Assessing the impact of climate change on wheat and Maize using ARIMA modeling. A case study of Sargodha and Faisalabad

By

Numrah Hina

Registration No. 00000327223

Supervisor

Dr. Deedar Nabi

Institute of Environmental Science & Engineering
School of Civil & Environmental Engineering
National University of Sciences & Technology
Islamabad, Pakistan

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A thesis submitted in partial fulfillment of the requirement for the degree of Master of Science in Environmental Science

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Ms. Numrah Hina

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Supervisor: ....
Associate Professor
Dr. Deedar Nabi
IESE, SCEE, NUST

GEC Member: …………………………………
Dr. Muhammad Fahim khokhar
Professor
IESE, SCEE, NUST

GEC Member: ……………………………….
Dr. Zamir Hussain
Associate Professor
(SINES),NUST

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DEDICATION

This research is dedicated to my loving, caring, and industrious parents and my best friend Misha Nadeem whose efforts and sacrifice have made my dream of having this degree a reality. words cannot adequately express my deep gratitude to them.
"O My Sustainer, Bestow on my parents your mercy even as they cherished me in my childhood".

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TABLE OF CONTENTS

LIST OF ABBREVIATION

ARIMA	Autoregressive Integrated Moving Average
ADF	Augmented Dickey Fuller test
ACF	Autocorrelation Factor
PACF	Partial autocorrelation factor
P	Autoregressive
D	integrated
Q	Moving Average
AIC	Akaike information criteria
RMSE	Root Mean Square error
MPE	Mean Percentage Error
MAE	Mean Absolute Error
MPE	Mean percentage error
MASE	Mean Absolute Standard Error

LIST OF FIGURES

LIST OF TABLES

Abstract

Climate change is exhibiting detrimental effects in every wake of life. The impact on agriculture, water, food, and energy sector is very prominent. Though we should continue our efforts to slow down the rate of climate change in our favor, we should also think about climate adaptation measures. To better adapt to climate change, we need to have robust models to foresee the impact of climate change under the different scenarios. In my study, I try to evaluate the impact of different climatic factors on the productivity of wheat and maize crops using time series analysis and ARIMA modeling. The crop data was taken from the crop reporting service Punjab and climate data from Pakistan Meteorological Department for two cities Faisalabad and Sargodha. This study was conducted to find the patternicity and to forecast the mean maximum temperature, mean monthly precipitation, and yield(maund/acre) for Sargodha and Faisalabad for the year 2022-2028 using time series analysis and ARIMA modeling. The stationarity of time series was evaluated using ACF(Auto Correlation Factor) and PACF(Partial autocorrelation Factor). The best fit model was chosen based on Akaike Information Criteria. My study showed that the yield of wheat and maize has increased from 1990 to 2021 for Sargodha. This study conjectures that the yield(maund/acre) for wheat and maize would increase for the next six years, 2022-2027. The mean monthly maximum temperature has increased from the year 2004-2020 and it is estimated that the mean monthly maximum temperature will increase during the wheat crop sowing season for Sargodha from 2022-2027. It will have a negative impact on wheat crop development. But its effect on the growth of maize is nonsignificant. The timeseries analysis of monthly amount of precipitation for Sargodha from 2004-2020 show that precipitation is decreasing during the wheat crop sowing season and is increasing during the crop harvesting season. This will have negative effect on the wheat crop and maize crop. A multivariate timeseries analysis was also performed. And results support the conducted research. Taken together the climate change has negative impact on crop productivity. There is a need to adjust the sowing and harvesting dates of wheat and maize. Drought and water lodging resistant varieties should be grown that are not susceptible to the increase in temperature and precipitation.

CHAPTER # 1

1. INTRODUCTION

1.1Background Information

Climate change is particularly associated with the unprecedented increase in greenhouse gases, carbon dioxide, fluorinated gases, nitrous oxide, and methane that leads to drastic changes in precipitation, and temperature extremes that impart negative impacts on the hydrological cycle, causing irregular precipitation trends and droughts. Climate change is termed to be a global issue (Ali et al., 2017). The agriculture sector is considered to be the most affected by climate change which can reduce crop productivity.

According to IPCC "Humans have caused net positive radiating forcing that leads to accumulation of excessive energy causing heating. From 1971 -2016, there has been an increase in the heating of the climate system from 0.50-to 0.79. Ocean warming has increased by 91%, land warming, atmospheric warming, and ice loss constituted around 1%, 3%, and 5%''respectively.

There is a strong association between climate and Agriculture. Climate change is responsible for the biotic and abiotic stresses that have impacts on agriculture. Crop productivity is affected by various climatic factors for example annual rainfall, heatwaves, average temperature, weed infestation, insect pest attack, global variation in atmospheric CO_2, and ozone level. Therefore, climate change has diverted the attention of researchers as these variations are affecting global food production and leading to food security issues. Agriculture is considered to be the most endangered sector that is drastically affected (Raza et al., 2019). The intensity and frequency of weather patterns have increased resulting in global climate change (Mäkinen et al., 2018a). The global climate is changing and increasing in carbon dioxide and temperature. The burning of fossil fuels is the main cause of warming. Therefore, it is estimated that the current fossil fuel reserves can increase the temperature of the globe by about 2°C by 2050 (Fatima et al., 2020).

1.2 Climate and crop yield relationship

The crop yield association between climatic variables plays an important role to cope with the increased food demand to feed a large population (Iizumi & Ramankutty, 2016). Various studies consider the climate crop yield relationship to be constant with time. But, due to recent warming trends and changed agricultural practices, climate yield associations may vary with time (Ágústsdóttir, 2016). The relationship is important to understand the response of crop yield to climatic extremes (Toreti et al., 2019). Recent research findings have depicted the occurrence of extreme weather events like heatwaves and droughts that may affect agriculture productivity and vegetation, as compared to separated temperatures and drought extremes (Hao et al., 2018).

Around the globe, a few regions are currently undergoing precipitation changes. Hydrological limitations effects on plants include, bending of the stems, lodging, Failure of the root anchorage in soil, Soil-borne fungal diseases, Limited radiation use efficiency, Reduce the yield, Hypoxia, or anoxia, that causes the crop to remain Unharvested and leading to Lower biomass growth and yields (Miedaner & Juroszek, 2021).

Wheat and Rice yields depict higher sensitivity to the precipitation variations (Iizumi & Ramankutty, 2016). Total food grain yield over India during Kharif (summer) season is directly affected by variations in the summer monsoon precipitation (June-September) (Prasanna, 2014).

(Mäkinen et al., 2018b) found out the impact of climatic variations on the wheat crop in Europe. It was found that in total out of 784 cultivars of wheat 55% of the cultivars tolerated the precipitation whereas only and 1 cultivar responded positively in southern Europe. Whereas out of 756 cultivars 24% tolerated the heavy rainfall and the remaining all the wheat cultivars suffered the negative impacts whereas only 1 cultivar responded positively to the heavy rainfall.

After carefully assessing the effects of climatic conditions and the previous reports about wheat and maize crop production trends I formulated the problem statement for my research.

1.3 Problem Statement

Changing climatic pattern is causing unprecedented increase in temperature and irregular rainfall that has negative impact on the production of wheat and maize causing reduced growth and yield production.

Therefore, we need to have robust models that forecast future yield estimates and climatic variables to ensure food security and give insight of climate change.

1.4 Study Area

This study area of my research comprised of two cities of Punjab, Pakistan. These are Sargodha and Faisalabad.

1.4.1 Sargodha

Sargodha is an agrarian district of Punjab, Pakistan. The region comprises a population of 3,696,212 where around a population of 2,608,00 lives in rural areas and 1,088,205 lives in Urban areas according to the 2017 Census (Pakistan Bureau of Statistics). It is situated on the latitudinal position of 31.34º N to 32.36ºN and 72.10ºE to 73.18ºE. It ranks among the 12 biggest cities in Pakistan. It is also known as the city of Eagles. The region is located between the two rivers Chenab and Jhelum. The alluvium provided by these two rivers enhances the fertility status of the area. Agriculture is the backbone of the rural economy and the major source of livelihood for the people. The district is dependent on rainfall and temperature for agricultural produce (Muhammad et al., 2017). Maize and wheat are one of the most grown crops in the Sargodha.

1.4.2 Faisalabad

Faisalabad is the third largest city in Pakistan (Jabeen et al., 2021). It is also known as the "Manchester of Pakistan". And it is located in the northern part of Punjab province and comprises an area of 5286 km^2. It is situated at Latitude of 31.4504° N and longitude 73.1350° E. According to the 2017 census the district comprises of 7882444 inhabitants where around 3766866 and 4115578 are residents of the urban areas and rural areas respectively (Pakistan Bureau of Statistics). Wheat and maize are one of the most grown crops in the district.

1.5 Aims and objectives of the Study

After analyzing the impacts of climatic variations on food crops like wheat and maize my study aimed to forecast the yield (maunds/acre) of wheat and maize along with climatic variables. The study would enable us to get know the impact of climate change on the major crops of Sargodha and Faisalabad with the help of the ARIMA model. As both cities are crop-growing areas. And it would enable the government to formulate policies to cope with the effects of food security due to extreme weather patterns. The objectives of my study are listed below.

1. To forecast the yield (Maund/Acre) of Wheat, in Sargodha for the year 2022-2027.

2. To forecast the yield (Maund/Acre) of Maize, in Sargodha for the year 2021-2027.

3. To forecast the yield (Maund/Acre) of Wheat, in Faisalabad for the year 2022-2027.

4. To forecast the yield (Maund/Acre) of Maize, in Faisalabad for the year 2021-2027.

5. To forecast the mean monthly maximum temperature for Sargodha for the year 2022-2027.

6. To forecast the total monthly amount of precipitation in mm for the Sargodha for the year 2022-2027.

7. To forecast the mean monthly maximum temperature in Faisalabad for the year 2022-2027.

8. To forecast the total monthly amount of precipitation in mm for Faisalabad for the year 2022-2027.

CHAPTER # 2

2. Literature Review

This chapter shows the methods and statistical techniques that are used to estimate and forecast different weather and crop parameters for efficient and accurate research in recent times. The techniques are according to the aims and objectives of the study. An extensive literature review was carried out by consulting various articles and journals from international and domestic publications to study how ARIMA Modeling can be used to assess the impact of climate change and forecast crop production.

It has been found that an increase in warming has significant trends in the temperature patterns of Sargodha and Rawalpindi (Abbas, 2013). It has been found that the production of maize in semi-arid areas will be impacted due to climatic extremes, particularly in Punjab Pakistan. An increase in temperature during the initial stages of a crop reduces yield (Waqas et al., 2020).

2.1 Wheat Production

Wheat is a major rabi season crop in Pakistan. Forecasting techniques are used mainly for the estimation of production, yield, and area of crops along with the impacts of climatic variables. These estimations are necessary for the Government to meet its aims regarding the storage, exports, and imports of the crop. The Timeseries technique provides a method to use historical data on Yield, production, and area of the corresponding crop to estimate future trends (M. Amin et al., 2014). Wheat production forecasting is mainly dependent on the cultivation area. Therefore, it is necessary to determine a model to select, identify and estimate wheat production based on the cultivated area in terms of yield production of major crops like wheat, maize, rice, Cotton, etc. in Pakistan. Forecasting crop yield and production requires the application of statistical techniques. Various studies have applied the ARIMA model to forecast future yields. (Đoković et al., 2019), applied the Box-Jenkins ARIMA model to forecast maize yields in Serbia. Therefore, it is necessary to determine a model to select, identify and estimate wheat production based on the cultivated area in terms of yield production of major crops like wheat, maize, rice, Cotton, etc. in Pakistan. Another study conducted by Saeed et al., focused on an empirical study for forecasting and modeling by using the box Jenkins Methodology for forecasting wheat production in

Pakistan ARIMA model (1,2,2) was found to be the most suitable (Muhammad Amin, 2015).

2.2 Maize Production

Maize belongs to the Poaceae Family. And it's also called Zea Mays. It originated in Central America and Mexico (*Broadening the Genetic Base of Grain Cereals*, n.d.). Maize is grown in spring and rabi season in Pakistan. A study conducted by (Badar et al., 2015) showed the yield production of some important food crops in Pakistan. The technique utilized was ARIMA Model. Where it was found that maize yield and production were estimated to be 6088 kg /ha and 5784 tons for the year 2020-2029. Another research conducted in Nigeria by (Badmus et al., 2011), found that ARIMA (2,1,2) and (1,1,1) were estimated for maize production and area estimation. Where it was found that forecasted production has an increasing trend.

2.3 Impact of climatic variables on wheat and maize

Precipitation and temperature are among the mainly important climatic variables that are used to describe some extreme weather effects, that can have great impacts on society and ecosystems (Wazneh et al., 2020). Climatic variables not only change the water availability process but also impact crop productivity. In some parts of the world increase in temperature have drastic impacts on crop growth and development by impacting the metabolic and physiological processes. An increase in temperature affects the sensitive crop growth stage. The variations in the crop area are affected by climatic variations, and crop water availability may also be affected (Raza et al., 2019). The phenology of crops is determined by several environmental and agronomic practices. The phenological phases of the crops are strictly associated with the seasonality of the surrounding environment and can be affected by changes in the environment. The length of phenological stages is associated with CO_2 assimilation. Therefore, change in phenological shift impact crop yield (Fatima et al., 2020). According to Fatima et al., wheat phenology has been affected by climate change. It is difficult to find the impact of climate change on wheat phenology due to changing cultivars and sowing dates. Wang et al., studied the phenological trends in winter wheat and spring cotton in response to climate changes in northwest China. It was found that the production persisted maximum in northwest China from 1983-2004. Whereas the highest trend was found in 1981-2010. There was an increased reduction trend observed in phenological stages in the north-south regions of China during 1981-2010.

(Waqas et al., 2020) stated that an increase in climatic variations within and between years is unavoidable and considerable shifts in the start of monsoon, precipitation intensity, and frequency were observed along with the change in the hydrological cycle in south Asia. An increase in climatic variations can not only cause droughts and floods but also impact net crop production by inducing biochemical and metabolic processes. Therefore, it ultimately reduces yield. And it is found that these variations reduces the lengths of the growing season (Siatwiinda et al., 2021). Yield loss is higher when high and low temperatures extremes overlap with sensitive crop growth stages e.g., the reproductive stage. Another study conducted by (Fatima et al., 2020) showed that crop exposure to water and heat stress may affect various crop growth stages which ultimately affects the yield. This leads to reduced crop production and grain quality. Therefore, this leads to adverse effect on the phenology of crop. According to Li and Zhang, the critical maximum temperature at flowering ranges from 32℃ to 35℃ for maize. But temperature above 35℃ impacts reproductive success and affects fertilization and flowering. This leads to poor grain filling which affects normal grain production (Li & Zhang, 2022). Another research conducted by (Abid et al., 2015) also suggested that temperature stress has a significant impact on wheat production.

2.4 ARIMA modeling and Climatic Variables

Meteorological parameters not only effect the water availability process but also influence crop productivity . (Al Sayah et al., 2021) conducted research and studied for evaluating the impact of climate change on the Mediterranean context. Forecasting was completed using ARIMA Model and showed an increase in variability of rainfall and aridity. The results show that there was an increase of 0.7 °C maximal, 0.8°C, and 0.9°C average temperature. It was observed that there was an average 6mm decreased of precipitation for the year 2020.

Rainfall is an important part of hydrological cycle (Venkata Ramana et al., 2013).Therefore, the forecast of climatic variables, the analysis and investigation of rainfall is also essential. The accurate forecasting of rainfall is also important for the better management of water reserves, especially in arid regions. A study conducted by (Venkata Ramana et al., 2013) employed ARIMA modeling for the forecast of rainfall in Ghana. It was found that ARIMA model can be used for the various analysis of forecasting future water planning. Another research conducted by (Bari et al., 2015) used ARIMA model for estimating the monthly rainfall in Sylhet city. The researchers found that the results could be used in agriculture, urban planning, flood prediction and many other fields.

CHAPTER # 3

3. Material and Methods

The methodology is the systematic and organized, academic assessment of the techniques being employed in the field of study. Forecasting future crop production and the impacts of climatic variables is of significant concern for a country. Therefore, it needs accurate data sources, data handling, and data curation to find the best suitable models for quality-oriented research work. Studying the previous crop production trend and future trends needs authentic modeling studies and evaluations.

3.1. Data Sources

Data of yield(maund/acre) of Wheat and maize crops for Sargodha and Faisalabad in the period 1990–2021 was collected from the crop reporting service Punjab. Yield data were taken yearly, such as 1990–1991, 1992–1993, etc. Then, these collected data as a fiscal year were transformed to yearly data, like, 1990 to 1991 was found as 1990. Weather data was taken as monthly mean data from Pakistan Meteorological Department for the Sargodha year 2004 to 2021, and Faisalabad for the years 2004 to 2020. Then I used the collected year-wise monthly data and then converted it into seasonal data according to the growing period of the Wheat and Maize crops. In the case of wheat, the length of the crop growing season continues from October to May respectively. Therefore, the climatic variables have been specified for this overall period. Hence, the growing period for maize for spring and autumn has been considered from Mid-April to November respectively according to the cropping calendar provided by the National Agromet Centre. Generally, the monthly mean data for all climatic parameters have been taken into consideration except for the rainfall which is taken as the total monthly amount of rainfall in mm.

3.2 Study Design

In this study, the research work was done on RStudio. The research was divided into two phases. In the first phase, ARIMA modeling was employed to forecast the wheat and maize yield (maunds/acre) for Sargodha and Faisalabad for the year 2004-2020. And the forecasting of climatic variables maximum temperature and the monthly total amount of rainfall for the year 2022-2027. And in the second phase, a multivariate analysis was performed between yield and climatic variables was drawn.

3.3 ARIMA Methodology

ARIMA (Auto Regressive Integrated Moving Average) modeling was employed for forecasting the production of crops and climatic variables for the year 2022-2027. ARIMA modeling is also called Autoregressive Integrated Moving Average. The model is applied to time series data. ARIMA methodology has a wide range of applications in social sciences, environmental sciences, business derive decisions, and many other fields.

While taking meteorological parameters from datasets, I considered the impact of stochastic and deterministic factors. The deterministic factor is those factors in datasets that include propensity, periodicity, and sudden changes whereas the stochastic factors include trends and different conditions of non-stationary and stationary. In ARIMA models, it is required to remove the trend, any seasonal changes, and changes in mean values. A stationary series is defined as a series whose statistical properties (variance and mean) are independent of time. ARIMA model is a linear model that is the combination of the autoregressive model AR which is denoted by "p" and the moving average model MA which is denoted by "q". ARIMA model that removes the non-stationarity of the time series data has been done by the differencing approach. It is called Integrated and is denoted by "d".

There are four main steps for the application of the ARIMA model:

I. Identification:

To apply the time-series model it is necessary to check the stationarity of data sets. Augmented Dickey fuller test is used to identify the stationarity of a time series. If the p-value is less than 0.05 then the data is stationary. Hence null hypothesis is rejected, and the alternative hypothesis is accepted that data is stationary. If the p-value is greater than 0.05 then the differencing of data is done to make data stationery. The order of differencing defines the Integration component in the ARIMA model. Hence the order of the model is also identified by the Auto Correlation Function (ACF) and Partial Autocorrelation Function (PACF).

II. Estimation:

Different models are estimated based on the order of ARIMA and the best model is selected on AIC value. And the model with the lowest Akaike Information Criteria (AIC) is selected as the best model.

III. Model diagnostics:

The selected models are tested for the goodness of fit by performing various numerical and graphical tests.

IV. Forecast:

This step is considered after selecting the most suitable model to forecast future outcomes (Tseng & Tzeng, 2002).

3.4 Climate and Crop yield Relationship:

I applied multivariate time series analysis to investigate the relationship between climate and crop yield. For this purpose, data sets of crop yield(maunds/acre) for maize and wheat of Sargodha for the year 2004 to 2021 for mean monthly maximum temperature and precipitation in mm were taken for the wheat and for the Sargodha maize the data was taken from 2004 to 2020, and for the Faisalabad climatic variables of maximum temperature and the monthly total amount of rainfall in mm was taken from 2004 to 2021. Hence all the multivariate time series analysis between these parameters was performed.

