.47^{0}C to 31.61^{0}C with a coefficient of variation (CV) less than 6. The minimum temperature varied from 22.00^{0}C to 24.25^{0}C with CV

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less than 6. However, the range of total rain fall was very high (878.95-2311.80mm) with very high and fluctuating CV.

ARIMA (101) (111) and ARIMA (011) (011) were the best fitted models for maximum and minimum temperature respectively as their AIC and BIC were found to be the least. Weather forecasting was done for both parameters based on respective best selected models and the mean absolute error was found to be 0.034 and 0.14 respectively for maximum temperature and minimum temperature.

Total rainfall data showed high variability throughout the period of study GARCH (1,1) with one lag was the model found to be the best fitted model with sum of coefficients ($\alpha+\beta$) as 0.943. GARCH (2,1) with sum ($\alpha+\beta$) as 0.7 and E-GARCH (1,1) with sum of coefficients ($\alpha+\beta$) as 0.79 and with one lag were the best model for deseasonalised total rainfall. The result of GARCH model suggest high volatility in total rainfall during the years and it was persistant for long time.

MANOVA was carried out for some years, kharif and rabi seasons separately and there was a significant difference for all years except the first year was observed in both seasons. The result of MANOVA indicated that there was significant difference in soil organic carbon, soil phosphorus and soil potassium in all years except first year. T_8 recorded maximum soil organic carbon in most of the years. T_3 and T_6 showed maximum soil phosphorus value and T_8 and T_9 showed maximum soil potassium value in most of the years.

Split-split plot design was carried out to find out the interaction effect of treatment×season, treatment×year and treatment×season×year on soil parameters. Treatment effect was found significant, year × treatment interaction, year × season interaction and year × season × treatment interactions were also found significant in soil organic carbon. All individual effects and year×treatment, season×treatment and year ×season× treatment interactions were found significant for soil phosphorus and potassium.

Total rainfall was positively and significantly influencing the yield of all the treatments except T_2. It was also noticed that minimum temperature had positively significant effect for T_6 and T_7.

To find out the impact of weather parameters and soil parameters on grain yield, regression was performed by taking yield as the dependent variable of all the treatments and soil and weather parameters as independent variables. In kharif season maximum temperature and soil potassium had negative and significant influence on grain yield whereas, total rainfall had positive and significant effect on grain yield. Minimum temperature was found to be positively influencing (significant) grain yield in rabi season.

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Abstract

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STATISTICAL MODELING FOR THE IMPACT OF WEATHER AND SOIL PARAMETERS ON THE YIELD OF PADDY UNDER LONG TERM FERTILIZER EXPERIMENT

by
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Statistical modeling for the impact of weather and soil parameters on the yield of paddy under Long Term Fertilizer Experiment

The study entitled "Statistical modeling for the impact of weather and soil parameters on the yield of paddy under Long Term Fertilizer Experiment" was undertaken with the objective to develop suitable statistical models to analyse the change in weather variables over time. It also focused on changes in soil parameters across treatments in Long Term Fertilizer Experiment (LTFE) over the years and the impact of weather and soil parameters on the yield of paddy. The analysis was carried out based on secondary monthly data of weather parameters *viz* maximum temperature, minimum temperature and total rainfall, collected for a period 1985-2014 from the Department of Agricultural Meteorology, College of Agriculture, Vellayani. Data on soil organic carbon, phosphorus, potassium, grain yield and straw yield in kharif and rabi season were collected from the 'Permanent plot experiment on integrated nutrient system for a cereal based crop sequence' conducted at Integrated Farming System Research Station (IFSRS), Karamana on rice (variety Aiswarya) for a period 1985-2013. The experiment was conducted in Randomised Block Design with 12 treatments (named as $T_1, T_2, \ldots, T_{12}$) and 4 replications.

Mean, Standard deviation and coefficient of variation of maximum temperature, minimum temperature and total rainfall was worked out for different years. Maximum temperature (2.69-5.36) and minimum temperature (2.78-7.26) have shown less coefficient of variation however, coefficient of variation was very high for total rainfall (74.11-127.17). Autoregressive Integrated Moving Average (ARIMA) models were used to model maximum and minimum temperature based on their own past lagged values. ARIMA (101) (111) was found to be the best model for maximum temperature as it has satisfied least AIC (Akaike Information Criteria) and BIC (Bayesian Information Criteria). ARIMA (011) (011) was found to be the best model for minimum temperature. Seasonal effect was removed to avoid cyclical fluctuations in rainfall and variation in monthly rainfall over time was estimated using Generalized Auto Regressive Conditional Heteroscedasticity (GARCH) model. GARCH (2, 1) and E-GARCH (1, 1) with 1 lag were found to be the best model to explain the variability

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over the period (1985-2013). High fluctuation in total rainfall was noticed during the years 1999 and 2000 based on conditional standard deviation graph.

Multivariate Analysis of Variance (MANOVA) was performed on soil parameters to test the significant difference between treatments over the years in kharif and rabi. There was significant difference between soil organic carbon, phosphorus and potassium between 12 treatments during 6 years (1990, 1995, 2000, 2005, 2010, and 2013) in both seasons. Further ANOVA was done to test the significant difference between treatments based on each soil parameters. Results of Analysis of Variance (ANOVA) revealed that T_8 had high soil organic carbon and potassium whereas T_3, T_8 and T_9 showed high soil phosphorus in kharif. T_8, T_3 and T_9 showed highest soil organic carbon, phosphorus and potassium respectively in rabi. Split-split plot analysis was conducted with main plot as year, sub plot as seasons and sub-sub plot as treatments to test the interaction effect of treatments with season and year. Only the year×treatment interaction was found significant in case of organic carbon whereas year×treatment, season×treatment interactions were found significant for phosphorus and potassium. This result indicated that there was significant difference in potassium and phosphorous over the seasons with respect to treatments.

On comparing the yield of different treatments T_6 was found with highest grain yield and T_1 was the least in both seasons. The graph for trend in grain yield and straw yield suggest same pattern for all the treatments over the entire period. Split-split plot analysis was carried out to find out the interaction effect of treatment×season, treatment×year and treatment×season×year on grain yield and straw yield. There was significant interaction between years and seasons for straw yield.

To find out the impact of weather parameters and soil parameters on grain yield, regression was performed by taking soil and weather parameters as independent variables. The results of regression analysis suggest that there was significant and negative influence of maximum temperature and soil potassium on grain yield whereas the effect of total rainfall on grain yield was positive and significant in kharif season. However, minimum temperature and total rainfall were influencing positively and significantly the grain yield in rabi season.

ARIMA models were found to be the best model for predicting maximum and minimum temperature and GARCH models were found to be good in estimating volatility of total rainfall. T_6 (50 percent Recommended dose of fertilizers (RDF) - (90: 45: 45 kg NPK/ha) of NPK+ 50 percent FYM in kharif and 50 percent RDF of NPK in rabi) showed good result for grain yield by comparing treatment wise performance throughout the experiment during kahrif and rabi. The treatment absolute control (T_1) has recorded with lowest yield. The effect of weather and soil parameters on the yield of rice studied using regression analysis across treatments revealed that total rain fall had positive and significant effect on grain yield of twelve treatments except T_2. In case of treatments T_6 and T_7, minimum temperature also had positive effect on grain yield but in case of T_1 soil phosphorus and maximum temperature also showed positive significant result.