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Climatic Effects on Major Pulse Crops Production in Bangladesh: An Application of Box-Jenkins ARIMAX Model

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Abstract
The objective of this study is to measure the climatic effects on different types of pulse crops production in Bangladesh using Box-Jenkins Auto-Regressive Integrated Moving Average with external regressor, that is, ARIMAX model. The ARIMAX model is used in this study to measure climatic effects as a measuring tool of cause-effect relation between response and predictor variables because of time sequence dataset. From this study, it is found that the best selected Box-Jenkins ARIMAX model for measuring the climatic effects on pulse crops production are ARIMAX(1,1,3), ARIMAX(2,1,0), ARIMAX(1,1,2) and ARIMAX(2,1,1) for Mug, Gram, Khesari and Masur productions respectively.
Keywords: Climatic effects, Pulse Crops, ARIMAX Model, Bangladesh.

1. Introduction
Bangladesh has a large agrarian base country with 77% of total population is living in the rural areas and 90% of the rural population is directly related with agriculture. *Agriculture* is the single largest producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's *GDP* and employs around 45% of the total labor force. Out of the total cropped area of Bangladesh rice alone covers about 77% while the all pulse crops cover only 2.45%. The cultivation of legumes gains primary importance in Bangladesh. Pulses are considered as "the meat of the poor" because still pulses are the cheapest source of protein. There are different types of pulse crop are produced in Bangladesh such as Musur, Mug, Grain, Kheshari (all are locally named) etc. are the major pulse crops. Most of them are used as dal or soup.
Lentil is the most nutritious of all pulses containing high protein in their seeds. It is known as 'masur dal' in Bangladesh. Among the pulses grown in Bangladesh, lentil holds the second position in respect of both total area & cultivation just after cultivation. Another most important pulse crop is mug bean which is showing an increasing trend in relation to its both cultivation area & production now a days in Bangladesh. It is originated in India. Containing an appreciable amount of high quality protein, it is used mainly used as dal or soup. Lathyrus or Grasspea is commonly known as Khesary in Bangladesh. Among the pulses grown in Bangladesh, it holds the first position in terms of both cultivation area and production. Grasspea is probably originated in Southern Europe & Western Asia. In Bangladesh grasspea is grown in almost every district. There are some merits of lathyrus such as- it contains 25% protein in grains, adds atmospheric nitrogen & organic matter to soil.
Climate change in Bangladesh is an extremely crucial issue and according to National Geographic, Bangladesh ranks first as the nation most vulnerable to the impacts of climate change in the coming decades. Climate change and agriculture are interrelated processes, both of which take place on a global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements. These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production.

2. Objectives of the Study
The main objective of this study is to develop an appropriate ARIMAX model for measuring the climatic effects on major pulse crops production in the Bangladesh. The specific objective of the study is to develop the best Autoregressive Integrated Moving Average with external regressors (ARIMAX) model for different types of pulse crops production such as Kheshori, Mug, Musar and Gram in Bangladesh.

3. Review of Literature
There are not enough review of the literature for measuring the effects on agricultural crops production such as pulse crops using ARIMAX model. But some of such relevant study using ARIMAX model has been done such as Julio and hipoli (2005) have conducted an analysis with the title “short term electricity future prices at Nord Pool forecasting power and risk premiums”. This study analyses how weekly prices at Nord pool are formed. Forecasting power of future prices is compared with an ARIMAX model in the spot prices. Hamjah and

Chowdhury (2014) has conducted a study to measure the climatic and hydrological effects on cash crop production in Bangladesh and they also forecast the production using the ARIMAX model.

4. Reasons for Choosing ARIAMX model

Generally, To measure any cause-effect relationship among the variables under study, we use regression approach like Multiple Regression Model which is the most suitable model for cross-sectional data analysis. The dataset used in this study is a time sequence dataset, that is, it has time effects on the variable under study which should be considered. We don't avoid the problems of time effects on the variable under study and that's why, it is tried to fit the model using Box-Jenkins (Box and Jenkins, 1970) ARIMA with external regressors, that is, ARIMAX model. Using ARIMAX model, we can overcome time effects problems by adding some Auto-Regressive and/or Moving Average term in the model to adjust these time effects. Definitely, in as usual Regression model, we don't consider these time effects, so ARIMAX model could be better than Multiple Regression Model for the time sequence data analysis in this study.

5. Methodology

A time series is a set of numbers that measures the status of some activity over equally spaced time interval. It is the historical record of some activity, with measurements taken at equally spaced intervals with a consistency in the activity and the method of measurement.

5.1. Moving Average Processes

Moving average models were first considered by Slutsky (1927) and Wold (1938). The Moving Average Series can be written as

$$Y_t = e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} - \theta_3 e_{t-3} - \dots - \theta_q e_{t-q} \quad (1)$$

We call such a series a moving average of order **q** and abbreviate the name to **MA(q)**. where, Y_t is the original series and e_t is the series of errors.

5.2. Auto-Regressive Proces

Yule (1926) carried out the original work on autoregressive processes. Autoregressive processes are as their name suggests regressions on themselves. Specifically, a p^{th-} order autoregressive process {Yt} satisfies the equation

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \Phi_3 Y_{t-3} + \dots + \Phi_p Y_{t-p} + e_t \quad (2)$$

The current value of the series Y_t is a linear combination of the p most recent past values of itself plus an "innovation" term e_t that incorporates everything new in the series at time t that is not explained by the past values. Thus, for every t, we assume that e_t is independent of $Y_{t-1}, Y_{t-2}, Y_{t-3}, \dots Y_{t-q}$.