CHAPTER # 4

4. Results and Discussion

This chapter explains the results of my objectives using the ARIMA methodology. All four steps of ARIMA modeling are reported. The forecasted results of my study are shown in the form of graphical and numerical estimations and the validation results are also shown.

4.1 Descriptive Statistics

The descriptive statistics are estimated using Minitab. The data was taken from the crop reporting service for the wheat and maize crops for the Sargodha and Faisalabad. The results are shown in Table 1 and Table 2. Descriptive statistics describe the basic properties of all the variables of the study. I compared the wheat and maize yield (maund/acre) for both cities, and it was found that for wheat yield (maund/acre) in Faisalabad, the mean yield was the highest as of 30.31 for the year 2004 to the year 2021. The maximum yield(maund/acre) was found to be 37.30 for Faisalabad from the year 2004 to 2020.

Table 1: Descriptive Statistics of Wheat estimated from Crop Reporting Service for Faisalabad and Sargodha, the Year 1990-2021.

City	**Variable**	**Crops**	**Mean**	**Minimum**	**Maximum**
Sargodha	Yield (Maund/Acre)	Wheat	26.502	22.200	30.300
Faisalabad	Yield (Maund/Acre)	Wheat	30.318	20.100	37.300

Table 2: Descriptive Statistics of Maize estimated from Crop Reporting Service for Sargodha, the years 1990-2021 and Faisalabad 1990-2020.

City	**Variable**	**Crops**	**Mean**	**Minimum**	**Maximum**
Faisalabad	Yield (Maund/Acre)	Maize	39.65	16.04	71.08
Sargodha	Yield (Maund/Acre)	Maize	26.73	9.98	72.51

In the case of average mean maize Yield(Maunds/Acre), Faisalabad the mean value was found to be 39.65 for the year 1990-2020. And for the Sargodha, the mean value was found to be 26.73 for the year 1990-2020. And the maximum yield(maund/acre) for maize was found to be 72.21 for Faisalabad for the years 2004 to 2020.

4.2.1 Forecast of Faisalabad for wheat yield (maund/acre) for the years 2022-2027

Wheat is one of the most important crops grown in Faisalabad. A report published by the National Agromet center in 2017-2018 in Faisalabad highlighted that high temperatures during the milk maturity stage prevented the normal growth of weight and size. And the continuous rainfall during the flowering stage caused the shredding of flowers which presented another factor for the low yield. The yield produced was 760 kg /acre less than the actual yield. (Saleh, 2017-2018) Hence, to forecast wheat yield (maund/acre) for the year 2022-2027 Box-Jenkins methodology was applied. The first step was to analyze the historical time series plot for the wheat Faisalabad. It can be observed that wheat yield(maund/acre) is showing an increasing trend along with decreasing trend after some years. Hence, to forecast wheat yield (maund/acre) for the year 2022-2027 ARIMA methodology was applied. The first step was to analyze the historical time series plot for the wheat yield(maund/acre) for the Faisalabad year 1990 to 2021.

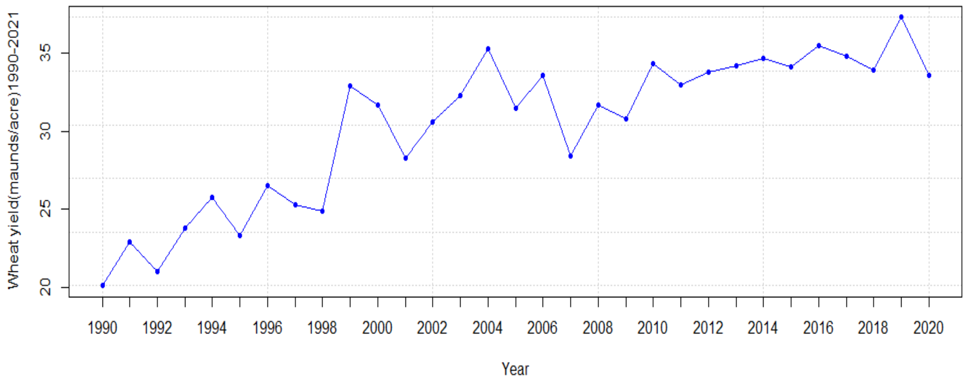


Figure 1:Historical timeseries of Faisalabad wheat yield(maund/acre) for the year 1990-2021.

4.2.1 Identification

To apply the ARIMA methodology, it is necessary to check whether data is stationary or not. To check stationarity, ADF (Augmented Ducky fuller) test is applied (Seddighi, 2000). The result showed that the p-value is 0.6399. It is assumed that the time series is not stationary. ACF and PACF plots were also made to determine the stationarity. The ACF and PACF are shown in figure 2(a) and figure 2(b). The plots also show that the data is not stationary. To make a non-stationary series to stationary, we make time-series different. Hence the difference is taken for the wheat yield (maund/acre) for Faisalabad year 1990-2021.

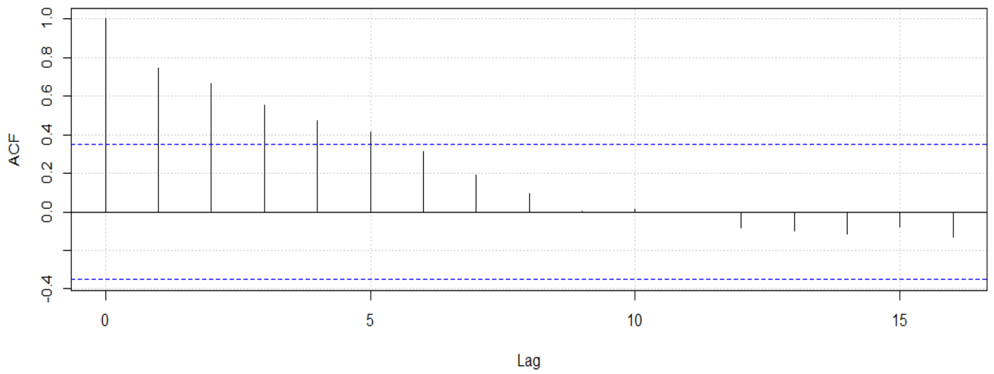


Figure 2(a) ACF Yield Maund/Acre Faisalabad for the year 1990-2021

After taking the first difference we get a p-value of 0.01 which means that my data is stationary. Hence for identification correlogram is used. The ACF defines a data series correlation with itself at different lags. PACF on the other hand is computed as the regression of the data series against its past lags. Hence after the first differencing the ACF, it showed exponential decay. Hence for PACF, it was found that autocorrelation fall after lag 1. Hence, I took moving average MA(1). But several other models were also identified.

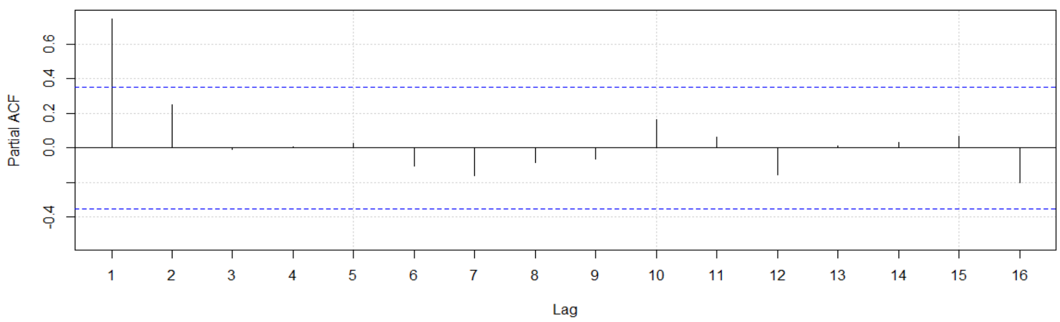


Figure 2(b):PACF for Yield Maund/Acre Faisalabad for the year 1990-2021.

4.2.3 Model Estimation

The next step is a model estimation. In ARIMA methodology to find the best fit model, several models are made based on the ACF and PACF values. Using the auto. arima function and ACF and PACF several possibilities are made for Faisalabad Wheat in terms of Yield(Maunds/Acre). Table 1 shows the order of the ARIMA model and their AIC values for the wheat yield(maund/acre).

Table 3:AIC values of the ARIMA order for the wheat yield(maund/acre) Faisalabad.

ARIMA ORDER	AIC VALUE
ARIMA(0,1,0)	150.39
ARIMA(0,1,0)	149.17
ARIMA(2,1,1)	147.4
ARIMA(1,0,2)	155.45
ARIMA(1,1,2)	144.91

4.2.4 Model diagnostics

For diagnostic checking of the estimated models, different numerical and graphical approaches were applied to check whether they were properly fitted or not. Therefore, Ljung Box-test was applied. And p-value was found to be 0.82.

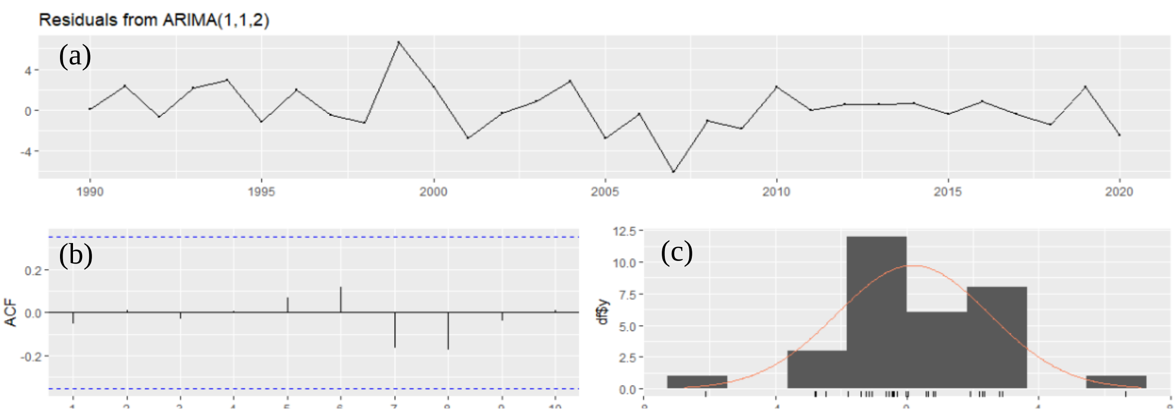


Figure 3: Graphical representation of Residuals from ARIMA(1,1,2) for the wheat yield(maund/acre) for the Faisalabad year 1990-2021.(a) shows the differenced timeseries for wheat yield(maund/acre) for Faisalabad.(b) shows the ACF for wheat yield (maund/acre).(c)Histogram of residuals

The null hypothesis of the Ljung Box-test, H_o, is that our model does not show a lack of fit. The alternate hypothesis, H_a, is just that the model does show a lack of fit. This means that the model is the best fit. Figure 3 (a) shows the differenced timeseries , (b) ACF (c) and normality test of the histogram of residuals . If the histogram shows normality, the model is a good fit. The histogram of residuals of wheat yield (maund/acre) showed normality.

4.2.4 Forecast

I forecast the wheat yield maund/acre for Faisalabad from 2022-to 2027 based on the historical timeseries data . The results of forecast are shown in figure 4 indicates that the predicted values follow the observed data series. Here, x-axis represent the year and y-axis represent the yield (maund/acre) for Faisalabad. The estimated results are based on the predicted value there was an increase of 0.178 maund/acre for the Faisalabad wheat with R of 0.83 for the year 2022-2027.

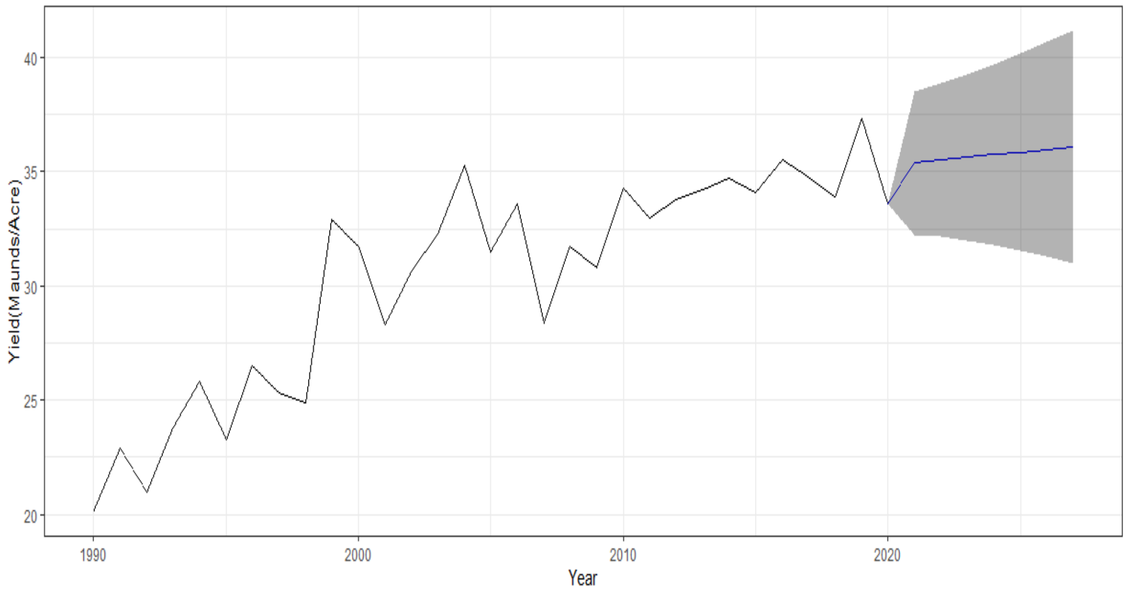


Figure 4: Forecast for the Faisalabad wheat yield (maund/acre) for the year 2022-2027.

4.3 Forecast Maize yield(Maund/Acre) for Faisalabad year 2021-2027.

A historical timeseries analysis was performed for the maize yield(maund/acre) for the year 1990-2020. It was observed that maximum production for yield(maund/acre) was obtained in the year 2018 that is 71.2 (maund/acre), and the lowest yield was recorded as 16 (maund/acre) for the year 1992. The historical timeseries plot for the maize Faisalabad is also created in figure 5. It shows that there is an increase in the production of maize crop along with decreasing pattern after some years.

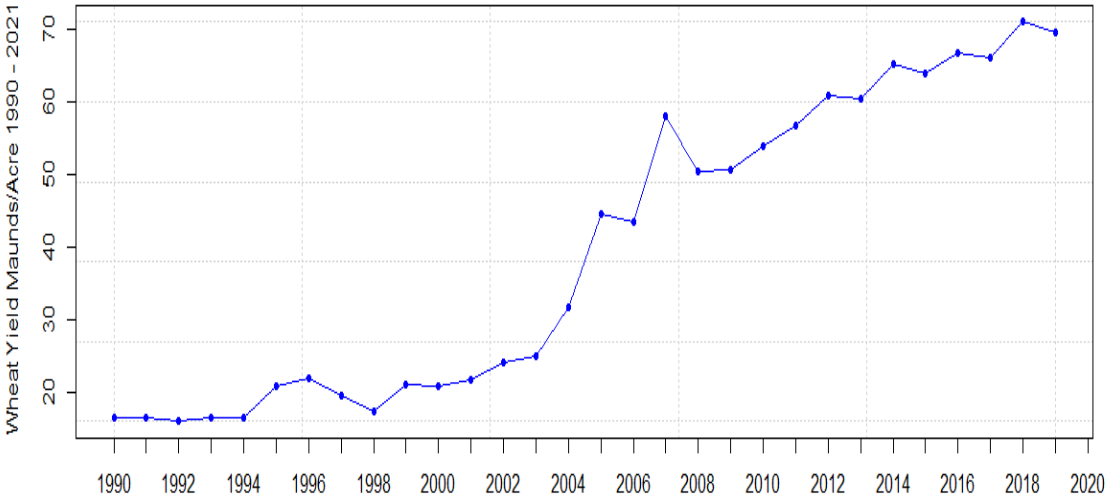


Figure 5: Historical timeseries of Maize yield(maund/acre) in Faisalabad for the year 1990-2020

4.3.1 Identification:

To check the stationarity of data set Augmented Dickey-Fuller test is applied. Therefore, the value is 0.4516 which means that the null hypothesis is rejected that data is stationary. And H_0 is accepted that data is not stationary. value becomes 0.3197. Therefore, I took the first difference of the timeseries data of Faisalabad maize.

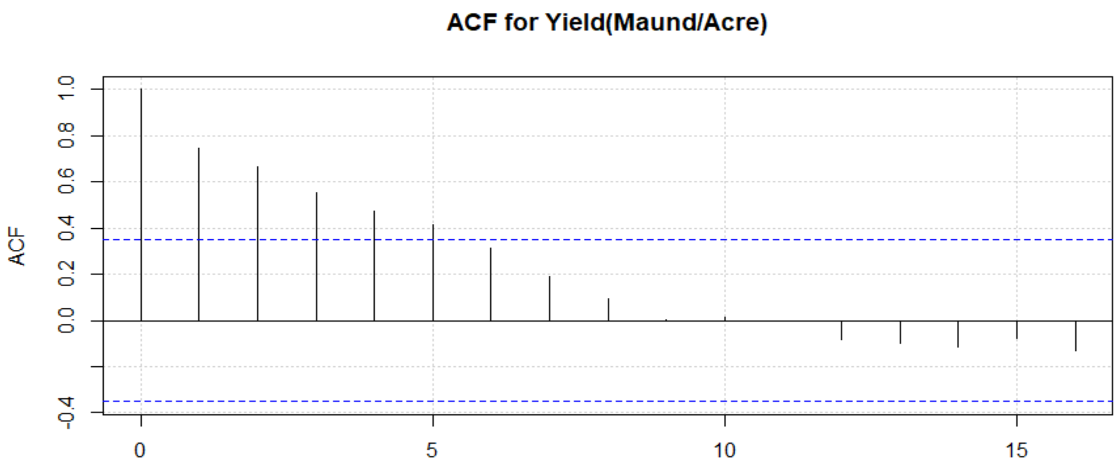


Figure 6(a) : ACF for Maize yield (maund/acre) for the Faisalabad

The figure 6a and 6b shows the ACF and PACF plots. After first differencing the Augmented dickey fuller test yield(maund/acre). It was observed that for the first difference ACF show exponential decay. And PACF also does not show any fall of lag. Then I applied second order differencing for Faisalabad maize yield (maund/acre) , it was found that there was an exponential decay for lag 1 and PACF shows a cut at lag 1. Hence after a second differencing the p-value becomes 0.023.

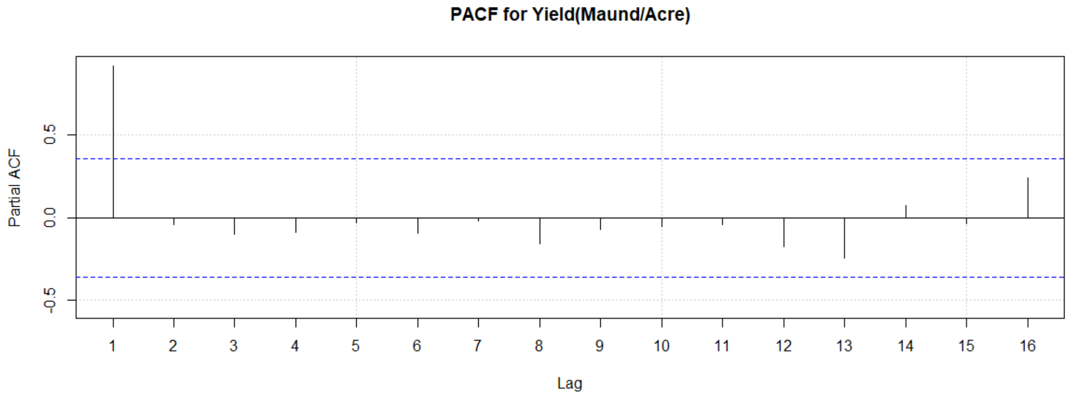


Figure 6 (b) :PACF for Maize yield(maund/acre)for the Faisalabad

4.3.2 Model estimation:

After identification various models were estimated from ACF and PACF function. Then the model was selected based on the AIC value. Hence ARIMA order (1,2,1) was found to be the best model based on the lowest AIC value. table 2 shows the ARIMA order and their AIC values. Where ARIMA (1,2,1) has the lowest AIC value of 168.9. Therefore, the model was found to be the best fit model.

Table 4:ARIMA models with AIC value for the Faisalabad maize yield (maund/acre) for the year 1990-2020.

ARIMA ODER	**AIC**
ARIMA(0,2,0)	189.82
ARIMA(1,2,0)	172.08
ARIMA(2,2,0)	171.28
ARIMA(1,2,1)	168.9
ARIMA(1,2,2)	170.23
ARIMA(0,2,2)	169.69

4.3.3 Model Diagnostics

After model estimation various statistical tests were employed to check the accuracy of the selected model. The value of the Ljung Box Test shows that the p-value is 0.96. Hence the model is best fit. I also draw graphical representation to check the accuracy of my model. Figure 7 shows the graphical representation of the selected model. The differenced timeseries shows that data is stationary. The ACF shows that all the residuals are independently distributed. And histogram show normality, which means that residuals are independently distributed.

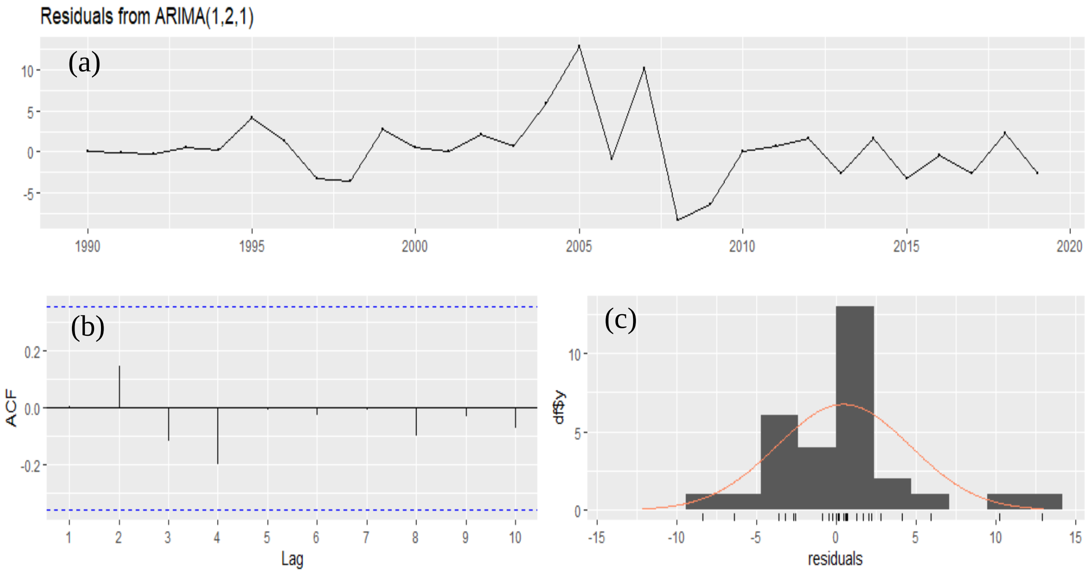


Figure 7: Graphical representation of Residuals from ARIMA(1,2,1) for the maize yield(maund/acre) for the Faisalabad year 1990-2020.(a) The differenced timeseries for maize yield(maund/acre) for Faisalabad.(b) ACF for wheat yield (maund/acre).(c) The histogram shows the residuals from ARIMA (1,2,1).

4.3.4 Forecast

Seven years forecast was made based on the selected model. the model results are according to the previous observed values. The grey line represents the 95% confidence interval. And the results show an increase in the yield(Maund/Acre) for the year 2021-2027. The result of forecast maize yield (maund/acre) is shown the figure 8. Here the x-axis represents the year and the y-axis represent the yield(maund/acre) for Faisalabad maize (maund/acre) for the year 1990 to year 2027.

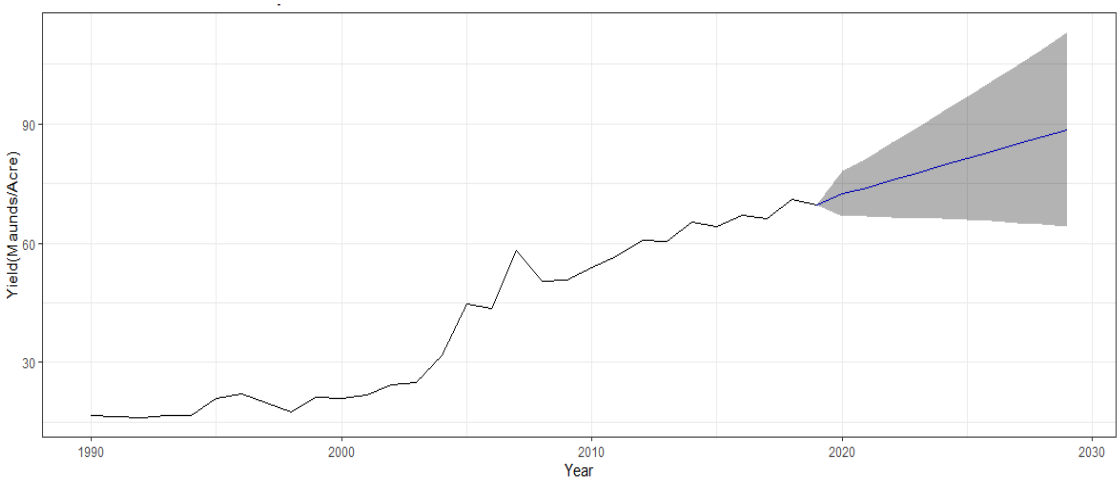


Figure 8:Forecast for maize yield(maund/acre) for the Faisalabad for the year 2021-2027.

4.4 Forecast the Sargodha wheat yield (maund/acre) for the year 2022-2027

Historical timeseries analysis of Sargodha wheat yield(maund/acre) was performed for the year 1990-2021 figure 9. It was estimated that maximum wheat yield(maund/acre) was found to be 30.3 yield (maund/acre) for the year 2016-2017. And the lowest wheat yield (maund/acre) was recorded in the year 1996-1997.

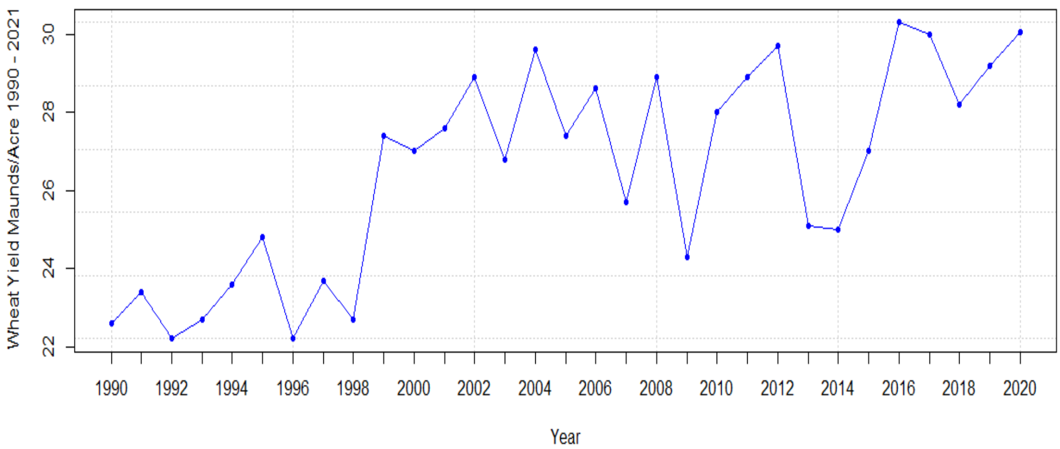


Figure 9: Historical timeseries analysis for the wheat yield(maund/acre) for the Sargodha year 1990-2021.

4.4.1 Identification

The results of Augmented Dickey Fuller (ADF) give the value of 0.47 which means that data is not stationary; therefore, it was found that the null hypothesis is rejected and after differencing the value was found to be 0.02 and alternative hypothesis is accepted.

4.4.2 Model estimation

After taking the differencing the ACF and PACF were analyzed to estimate the models. Figure 10a and 10 b show the ACF and PACF for the Sargodha wheat yield (maund/acre) for the year 1990-2021. After taking the first differencing the ACF show that there was an exponential decay and for PACF show a significant decay. Hence, various models were estimated and the models with the lowest AIC was selected as the best model. Table 5 shows the ARIMA order and their AIC values for the differenced timeseries for the Sargodha wheat yield (maund/acre) for the year 1990-2020. ARIMA model(3,1,0) was found to be the best model based on the lowest AIC value of 127.44.

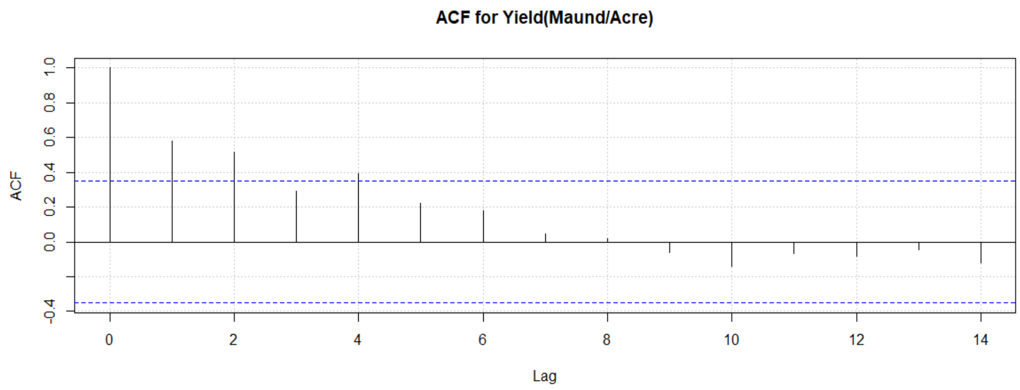


Figure 10 (a) ACF for wheat yield(maund/acre) for the Sargodha.

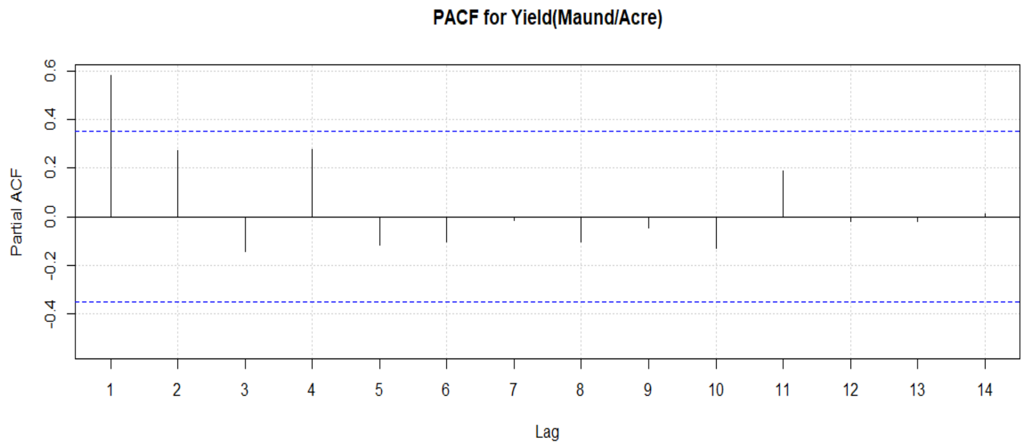


Figure 10 (b) :PACF for wheat yield (maund/acre) for the Sargodha

Table 5:AIC value for the wheat yield (maund/acre) for the Sargodha wheat yield(maund/acre) for the year 1990-2021.

ARIMA ORDER	AIC VALUE
(3, 1, 1)	132.14
(3, 1, 0)	127.44
(1, 1, 0)	131.12
(1, 1, 1)	131.12
(1, 1, 2)	132.9
(0, 1, 2)	132.18

4.4.3 Model Diagnostics

After model estimation various graphical and numerical tests were performed. The value of Ljung-box test was found to be 0.63 therefore the model was found to be the best fit.

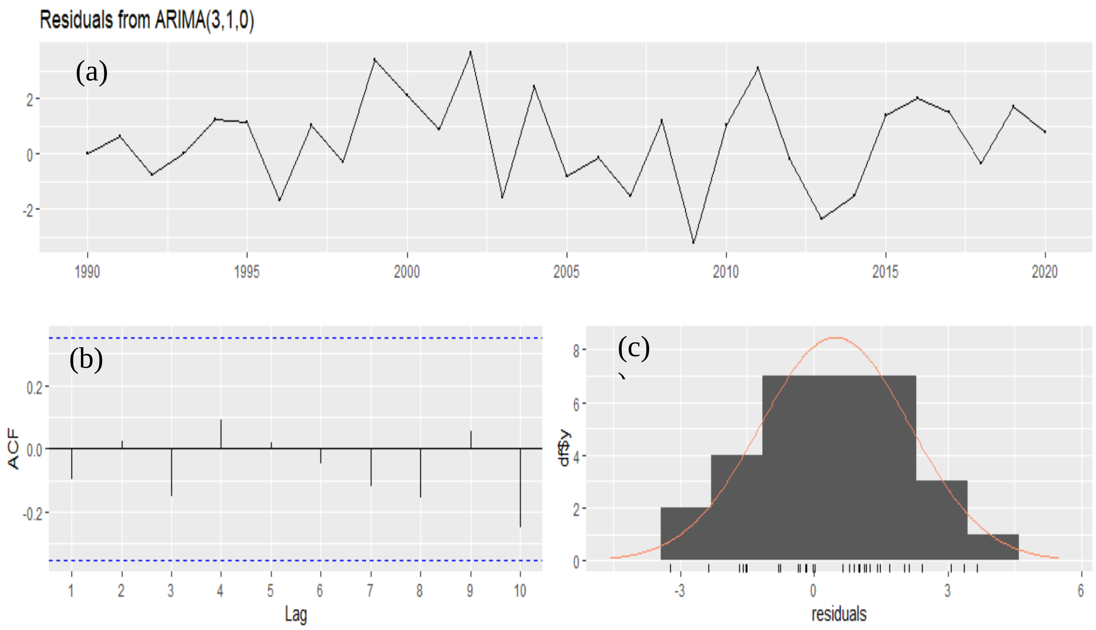


Figure 11:Graphical representation of Residuals from ARIMA(3,1,0) for the maize yield(maund/acre) for the Sargodha year 1990-2021.(a) The differenced timeseries for wheat yield(maund/acre) for Sargodha .(b) ACF for wheat yield (maund/acre).(c) The histogram of residuals from ARIMA(3,1,0).

The graphical representation of the model is shown in figure 11. Where (a) shows the differenced timeseries for the wheat yield (maund/acre) for the Sargodha for the year

1990-2021. (b) show the ACF represent that series is stationary and (c) represent that residuals are normaly distributed

4.4.4 Forecast

The forecast graph for the forecast from the ARIMA(3,1,0) for the wheat Sargodha is shown in figure 13. The forecast shows a sudden decrease and increase in the wheat yield (maund/acre) for the Sargodha of year 2022-2027. The results of forecast show the similar pattern with the previous historical data series. Where x-axis represents the year and y axis represent the yield(maund/acre) for the wheat Sargodha for the year 1990 to 2027.

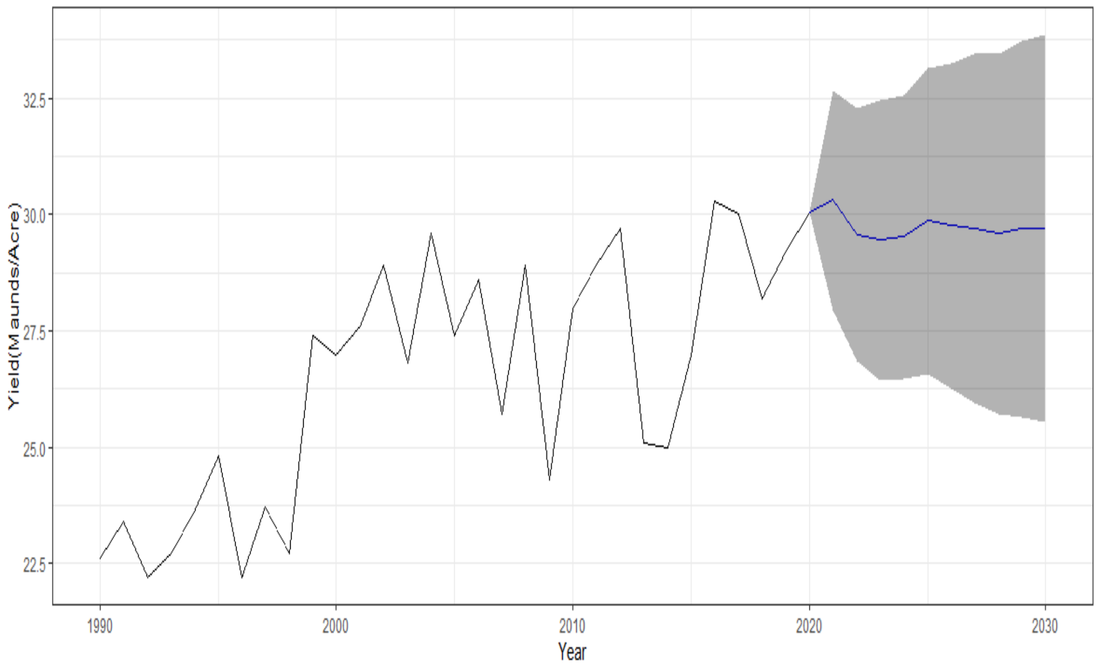


Figure 12:Forecast for the wheat yield(maund/acre) Sargodha for the year 2022-2027.

4.5 Forecast maize yield (maund/acre) for Sargodha for year 2021-2027

Timeseries analysis for maize yield maund/acre was performed for Sargodha in figure 14. It was found that the highest maize yield(maund/acre) was found for the year 2019-2020 that was greater than 50 maunds/acre. And the lowest maize yield(maund/acre) was found for the year 1992.

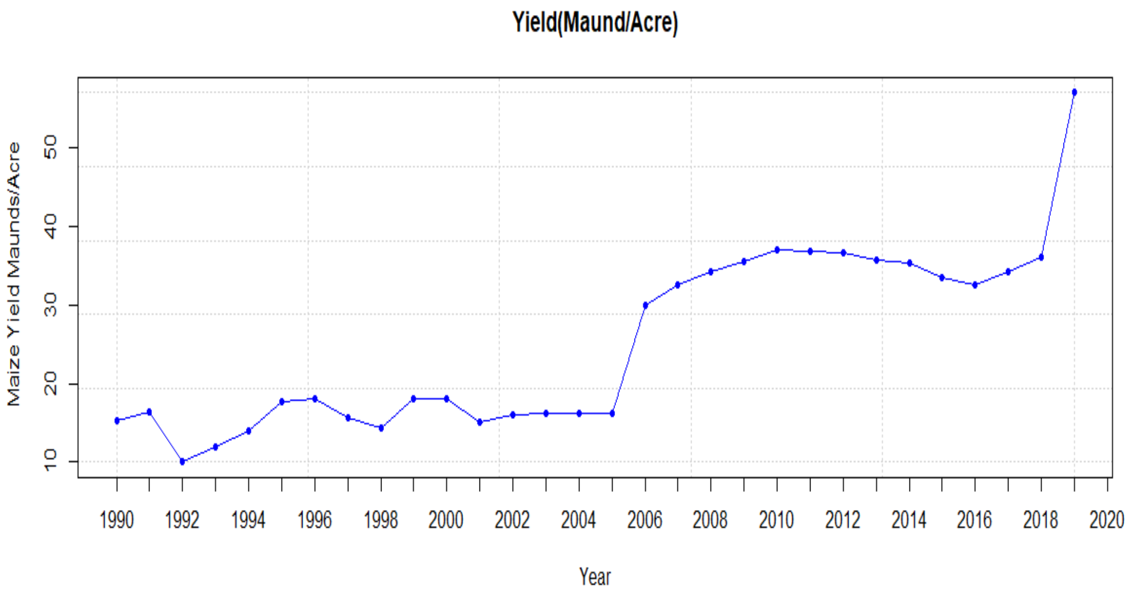


Figure 13: Historical timeseries for the Sargodha maize yield(maund/acre) for the year 1990 to 2020.

4.5.1 Identification:

The Augmented dickey fuller test was applied to check the stationarity of timeseies data. It was found that the p value was 0.65. Hence, first diffrencing was performed to make data series stationary. The p value was found to be 0.47. Since the p value was greater than 0.05 therefore I performed the second differencing. The p value was recorded as 0.10. therefore third differencing was performed and the p value was found to be 0.01 and my data series become stationary.

4.5.2 Model estimation:

After checking the stationarity of data various tentative models were made based on the ACF and PACF fuction. The figure 15a and 15b show the ACF and PACF of the ARIMA order. The ARIMA (0,3,2) was found to be the best model based on the lowest AIC value. The ARIMA order and AIC values are shown in the table 6.

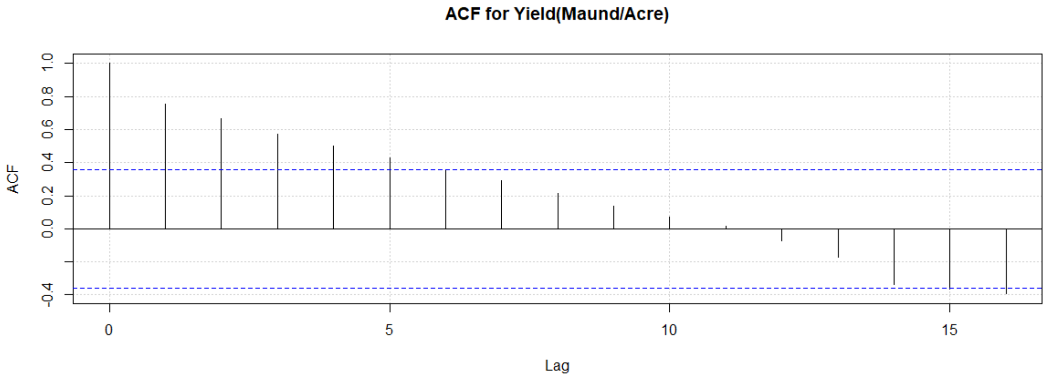
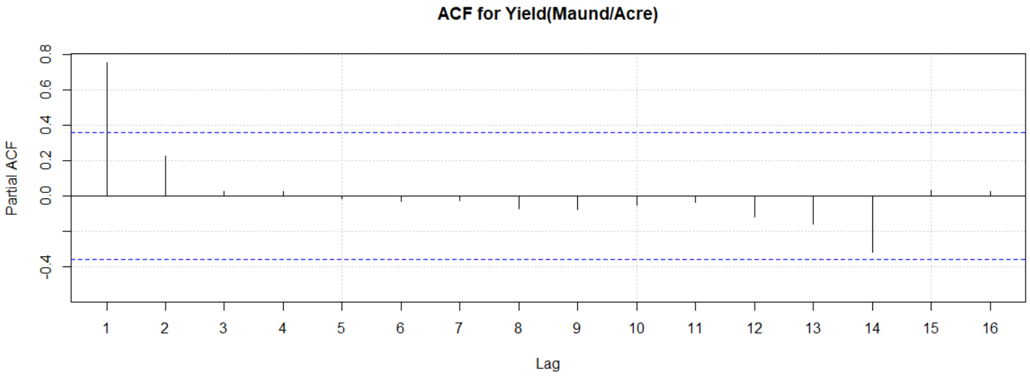


Figure 14 (a):ACF for Sargodha Maize wheat yield(maund/acre)



:Figure 14 (b) PACF for Sargodha Maize wheat yield(maund/acre)

Table 6:ARIMA order and their AIC values of Sargodha for the maize yield (maund/acre) for the year 1990-2020.

ARIMA ORDER	AIC VALUE
(0,3,2)	177.62
(1,3,1)	189.82
(2,3,2)	178.08
(0,3,0)	192.51
(2,3,1)	179.67

4.5.3 Model diagnostics:

After model estimation numerical and graphical test were used to measure the accuracy of our model. The Ljung Box Test show a p value of 0.96. Therefore, my model is best fit. The residuals of ACF show stationarity. And histogram show normal distribution.

The results of graphical estimation of ARIMA (0,3,2) are shown in the figure 15.

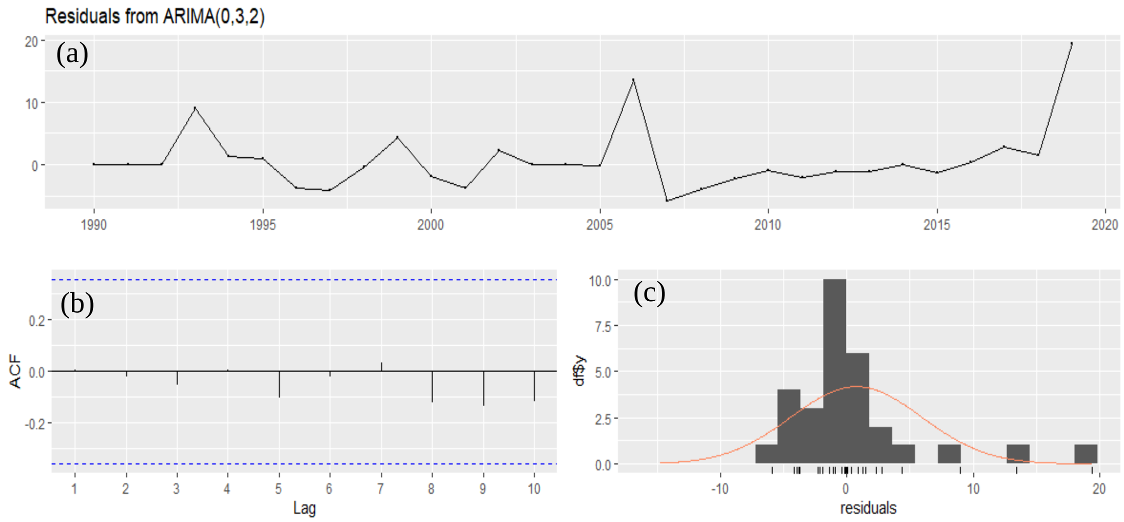


Figure 15:Graphical representation of Residuals from ARIMA(0,3,2) for the maize yield(maund/acre) for the Sargodha year 1990-2020.(a) The differenced timeseries for maize yield(maund/acre) for Faisalabad.(b) ACF for maize yield (maund/acre).(c) The histogram of residuals from ARIMA (0,3,2).

4.5.4 Forecasting

The forecasted model shows an increase for maize yield(maund/acre) for Sargodha. The results of forecast show that there is an increase in the maize yield (maund/acre) for the Maize yield(maund/acre) for the Sargodha for the year 2022-2027. The results of forecast are shown in the figure 16.

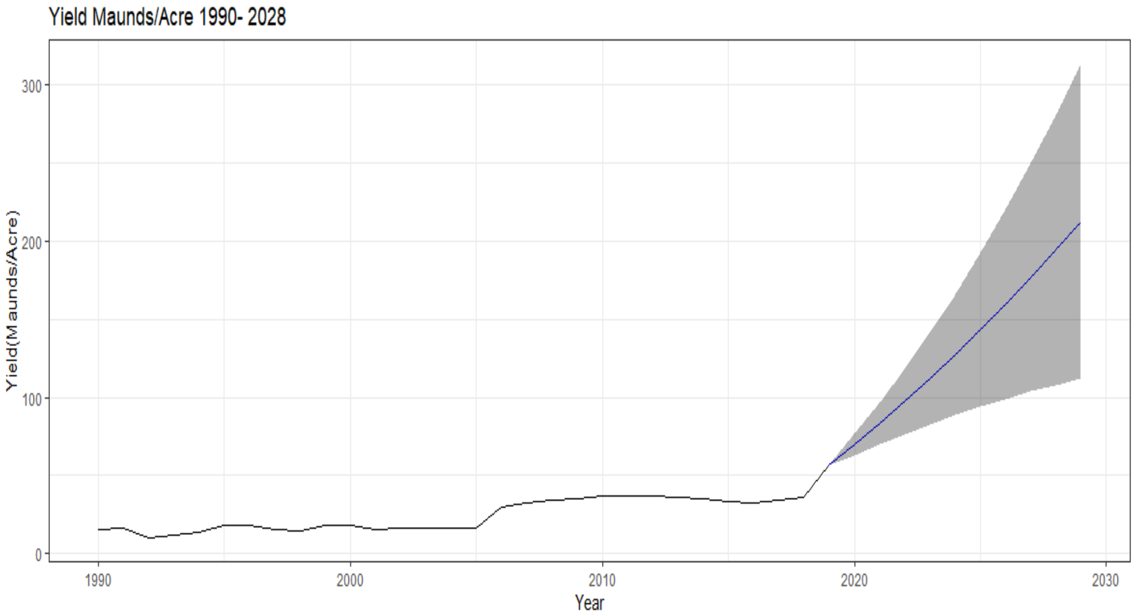


Figure 16:Forecast for the maize yield(maund/acre) for the Sargodha year 2022-2027.

4.6 Forecast total monthly amount of precipitation for Sargodha year 2022-2027.

According to the research conducted by (Bashir, 2018) on assessing and evaluating the effect of rainfall and temperature on citrus production were analyzed and compared. Also, the citrus production and monthly average meteorological conditions of all these weather events were utilized to assess trends and changes in an area's climate and Citrus Reticulata production. And they found out that a significant change was observed in the rainfall and temperature from 1986 to 2015.

4.6.1 Timeseries analysis

The data for Sargodha precipitation was taken from the Pakistan Meteorological Department. First step was to perform timeseries analysis. The data for the timeseries monthly amount of precipitation for the Sargodha city was taken from the year 2004 to the year 2021. Timeseries analysis is shown in figure 17. The x-axis represents the year and y-axis represent the precipitation in mm for the year 2004 t0 2021.The time-series graph shows that 2016 was the year with the highest rainfall .The time-series data were further assessed to analyze the seasonality, trend, and cyclic behavior of the rainfall in figure 18.The timeseries data of total monthly amount of precipitation in mm of Sargodha was further decomposed into seasonal, remainder, and trend. The trend strength was calculated as 0.1 and the seasonal strength was found to be 0.5. The trend strength near 1 is considered to be strong. The decomposition of timeseries data is shown in figure 18.

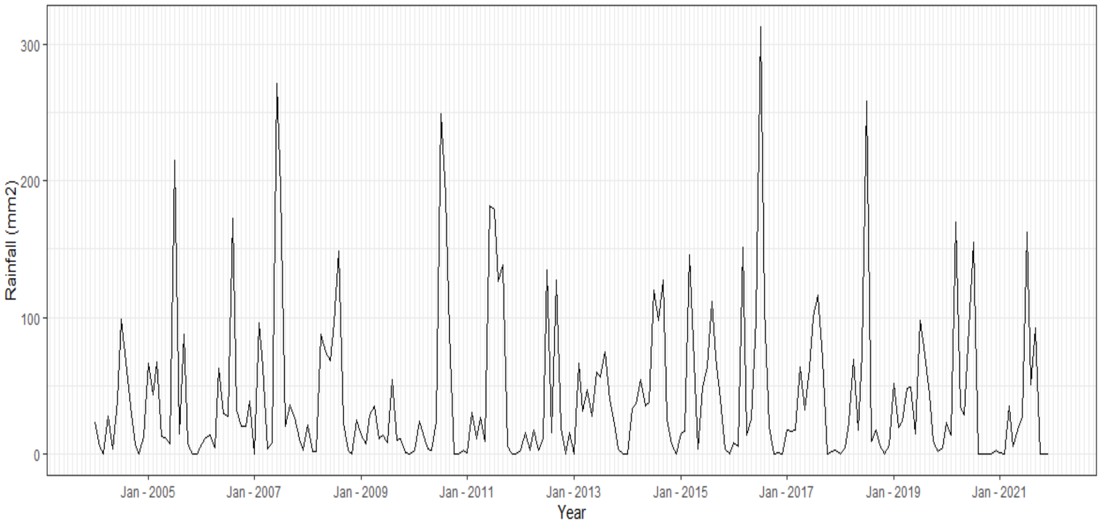


Figure 17: Historical timeseries of Monthly total amount of precipitation in mm in Sargodha for the year 2004-2021.

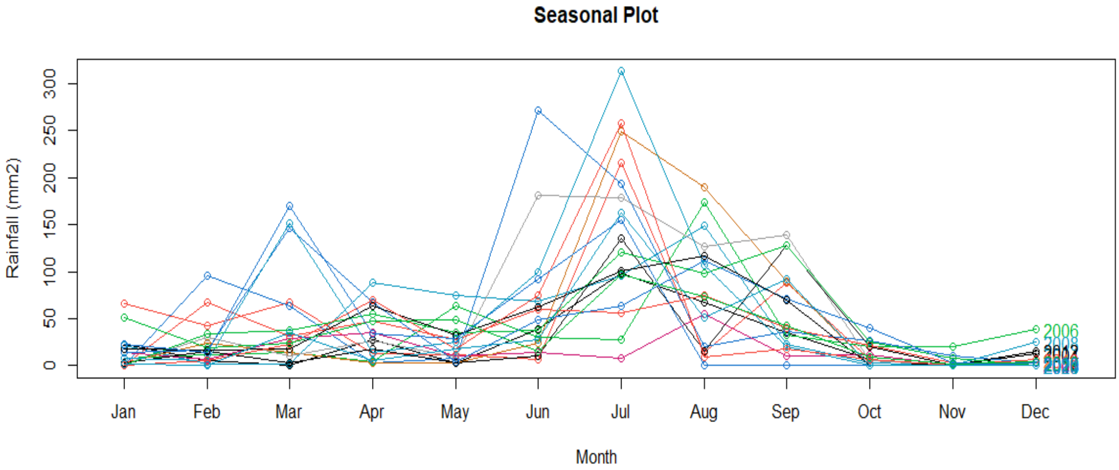


Figure 18: Seasonal plot: of Monthly total amount of precipitation in mm for the Sargodha for the year 2004-2021

The timeseries seasonal plot of maize Sargodha Precipitation is shown in the figure 18. Where x-axis represent months and y axis represents precipitation in mm. The seasonal plot that February to march and June to July are the months with heavy rainfall.

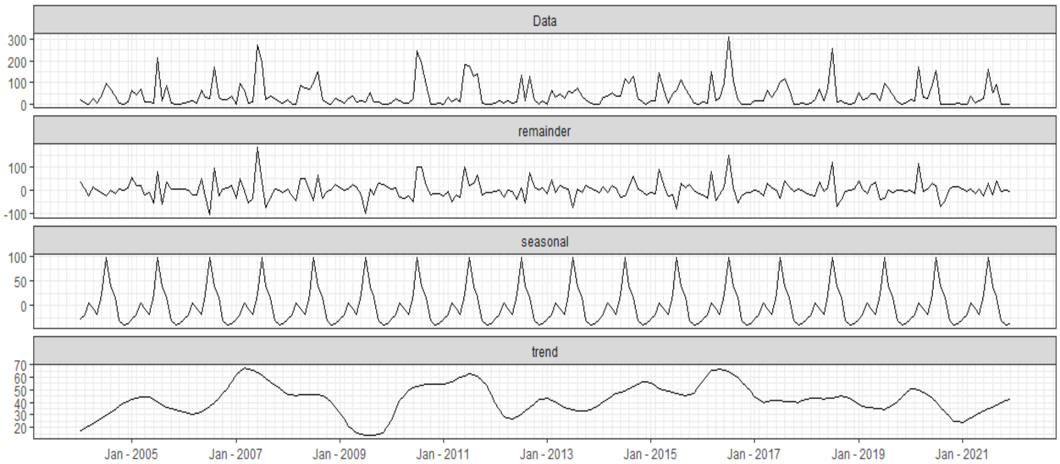


Figure 19:Decomposition of timeseries data of Monthly total amount of precipitation in mm in Sargodha for the year 2004 to 2021 into remainder, seasonal and trend component for Sargodha year 2004 -2021.

The seasonal box plot in figure 20 shows that July is the month with the highest monthly amount of precipitation in mm , whereas December has the lowest precipitation. But it is also observed that in April and May there was a slight increase in total amount of monthly precipitation in Sargodha. As these are wheat harvesting seasons. Therefore this amount of rainfall can impact the crop during the growing stage, reduce the net crop production and can also effect grain quality.

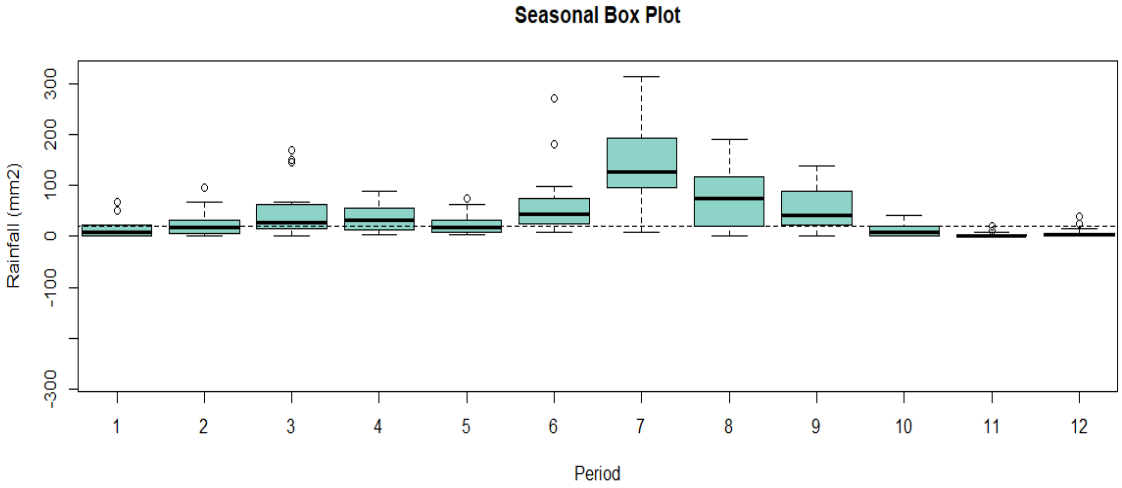


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Figure 20:Seasonal boxplot of Monthly total amount of precipitation in mm for the Sargodha year 2004 -2021

4.6.2 Identification

After assessing the plot of historical timeseries and its decomposition of total monthly amount of precipitation in mm then the data was divided into train and test sets. The data from January 2004 to 2021 June was taken as a trainset and data from January 2021 to July 2021 was taken as a test set. After creating the train and test set their stationarity was tested. The value of Augmented Dickey Fuller test was estimated to be less than 0.05. The model was also validated using statistical parameters of train set and test set. The ACF and PACF of Sargodha Monthly total amount of Precipitation in

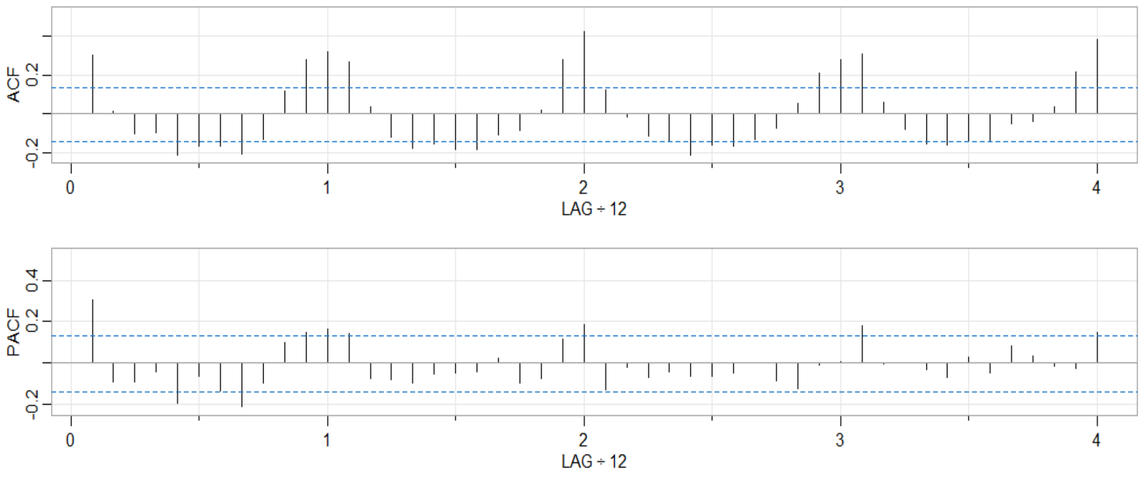

Figure 21: ACF and PACF for the Sargodha for the monthly amount of precipitation in mm.

mm is shown in figure 22. The results of train set, and test set are shown in the table 7 and table 8. The results show that the statistical results are suitable for the selected model.

Table 7: Statistical parameters for train set and test set for the Monthly total amount of precipitation in Sargodha.

TEST	**ME**	**RMSE**	**MAE**	**MASE**
Training set	0.91	42.76	28.25	0.68
Test set	0.63	19.27	16.27	0.39

4.6.3 Model estimation:

To find the best fit model various alternatives were considered. The model was estimated using the ACF and PACF function and also using the auto.arima function. Where, ARIMA(2,0,2)(2,0,1) was found to be the best model based on the least AIC value. The AIC value and ARIMA order is listed in the table 8.

Table 8:AIC value for model selection for Sargodha Precipitation

ARIMA ORDER	**AIC VALUE**
ARIMA(0,0,1)(0,0,1)	2281.7
ARIMA(2,0,2)(0,0,1)	2274.75
ARIMA(2,0,2)(1,0,0)	2269.32
ARIMA(2,0,2)(2,0,1)	2221.62

4.6.4 Model diagnostics

The results of validation of timeseries is shown in figure 22. Validation of data represents that our model follow a similar pattern with the previous values. Residuals from ARIMA(2,0,2)(2,0,1) showed that ACF shows no spikes and remains below the significant zone. The histogram shows a gaussian distribution. The value of box-Ljung shows that the p-value is 0.8519. Hence the model is the best fit. Figure 23 shows the graphical representation of residuals from ARIMA (2,0,2)(2,1,0). Where (a) represent the differenced timeseries plot of and (b) show the ACF plot (c) the histogram of residuals of the total monthly amount of precipitation in mm for Sargodha.

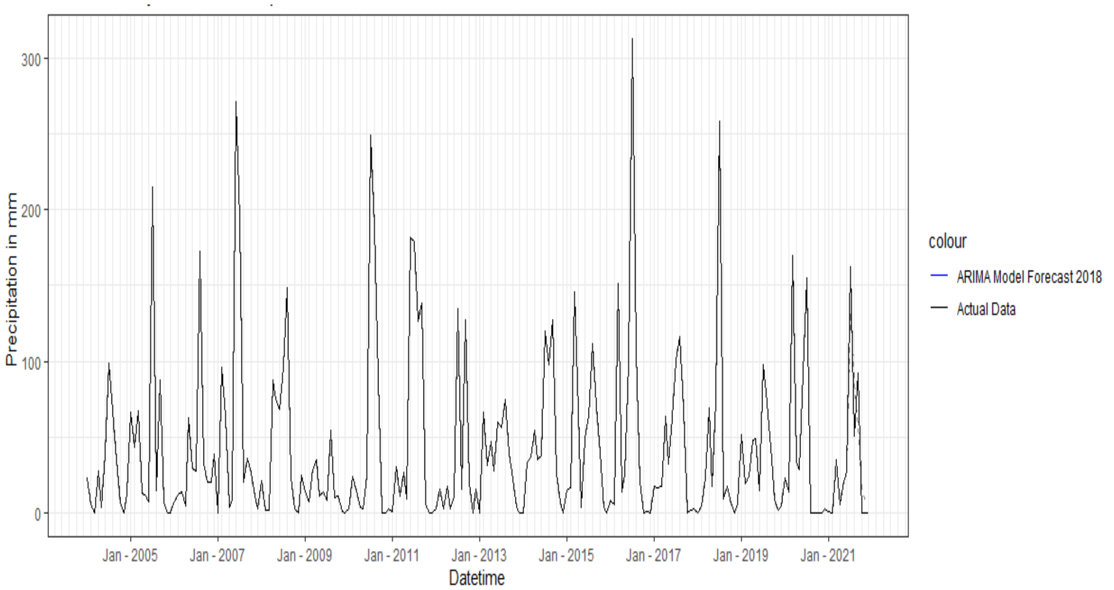

Figure 22: Validation results for the total monthly amount of precipitation in mm for the Sargodha

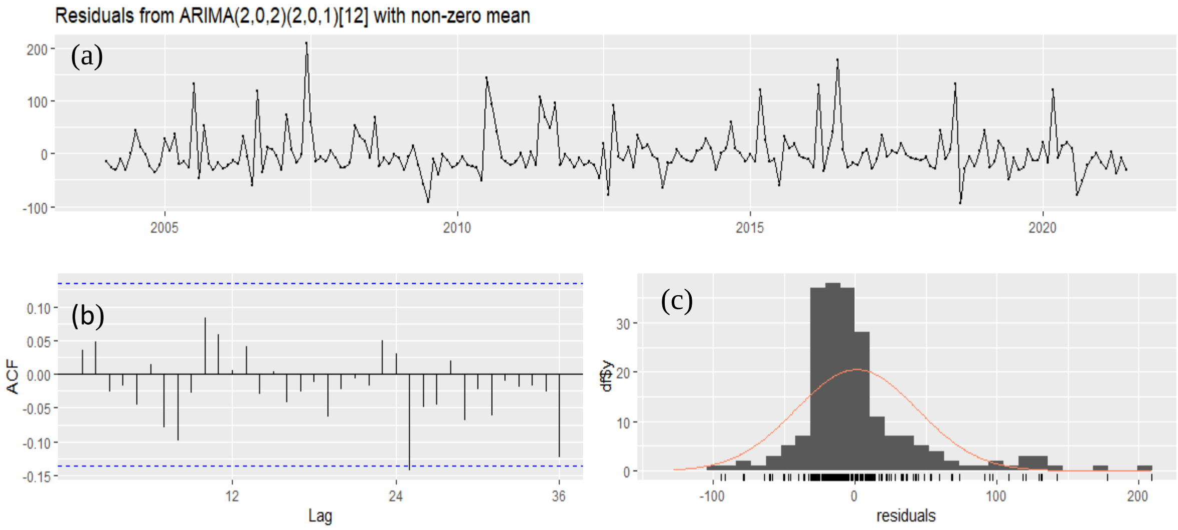

Figure 23: Graphical representation of Residuals from ARIMA(2,0,2) (2,0,1) for the monthly amount of precipitation in mm for the Sargodha year 2004-2021.(a) The differenced timeseries for precipitation in mm for Sargodha ,(b) ACF for total monthly amount of precipitation in mm for Sargodha,(c) The histogram for residuals from ARIMA(2,0,2) (2,0,1).

4.6.5 Forecast

The result showed that there is a decrease in the precipitation trend for the year 2022-2027. The results of forecast show a increase in precipitation during wheat harvesting season and a decrease in the crop sowing season. But its impact on maize was not observed to be significant. The results of forecast are shown in the figure 24. Here the x-axis represents the year and y-axis represent the rainfall in mm for the year 2004 to the 2027.

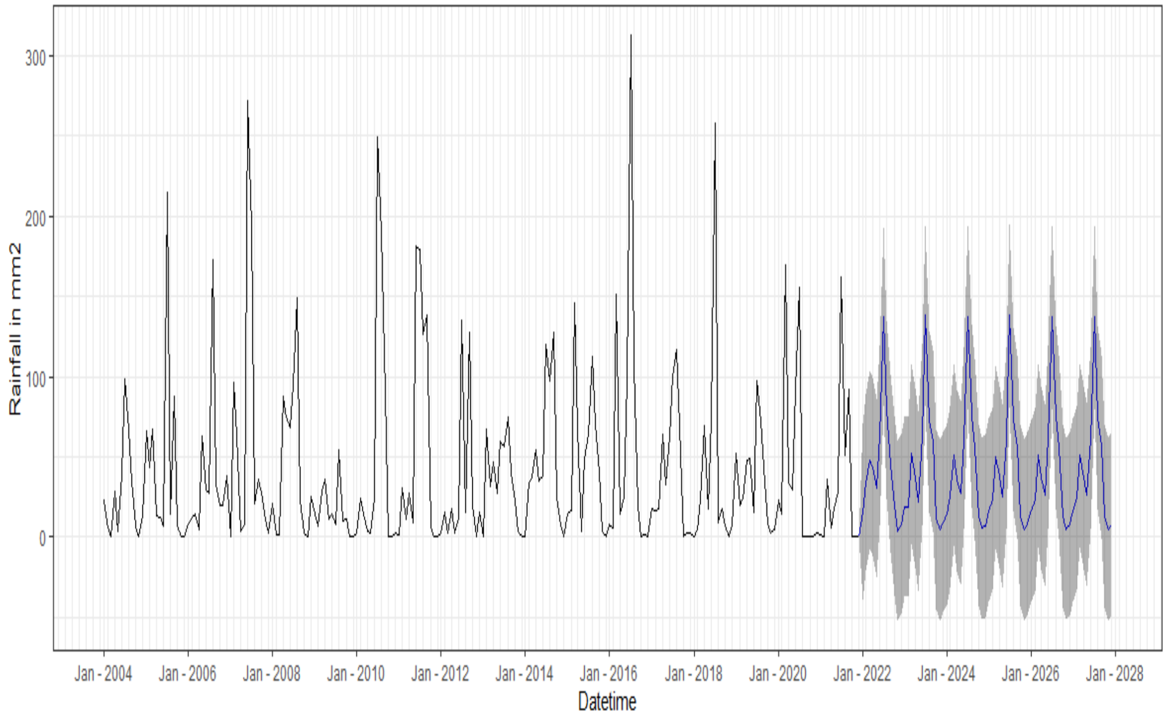

Figure 24:Forecast from ARIMA(2,0,2) (2,0,1) for total monthly amount of precipitation in mm in Sargodha for the year forecast for 2022-2027.

4.7 Forecast of the Mean Maximum temperature for Sargodha for year 2022 to 2027

According to the (Anwar, 2020), there is an increase in the ground temperature of Sargodha as it is observed in other parts of the world. The outcomes of the research are similar to the sea surface temperature drift displayed by Syed & Ahmed (2015). The results further show that the increase in the temperature of Sargodha is additionally being influenced by Global Warming. It also explained that the temperature of the Earth's Surface has expanded to 0.9°C since the last century.

4.7.1 Timeseries Analysis

I performed timeseries analysis to assess the historical patterns of mean monthly maximum temperature in Sargodha for the years 2004 to 2021. The results show that the lowest mean monthly maximum temperature was recorded as 16.80 in 2015. And the highest mean monthly maximum temperature was recorded as 43.1 in June 2012. The plot for mean maximum temperature in Sargodha is shown in the Figure 25. In the figure x-axis represent year and y-axis represent mean monthly maximum temperature for Sargodha.

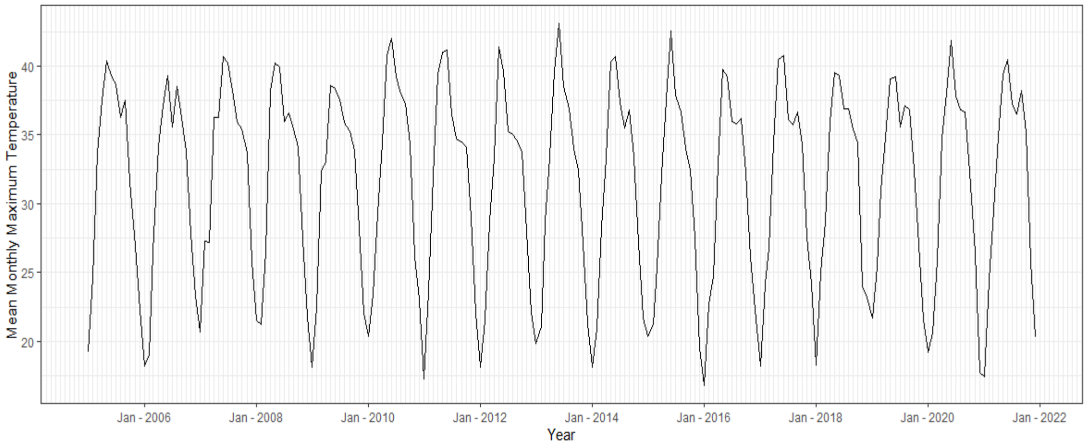

Figure 25: Mean Monthly Maximum Temperature in Sargodha for the year 2004 - 2021.

4.7.2 Decomposition:

The mean monthly maximum temperature for Sargodha timeseries data was decomposed using the st_l function to evaluate the seasonality, trend, and remainder.

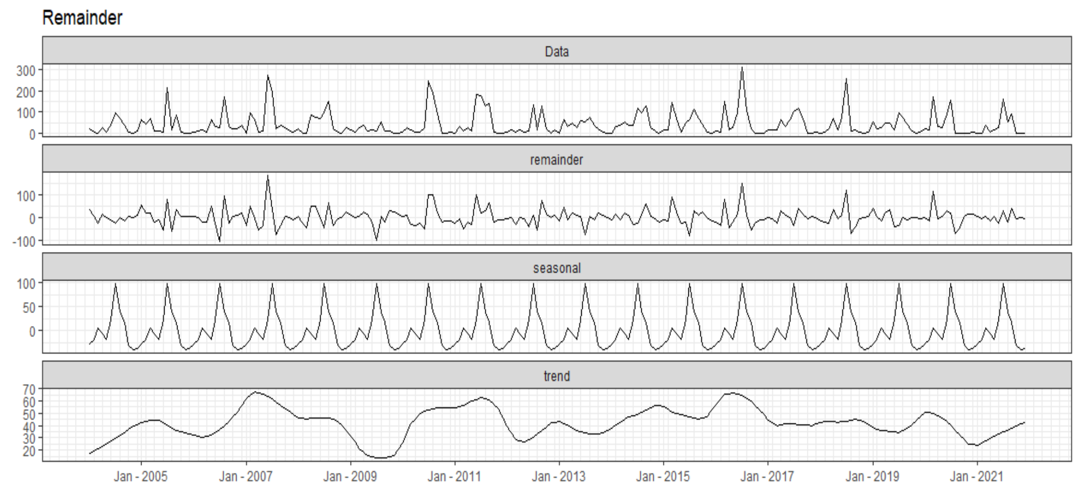

Figure 26:Decomposition of mean maximum temperature for Sargodha for the year 2004-2021. Timeseries is decomposed into Data, remainder, seasonal and trend.

The timeseries data was decomposed into data, remainder, seasonal and trend. Figure 26 shows the decomposition of Sargodha mean monthly maximum timeseries for the year 2004 to 2021. The degree of the trend and seasonality is based on a scale from 0 to 1, where 1 represents a very strong trend and seasonality.

The value of trend strength is 0.2 and the value of seasonal strength is 1. Figure 26 represent the decomposition of mean maximum temperature for Sargodha for the year 2004 to 2021.

4.7.3 Seasonal plot:

Seasonal plot for the Sargodha mean monthly maximum temperature was plotted for the year 2004 to 2021. The figure 27 shows seasonal plot where x -axis represent the months and y-axis represent the mean monthly maximum temperature for the year 2004 to 2021. The results showed that May to July are the months with the highest maximum temperature whereas December to January is the months with the lowest maximum temperature. The combined seasonal boxplot for the year 2004-2021 was drawn. It represents that May and June have the highest temperature whereas November to December has the maximum temperature above 20ºC. In October the temperature is above 30ºC which may impact the timely germination of wheat plants. The seasonal boxplot for mean maximum temperature Sargodha is shown in figure 28. In figure x-axis represents months and y a-axis represents the mean monthly maximum temperature for the year 2004 to 2021

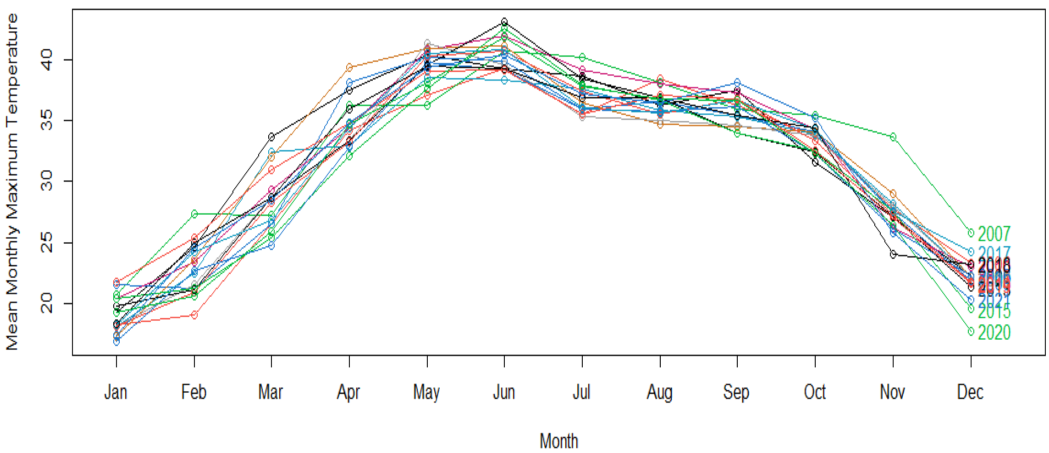

Figure 27: Seasonal plot ; Mean Maximum Temperature in Sargodha year 2004-2021.

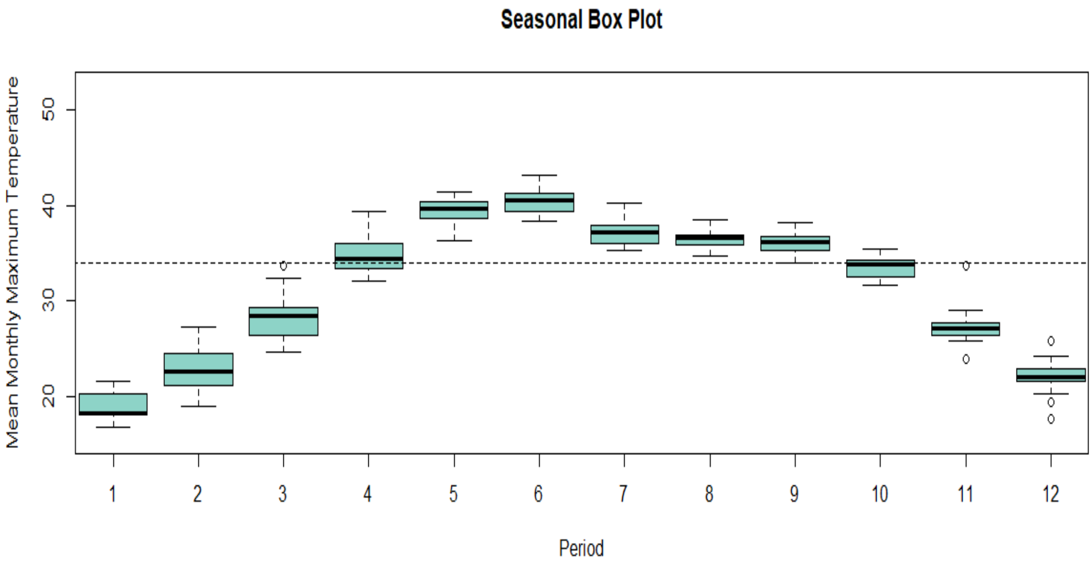

Figure 28: Boxplot for the Mean maximum temperature for Sargodha for the year 2004-2021.

4.7.4 Identification

To apply ARIMA methodology, it is necessary to check whether data is stationary or not. To check stationarity, ADF (Augmented Ducky fuller) test is applied. If data is not stationary, then it must be differenced to make it stationary, to apply box Jenkins's methodology . The data is trained from January 2004 to June 2021 and test set was taken from January 2004 to August for the year 2021. The results of ADF test show that p-value is less than 0.05. Therefore, we can say that our alternative hypothesis is accepted that data is stationary.

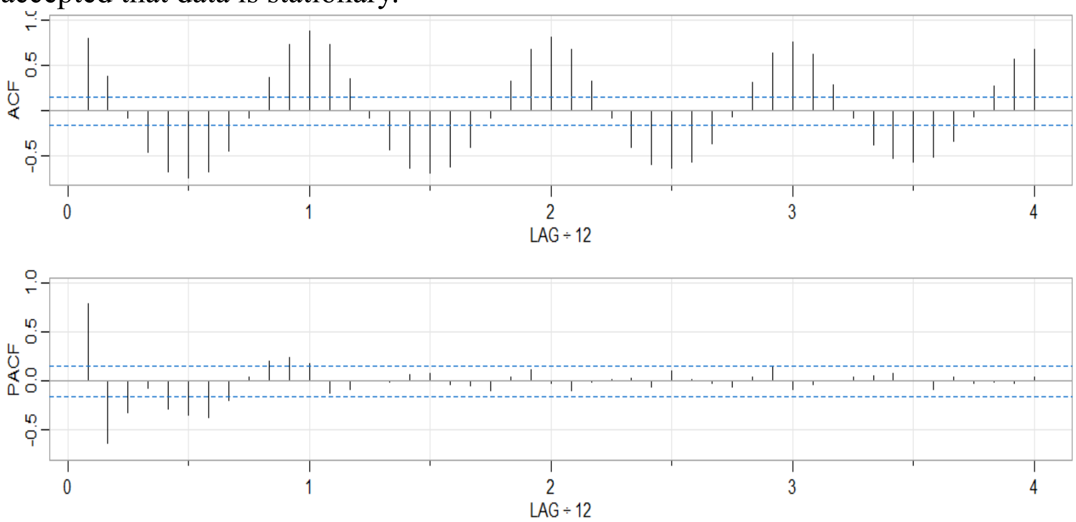

Figure 29:ACF and PACF for the Sargodha train mean maximum temperature for the Sargodha year 2004-2021

I also performed ACF and PACF plots for the mean monthly maximum temperature for Sargodha. Figure 29 shows the ACF and PACF of mean maximum temperature for Sargodha year 2004 to 2021.

4.7.5 Model Estimation

The next step in the development of the ARIMA model is a selection of tentative models. The best model was selected based on the lowest AIC value. Therefore model (2,0,2) (0,1,2) was found to be the best model with the AIC value of 503.44 for the mean monthly maximum temperature of the Sargodha for the years 2004-2021. The results of ARIMA order are shown in table 9.

Table 9:AIC values for ARIMA order mean monthly maximum temperature Sargodha

ARIMA ORDER	**AIC VALUE**
ARIMA(0,0,2)(0,1,1)	515.09
ARIMA(2,0,2)(1,1,1)	519.27
ARIMA(2,0,2)(0,1,2)	503.44
ARIMA(1,0,0)(1,1,0)	537.54
ARIMA(2,0,2)(1,1,0)	529.19
ARIMA(2,0,2)(2,1,0)	521.53
ARIMA(0,0,0)(0,1,0)	584.62

4.7.6 Diagnostic checking

After the selection of the best model different diagnostic checks are employed to check whether the model is the best fit or not. The results of the Ljung-Box test show that the p-value is 0.3538. The ACF plot shows that the spikes lie within the significant zone. And the histogram shows that the model is the best fit. The residuals for ARIMA(2,0,2)(0,1,2) are shown in the figure 31. Cross validation test was also performed. The result for the cross validation is shown in figure 31. Where the results are in accordance with the previous timeseries data. Statistical results for train set and test set show that the model is best fit. . The results represent that all the statistical values are in accordance to the standards.

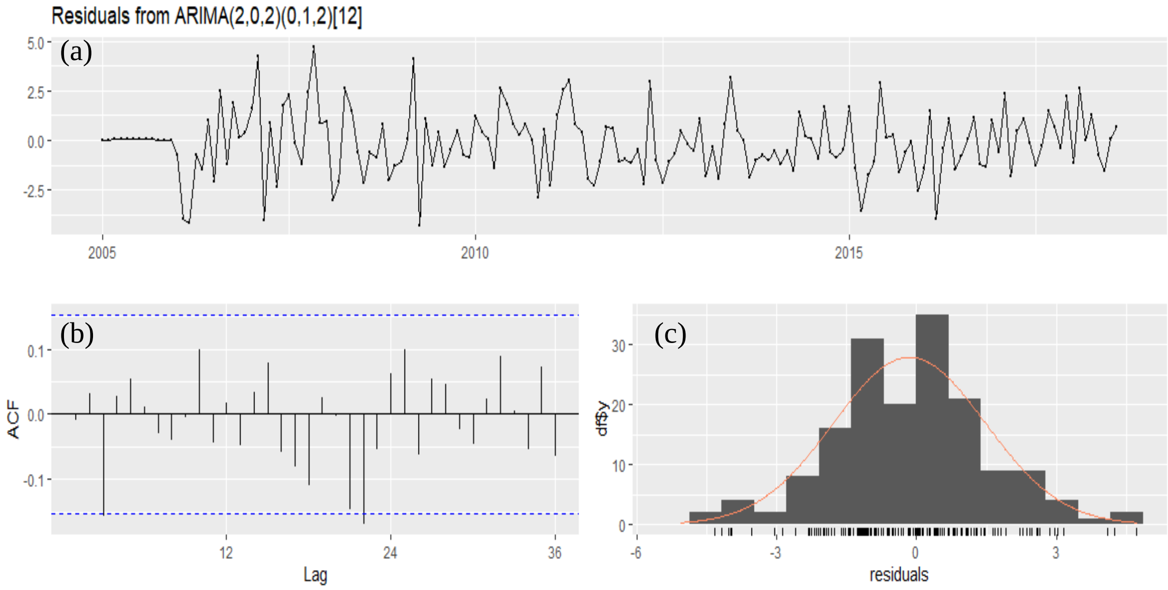

Figure 30:Graphical representation of Residuals from ARIMA(2,0,2)(0,1,2) for the mean monthly maximum temperature for the Sargodha year 2004 -2021.(a) The differenced timeseries for mean monthly maximum temperature for the Sargodha year 2004 -2021.(b) ACF for mean monthly maximum temperature for the Sargodha year 2004 -2021).(c) The histogram for residuals.

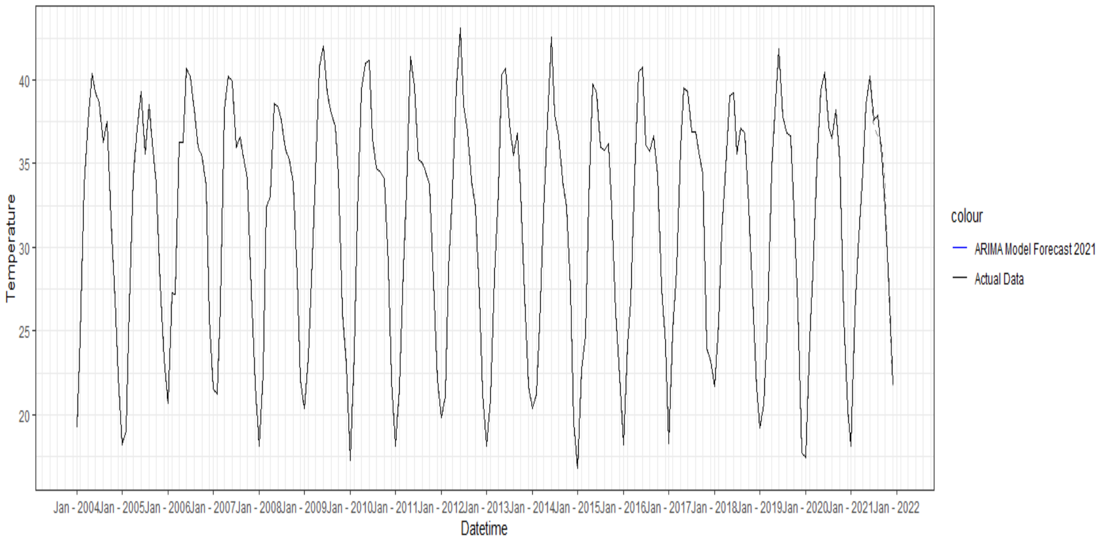

Figure 31: Cross Validation results for ARIMA (2,0,2)(0,1,2).

Table 10:Statistical parameters for train set and test set.

DATA	ME	RMSE	MAE
Training set	-0.15	1.59	1.20
Test set	-0.23	0.77	0.70

4.7.7 Forecast

The results of the forecast show that the monthly mean maximum temperature would increase during the growing seasons of wheat. It can change the sowing dates for wheat crop. Maize is a drought-tolerant crop and can withstand temperature. But there is a slight change being observed. The results of forecast are shown in the figure 32. Where x-axis represent the year and y-axis represent the monthly mean maximum temperature. The results are drawn for the monthly mean maximum temperature therefore there is a slight change observed for the forecast.

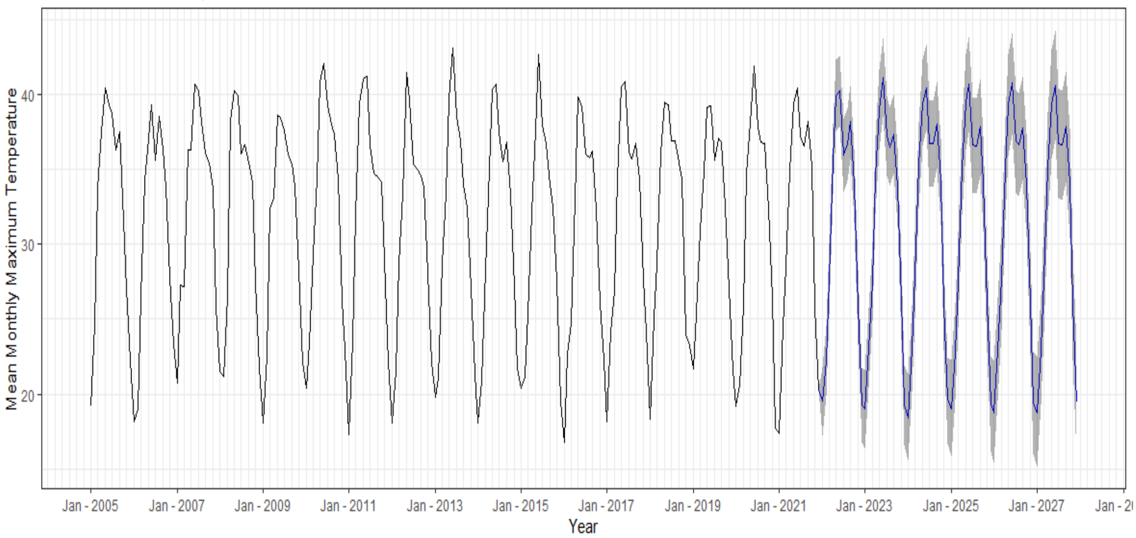

Figure 32: Forecast for Mean Maximum Temperature Sargodha 2022-2027.

4.8 Forecast monthly mean maximum Temperature Faisalabad 2021 to 2027

I developed the ARIMA model for monthly mean maximum temperature in Faisalabad for year 2004-2020. First timeseries analysis was performed. The plot for monthly mean maximum temperature for Faisalabad is shown in the figure 33. In figure x-axis represent the year and y-axis represent the monthly mean maximum temperature for the Faisalabad. Timeseries analysis showed that there is fluctuations observed in the monthly mean maximum temperature for Faisalabad. It was observed that lowest observed monthly mean maximum temperature is 16.30°C in January 2020 and highest mean maximum temperature is 41.90°C in June 2005 in Faisalabad.

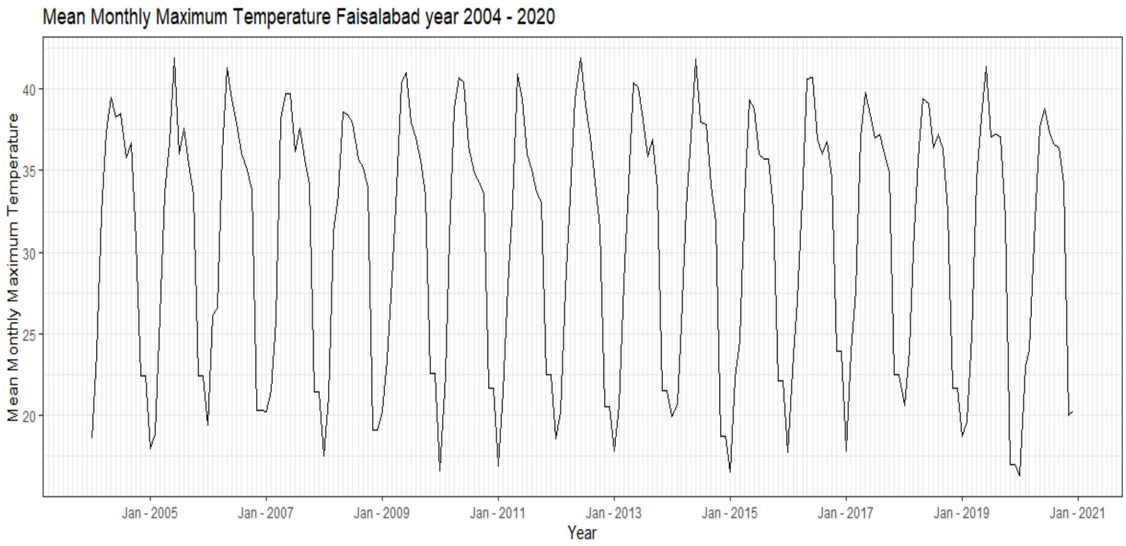

Figure 33: Timeseries Analysis of Mean Monthly Maximum Temperature Faisalabad 2004-2020.

Seasonal plot for monthly mean maximum temperature for the Faisalabad was plotted , where x-axis represent the months and y-axis represent the monthly mean maximum temperature. May and June are the months with high temperature and slight change observed during the October month in figure 34. The seasonal box plot is shown in the 35. The results represent that November and December for the year 2004 to 2020, are the months with lowest temperature.

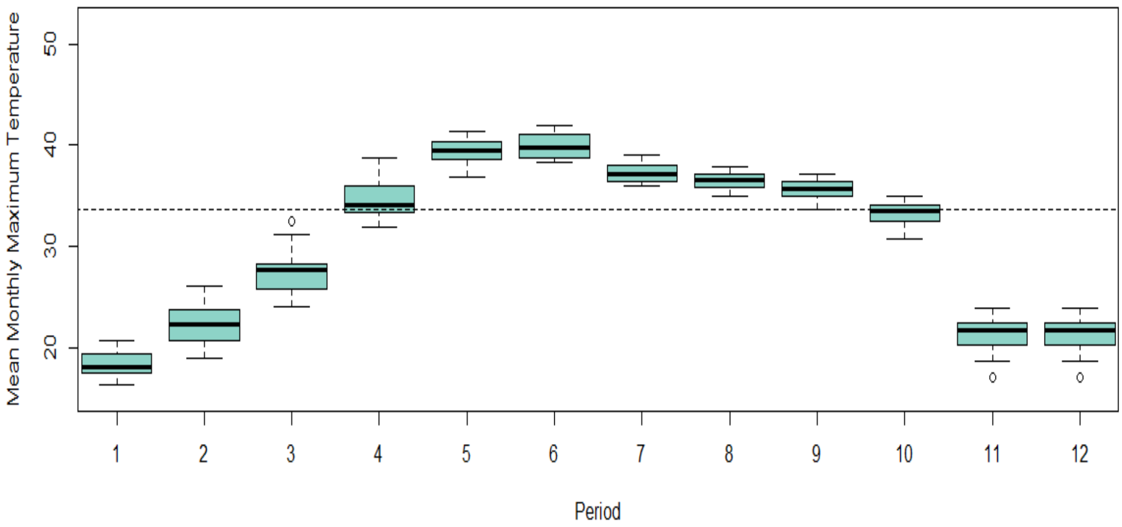

Figure 34: Seasonal Box plot for Mean Maximum Temperature Faisalabad year 2004-2020.

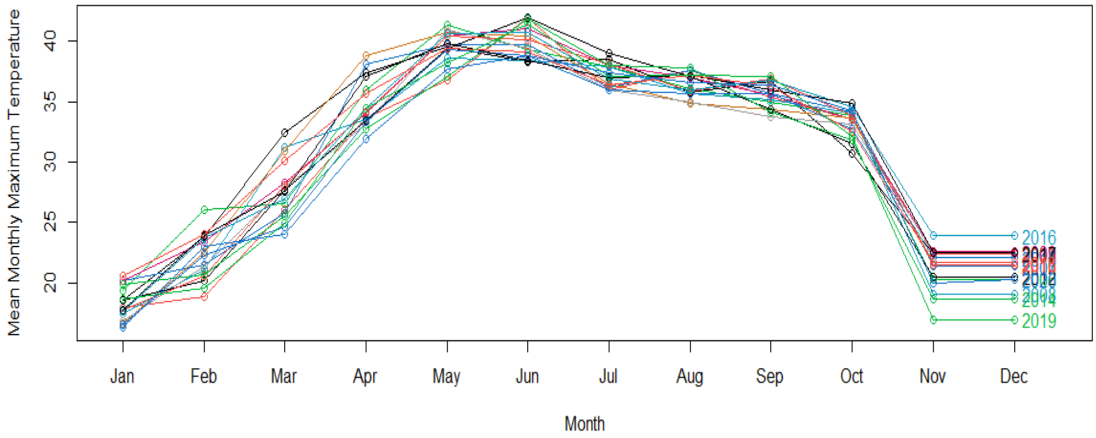

Figure 35: Seasonal Plot: Mean Monthly Maximum Temperature Faisalabad for year 2004-2020.

4.8.1 Decomposition of timeseries of mean maximum temperature Faisalabad

The data of monthly mean maximum temperature of Faisalabad for the year 2004 to the 2020 is decomposed into data , trend, seasonal, and remainder. The strength of the trend was found to be 0.3 and the seasonal strength to be 1. This means that a very weak trend strength occurred. The trend is an s shaped trend. The results of decomposition can be observed in figure 36 for the mean monthly maximum temperature Faisalabad for the year 2004 to 2020.

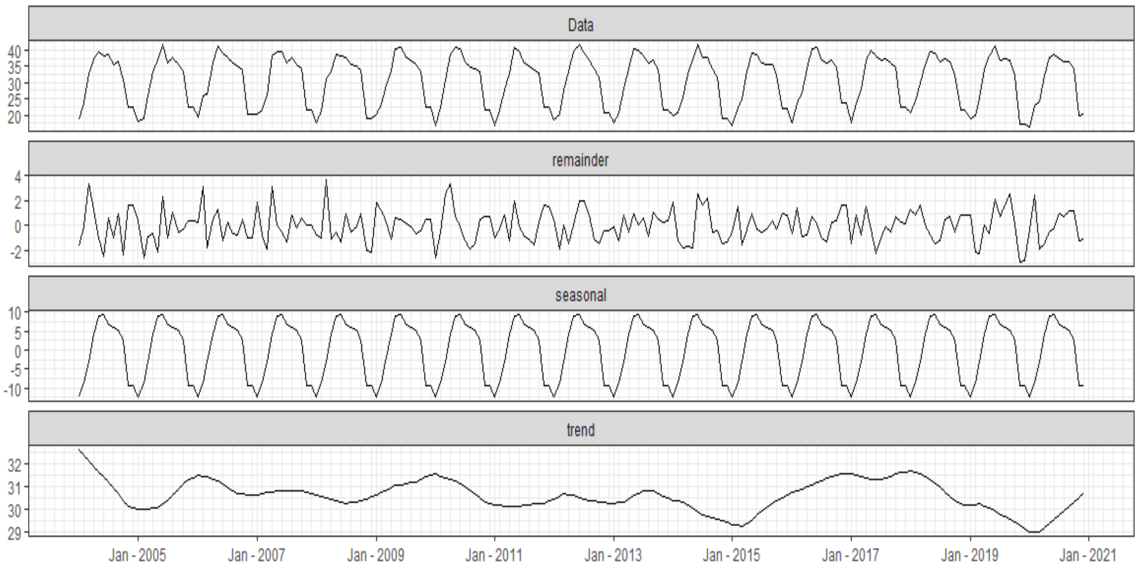

Figure 36: Decomposition of timeseries Monthly mean maximum timeseries Faisalabad 2004-2020

4.8.1 Identification:

To apply ARIMA methodology, it is necessary to check whether data is stationary or not. To check stationarity, ADF (Augmented Ducky fuller) test is applied. The data is trained from August 2021 to the January 2020. The p value of ADF test was less than 0.05 which means that the data is stationary.

4.8.2 Model Estimation:

Several models were selected from ACF and PACF plots. And also auto.arima function was also applied. The results of ACF and PACF plots are shown in figure 37. But several other possible models were also selected. The model with the lowest AIC value was selected. Therefore ARIMA model (2,0,2) (2,0,1) was found to be the best model. All the ARIMA orders and their AIC value is shown in table 11. Where ARIMA (2,0,2) (2,0,1) was found to be the best model with the lowest AIC vlue of 694.8.

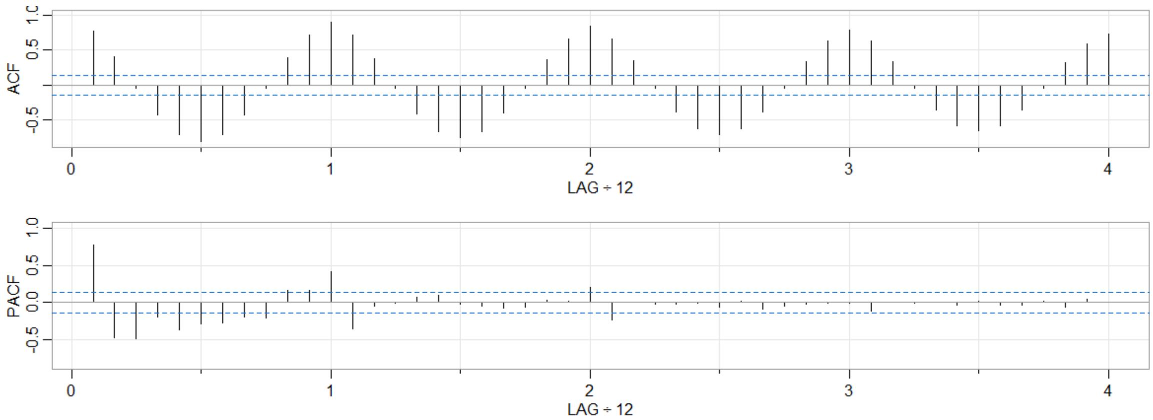

Figure 37:ACF and PACF for Monthly mean maximum Temperature Faisalabad.

Table 11:ARIMA order based on AIC value

ARIMA ORDER	AIC VALUE
ARIMA(2,0,2)(1,0,1)	823.4
ARIMA(2,0,2)(2,0,1)	694.8
ARIMA(2,0,1)(2,0,0)	856.4
ARIMA(1,0,1)(2,0,0)	854.32
ARIMA(2,0,1)(1,0,0)	905.46

4.8.3 Model Diagnostics

After estimating the tentative model graphical and numerical test were applied. The p value of Ljung-Box test is 0.90 this show that the model is best fit. The residuals for

ARIMA (2,0,2)(2,0,1) are shown in figure 38. It can be observed that that the histogram shows normal distribution and ACF plot show stationarity of our model. The validation of our model is represented in figure 39 where it can be observed that our model shows good representation of the predicted values.

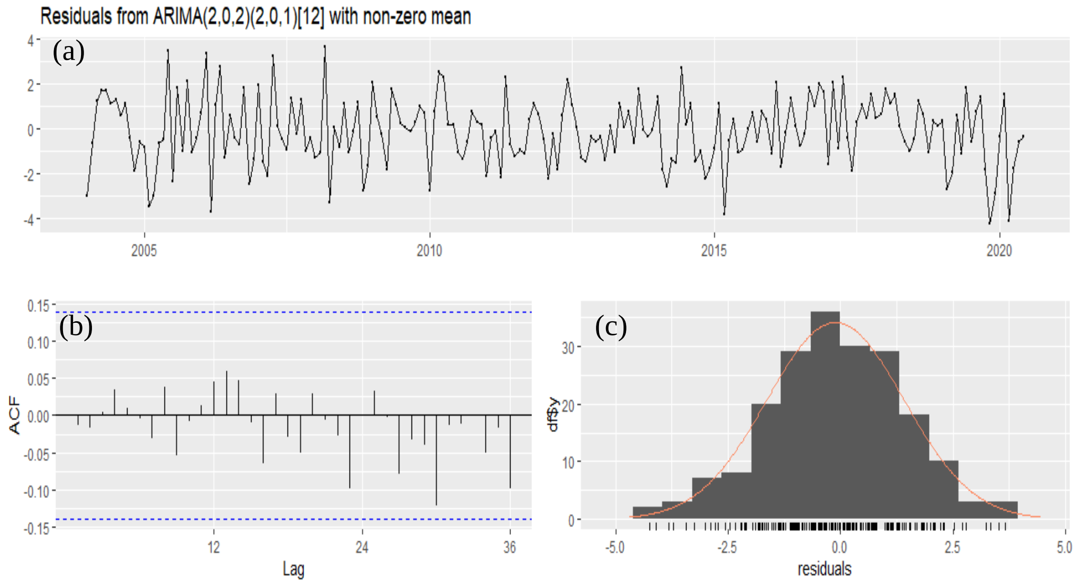

Figure 38: Graphical representation of Residuals from ARIMA (2,0,2) (2,0,1) for the mean monthly maximum temperature for the Faisalabad year 2004 -2020.(a) The differenced timeseries for mean monthly maximum temperature for the Faisalabad year 2004 -2020,(b)ACF of residuals (c) Histogram of residuals

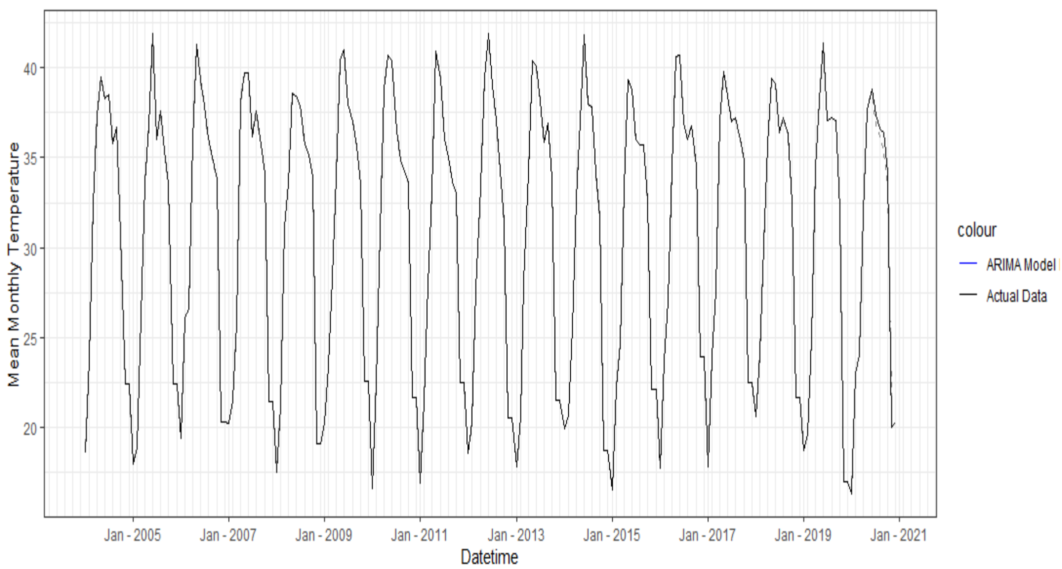

Figure 39: Validation results for ARIMA (2,0,2)(2,0,1)

Table 12:Statistical results for ARIMA (2,0,2)(2,0,1)

Data	**ME**	**RMSE**	**MAE**
Training set	-0.07	1.63	1.28
Test set	-1.50	1.52	1.50

4.8.4: Forecast

The forecasted results show that a significant trend in monthly mean maximum temperature was observed during the sowing season of wheat where monthly mean maximum temperature will increase during the months of October and November. Hence it would negatively impact on wheat crop germination. And it will also affect the sowing of maize. And temperature will also increase during harvesting seasons of both crops causing early crop maturity. The results of forecast are shown in the figure 40. In the figure x-axis represent year and the y axis represents the monthly mean maximum temperature for the Faisalabad. There is a slight increase in temperature being observed for the forecasted year 2021 to 2027.

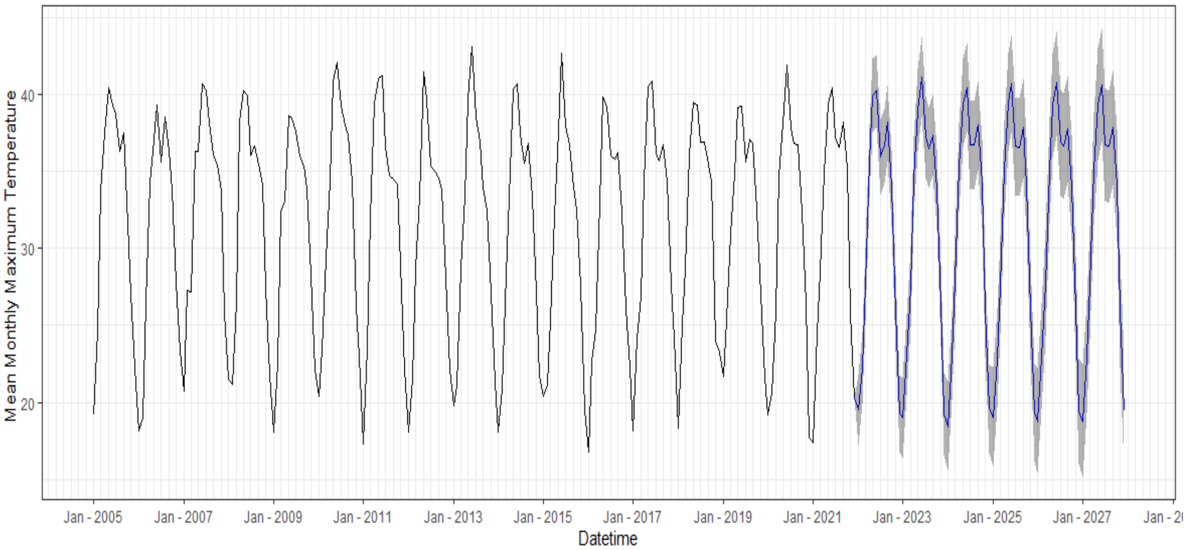

Figure 40: Forecast for monthly mean maximum Temperature for Faisalabad for the year 2022-2027.

4.9 Forecast of Faisalabad for total amount of Precipitation in mm for year 2021-2027

Historical Timeseries analysis was performed for the Faisalabad precipitation in mm for the year 2004 to 2020. It showed that 243.10 mm was the highest amount of precipitation received during the year in 2010. According to the data a significant amount of precipitation is being observed during the march. The plot of Faisalabad total amount of monthly precipitation in mm is shown in the figure 41 where x-axis represents the year and y axis represent the precipitation in mm for the Faisalabad for the year 2004 to 2020.

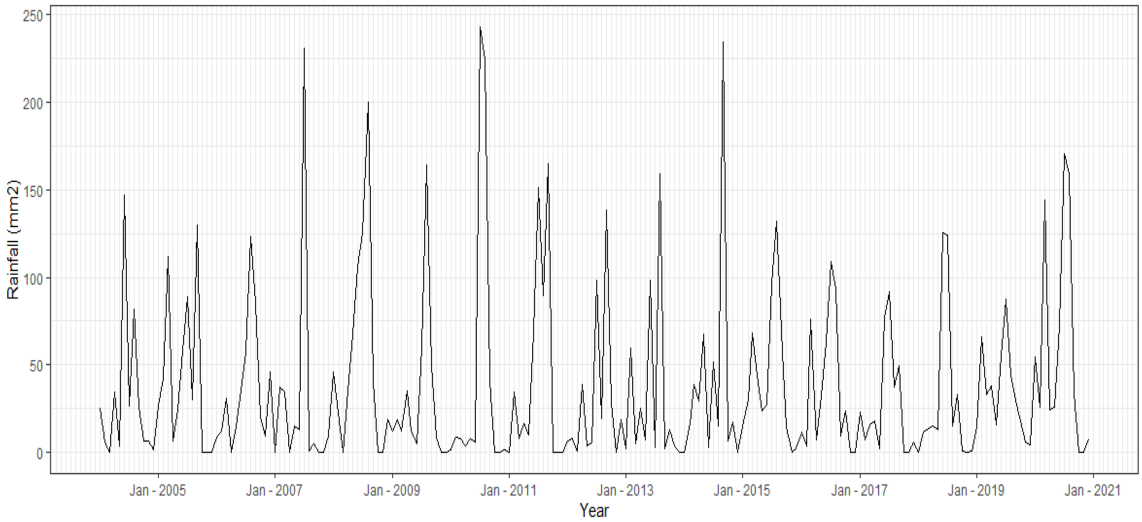

Figure 41: Timeseries Analysis for the total amount of monthly precipitation in mm in Faisalabad for the year 2004-2020.

Seasonal plot is shown in figure 42, where x-axis represents the months and y-axis represent the rainfall in mm .The results of seasonal plot represents that the maximum amount of precipitation is received in the month of July. And also a significant amount of rainfall is received in the month of September. The seasonal box plot was also drawn in figure 43 showing the collective trend over the years where x-axis represent the months and y-axis represent the rainfall in mm for the year and it is observed that July is the month with the highest precipitation and receives rainfall above 300mm. Whereas December has the lowest precipitation. But it is also observed that in April and May there is also a significant amount of precipitation. As these are wheat harvesting seasons. Whereas according to the data in 2016, in March 150.9 mm of rainfall was received.

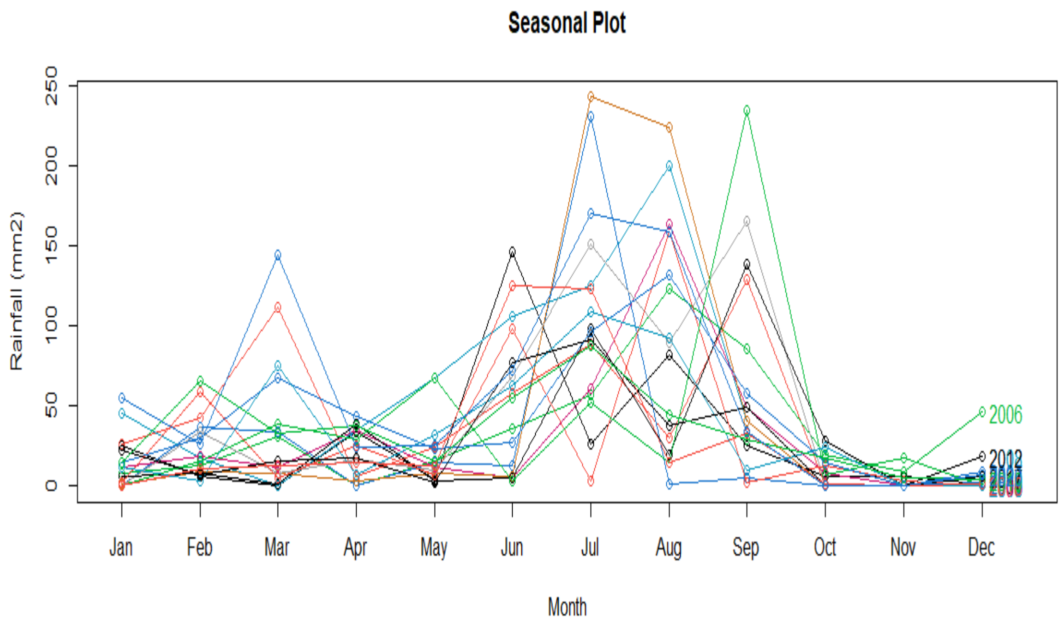

Figure 43: Seasonal plot for Faisalabad total amount of precipitation in mm for the year 2004-2020.

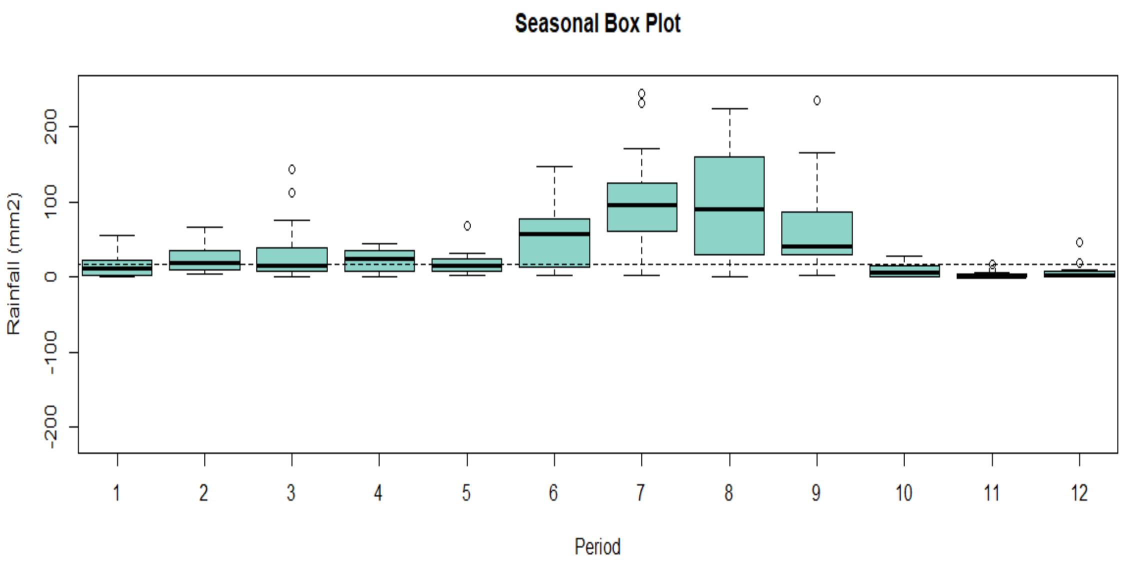

Figure 42: Seasonal subseries plot; total monthly amount of Precipitation in mm in Faisalabad for the year 2004 to 2020.

8.1.3 Decomposition of Timeseries

Timeseries data of total monthly amount of precipitation for the Faisalabad for the year 2004 to 2020 was taken. Timeseries data was decomposed into data, trend , seasonal and remainder. The figure 44 show the decomposition of timeseries data for total monthly amount of precipitation in mm of Faisalabad for the year 2004-2020. The trend strength was observed to be 0.1 and seasonal strength to be 0.5.

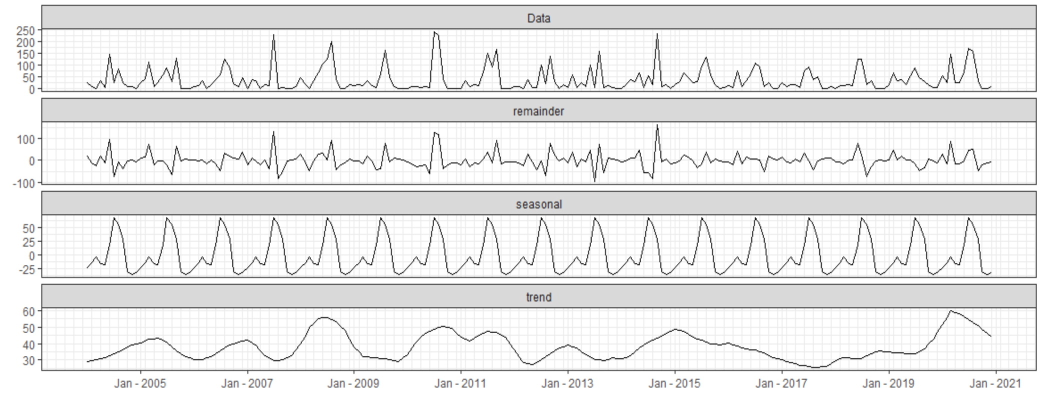

Figure 44: Decomposition of timeseries of total monthly amount of precipitation in mm of Faisalabad for the year 2004-2020.

4.9.2 Identification

The p value of ADF test proves to be less than 0.05 hence alternative hypothesis is accepted that data is stationary and null hypothesis is rejected that data is not stationary. ACF and PACF for the Faisalabad precipitation were drawn. Figure 45 show the ACF and PACF for the total monthly amount of precipitation in mm for the Faisalabad precipitation.

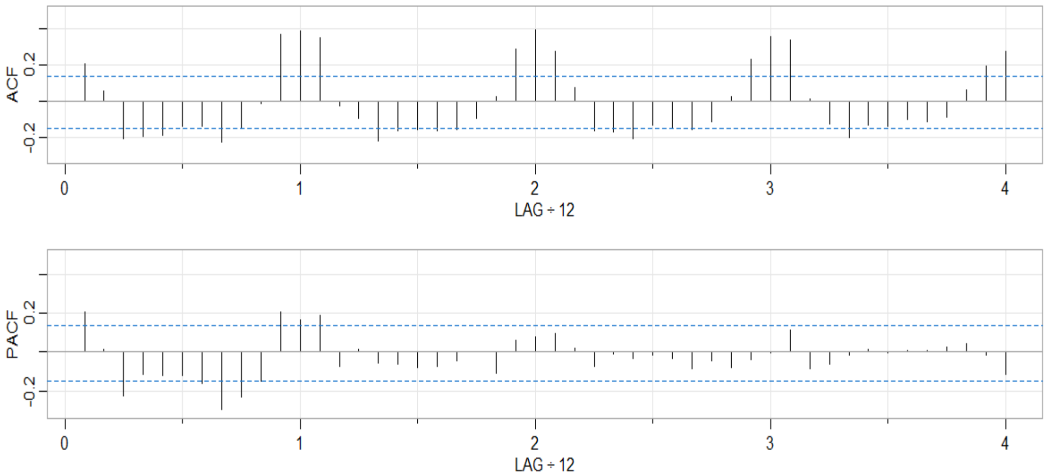

Figure 45: ACF and PACF for Faisalabad Monthly amount of Precipitation in mm

4.9.3 Model Estimation

Various ARIMA models were selected and the ARIMA(1,0,1)(2,0,0) was found to be the best. The table 13 show the AIC values for the ARIMA order for the model selection.

Table 13:ARIMA order based on AIC Values

ARIMA ORDER	**AIC VALUE**
ARIMA(1,0,1)(2,0,1)	2047.77
ARIMA(0,1,2)(0,1,2)	1932.82
ARIMA(1,1,0)(2,1,0)	2023.19
ARIMA(1,1,1)(1,1,1)	1932.66

4.9.4 Model Diagnostics

After model estimation various Models' diagnostics tests were applied. For numerical estimation Ljung- Box test was performed. The p-value was recorded as 0.56, which showed that the model is best fit. For graphical estimation residuals check was applied. The graphical representation was obtained. The results showed that that residuals are independently distributed for the ARIMA order (1,1,1) (1,1,1) .

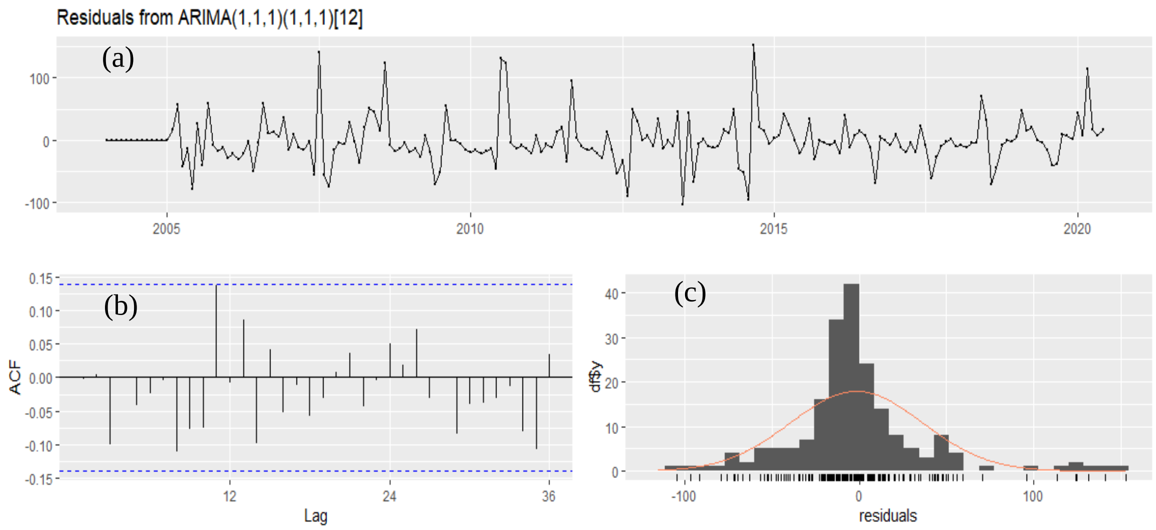

Figure 46: Graphical representation of Residuals from ARIMA(1,1,1)(1,1,1) for the total monthly amount of precipitation in mm for the Faisalabad year 2004 -2020.(a) The differenced timeseries for the total monthly amount of precipitation in mm for the Faisalabad year 2004 -2020. (b) ACF for precipitation in mm.(c) Histogram of residuals

The differenced timeseries showed that timeseries data is stationary and the ACF also represent that residuals are independently distributed. And histogram show normal distribution. It can be observed in Figure 46 that residuals are independently distributed.

Table 14: Train set for ARIMA (1,1,1)(1,1,1)

TEST	**ME**	**RMSE**	**MAE**
Training set	-1.68	37.93	24.16
Test set	-10.92	15.07	11.18

4.9.5 Forecast

The results of forecast are shown in figure 43. It can be observed that a significant amount of change in precipitation is being observed. This is forecasted based on the historical timeseries data therefore further availability of data can improve the results. The grey line represents confidence interval. Certain values lie blow 0 mark this is because of the months with drought. Therefore, during ARIMA process the forecasted values that are also 0 get show below the confidence interval and values get into minus. The x-axis represents the year and y axis represents the total monthly amount of precipitation in mm for the Faisalabad for the year 2004 to 2027.

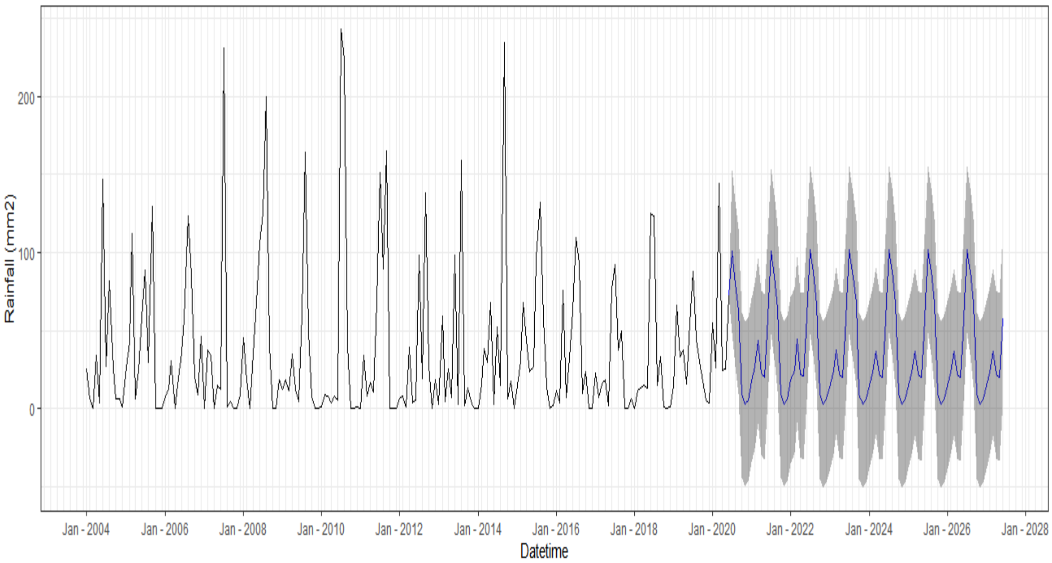

Figure 47:Forecast from Faisalabad for the total monthly amount of Precipitation in mm year 2021-2027.

5. MULTIVARIATE TIMESERIES ANALYSIS

I performed multivariate timeseries analysis for the Sargodha and Faisalabad. Two crops wheat and maize were selected along with the climatic variable's maximum temperature °C and precipitation in mm. For Sargodha the data was taken from 2004 to the 2021. And for the Faisalabad the data for crops and weather parameters were taken from the 2004 to the 2020.The multivariate timeseries analysis was performed for wheat and maize according to the crop adjustment calendar.

5.1 Multivariate timeseries analysis for wheat Faisalabad

A multivariate timeseries analysis was performed for the wheat yield (maund/acre) for Faisalabad for the year 2004-2020. The plot for multivariate timeseries is shown in figure 48. It can be observed that for increase in precipitation leads to the significant impact on yield, whereas for the decrease in precipitation yielded optimum production. For temperature the results show a significant impact. With decrease in temperature a significant increase in production is achieved. The lowest production of wheat yield (maund/acre) for year 2020 and increase in precipitation and temperature can be observed.

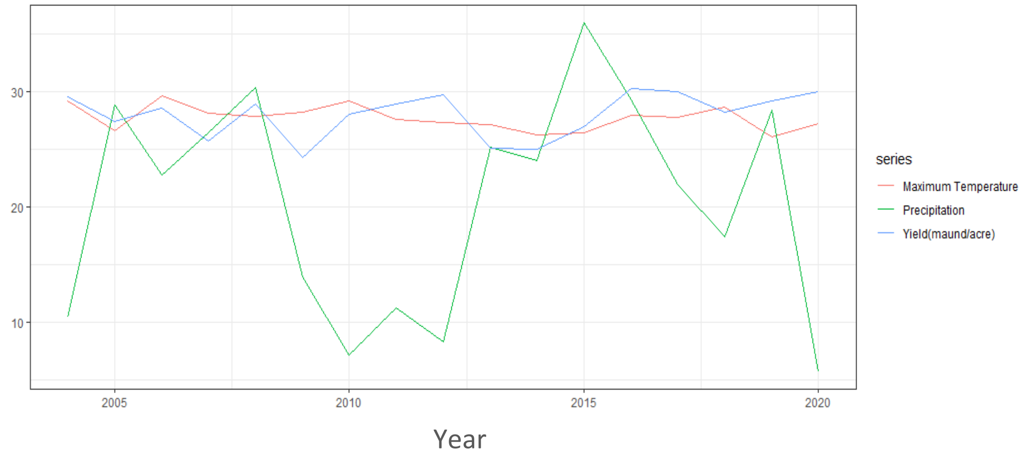

Figure 48:Multivariate timeseries for wheat yield (maund/acre) , maximum temperature and precipitation in mm for Faisalabad for the year 2004 to 2020.

5.2 Multivariate timeseries analysis for maize Faisalabad

A multivariate timeseries analysis for the maize yield (maund/acre) for Faisalabad along with maximum temperature and precipitation in mm for the year 2004-2020 was performed. The plot for multivariate timeseries is shown in the figure 49. From the figure it can be observed that yield is increasing and decreasing after some years whereas for the precipitation there is a rapid increase since past five years. Although the temperature is not showing a slight variation for the past five years. As it can be seen that 2020 recorded a decrease in production for maize yield(maund/acre) whereas a slight variability in precipitation.

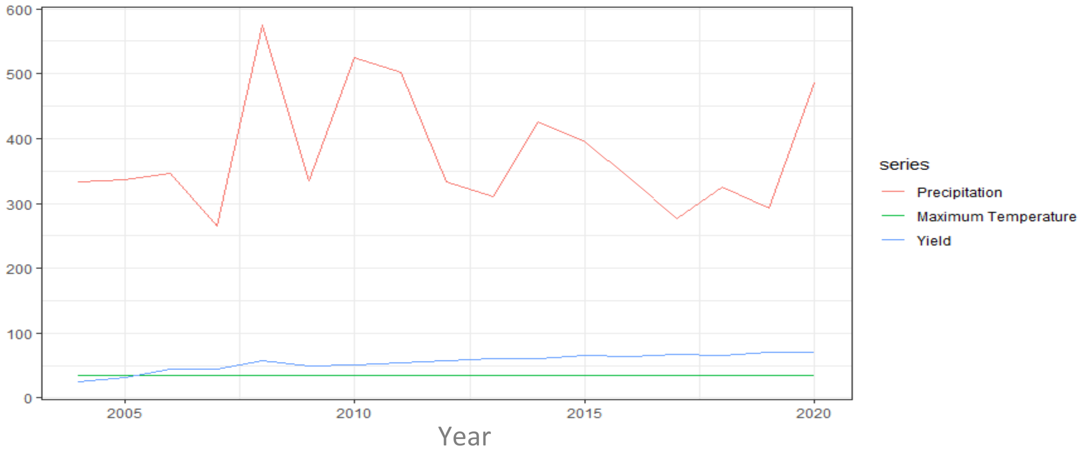

Figure 49: Multivariate timeseries analysis for the maize yield(maund/acre) , maximum temperature and precipitation for the year 2004-2020.

5.3 Multivariate timeseries for Wheat Sargodha and climatic variables

For wheat yield (maund/acre) , temperature and precipitation a multivariate timeseries analysis was also performed. The results are shown in the figure 50 . It can be seen that for the wheat yield (maund/acre) for year 2004 an increase is observed whereas a decrease in precipitation is observed. Similarly, a further decrease in yield (maund/acre) is observed for the year 2010 to year 2014 , and an increase precipitation was observed for corresponding years.

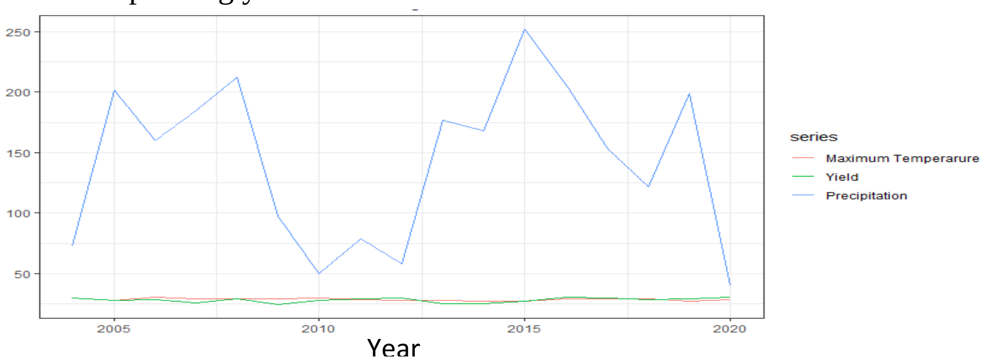

Figure 50: Multivariate timeseries analysis for wheat yield(maund/acre) for Sargodha for the year 2004-2021.

The year 2020 recorded a significant increase in yield. Whereas a decrease in precipitation was observed. Increase in maximum temperature also leads to significant impact on yield. It can be analyzed that yield is a decrease in the yield (maund/acre) is observed with increase in temperature.

5.4 Multivariate timeseries of Maize Sargodha and climatic variables

The multivariate timeseries analysis of maize yield (maund/acre) for Sargodha was performed for the year 2004-2020. It can be seen in the figure 51 that maize yield is increasing with the decrease in precipitation. The year 2020 showed a decrease in precipitation for the maize growing season and a significant increase in maize yield was observed. However, for maximum temperature the results do not show a significant impact.

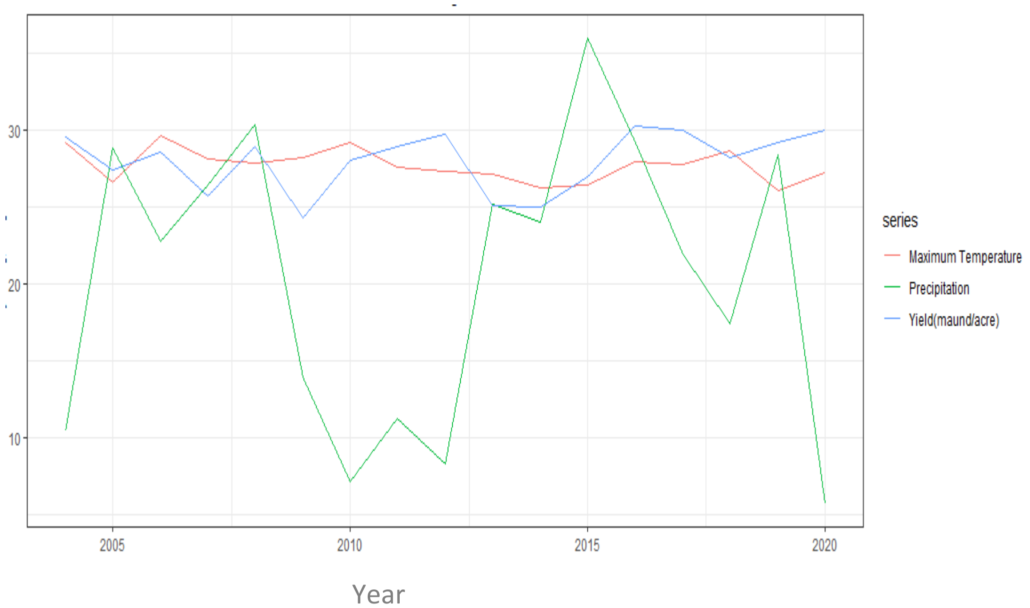

Figure 51: Multivariate timeseries analysis for the maize yield(maund/acre) for Sargodha year 2004-2020.

6. CONCLUSION AND RECOMMENDATIONS

climatic variables play important role in the growth and production of a crop. But due to the recent shift in the warming trend. These climatic variations have played a significant impact on the crops in terms of food security. Successful crop production depends on a balance between these climatic variations. High extremes play a negative impact. There is a need to come up with mitigation strategies to cope with these drastic changes to ensure food loss and crisis. And develop a better understanding, particularly for regions with low coping capacity.

6.1 Conclusion:

Following are the conclusions that are made from the conducted research. In the present study, wheat , maize , precipitation, and temperature data time series were investigated using ARIMA modeling. Forecasted wheat yield (maund/acre) for Faisalabad and Sargodha will slightly increase by 0.178 (maund/acre) for Faisalabad and 1.69 (maund/acre) for the Sargodha year 2022- 2027. Forecasted maize yield (maund/acre) for Faisalabad will increase by 4.1 (maund./acre) and for Sargodha will increase by 2.17 (maund/acre) for year 2022-2027.However, the forecast results for maximum temperature showing an increasing trend for Faisalabad , whereas for Sargodha it is showing the same pattern. For the year 2022-2027. In case of total amount of precipitation, the forecasted monthly rainfall for Sargodha is decreasing during the wheat crop sowing season and is increasing during the crop harvesting season. But its impact on maize is non-significant for the year 2022-2027.Forecasted monthly rainfall for Faisalabad show an increasing during the crop harvesting season. This will have negative effect on the wheat crop and maize crop for the year 2022-2027

6.2 Recommendations and Limitation

- Based on the results, numerous suggestions can be drawn to strengthen the level of food security, cropping intensity, and education of a common farmer.
- The forecasted results can be used in the crop adjustments calendar.
- It will allow policymakers to sort out the irrigation needs of the farmers living in Sargodha and Faisalabad.
- It will allow the better management of water supply and demand.
- Drought and precipitation resistant varieties should be introduced to mitigate the impact of climatic variations.

- Forecasting provides an effective tool for timely implementation of mitigation strategies.
- Data should be made available to the researchers for better quality forecasts.

6. 3 Limitations

- The results of forecast mainly depend on historical data; therefore, it is necessary to employ accurate data for forecast. Therefore, it poses a main issue.
- ARIMA modeling require careful statistical skills for interpretation.
- Forecast is not applicable for long term.

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