5.3. Autoregressive Integrated Moving Average (ARMIA) Model

The Box and Jenkins (1970) procedure is the milestone of the modern approach to time series analysis. Given an observed time series, the aim of the Box and Jenkins procedure is to build an ARIMA model. In particular, passing by opportune preliminary transformations of the data, the procedure focuses on Stationary processes.

In this study, it is tried to fit the Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) model. This model is the generalized model of the non-stationary ARMA model denoted by ARMA(p,q) can be written as

$$Y_t = \Phi_1 Y_{t-1} + \Phi_2 Y_{t-2} + \dots + \Phi_p Y_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} \dots \dots \dots - \theta_q e_{t-q} \quad (3)$$

Where, Y_t is the original series, for every t, we assume that e_t is independent of $Y_{t-1}, Y_{t-2}, Y_{t-3}, \dots, Y_{t-p}$.

A time series $\{Y_t\}$ is said to follow an integrated autoregressive moving average (ARIMA) model if the d^{th} difference $W_t = \nabla^d Y_t$ is a stationary ARMA process. If $\{W_t\}$ follows an ARMA (p,q) model, we say that $\{Y_t\}$ is an ARIMA(p,d,q) process. Fortunately, for practical purposes, we can usually take d = 1 or at most 2. Consider then an ARIMA (p,1,q) process. with $W_t = Y_t - Y_{t-1}$, we have

$$W_t = \Phi_1 W_{t-1} + \Phi_2 W_{t-2} + \dots + \Phi_p W_{t-p} + e_t - \theta_1 e_{t-1} - \theta_2 e_{t-2} \dots \dots \dots \theta_q e_{t-q} \quad (4)$$

5.4. Autoregressive Integrated Moving Average with External Regressor (ARMIAX) Model

An ARIMA model with external regressor, that is, ARIMAX model with d=1 can be written as

$$W_t = \Phi_1 W_{t-1} + \Phi_2 W_{t-2} \dots + \Phi_p W_{t-p} + e_t - \theta_1 e_{t-1} \dots - \theta_q e_{t-q} + \beta_1 X_{t1} + \beta_2 X_{t2}, \dots, \beta_m X_{tm} \quad (5)$$

Where X's are regressor variables and β's are the coefficients of regressor variable

Box and Jenkins procedure's steps

i. *Preliminary analysis:* create conditions such that the data at hand can be considered as the realization of a stationary stochastic process.
ii. *Identification:* specify the orders p, d, q of the ARIMA model so that it is clear the number of parameters to estimate. Recognizing the behavior of empirical autocorrelation functions plays an extremely important role.
iii. *Estimate:* efficient, consistent, sufficient estimate of the parameters of the ARIMA model (maximum likelihood estimator).
iv. *Diagnostics:* check if the model is a good one using tests on the parameters and residuals of the model. Note that also when the model is rejected, still this is a very useful step to obtain information to improve the model.

v. *Usage of the model:* if the model passes the diagnostics step, then it can be used to interpret a phenomenon, forecast.

5.1. Others Techniques and Tools Used in This Study

- To check normality assumption "Jarque-Bera" test (Jarque & Bera, 1980) is used which is a goodness of fit measure of departure from normality, based on the sample kurtosis and skewness.
- To check autocorrelation among the residuals, "Ljung-Box" (Box and Ljung, 1978) test is used under the hypothesis that there is no autocorrelation among the residuals.
- Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) are used to detect the order of difference of stationarity conditions.
- Akaike Information Criterion (AIC) and Baysian Information Criterion (BIC) are used as a model selection criterion.

6. Data Sources, Data Manipulation and Used Software

The climatic information are available from the Bangladesh Government's authorized websites of Bangladesh Rice Research Council (BARC) named as *www.barc.gov.bd.* The pulse crop datasets are also available from Bangladesh Agricultural Ministry's website named as *www.moa.gov.bd.* These dataset are available from the year 1972 to 2006. Climatic information was in the original form such a way that it is arranged in the monthly average information corresponding to the years from 1972 to 2006 according to the 30 climatic stations. The name of these stations are Dinajpur, Rangpur, Rajshahi, Bogra, Mymensingh, Sylhet, Srimangal, Ishurdi, Dhaka, Comilla, Chandpur, Josser, Faridpur, Madaripur, Khulna, Satkhira, Barisal, Bhola, Feni, MaijdeeCourt, Hatiya, Sitakunda, Sandwip, Chittagong, Kutubdia, Cox's Bazar, Teknaf, Rangamati, Patuakhali, Khepupara, Tangail, and Mongla. It is taken the month October, November, December, January and February as a "dry season" and March, April, May, June, July, August, September as a "summer season" considering the weather and climatic conditions of Bangladesh. Then, finally we take average seasonal climatic information of 30 climatic station corresponding to the year from 1972 to 2006. We take the average of 30 climatic area because of focusing the overall country's situation and overall model fitting for whole Bangladesh.

This analysis has completely done by statistical programming based open source Software R for windows (version 2.15.1). The additional library packages used for analysis are forecast, TSA and tseries, etc.

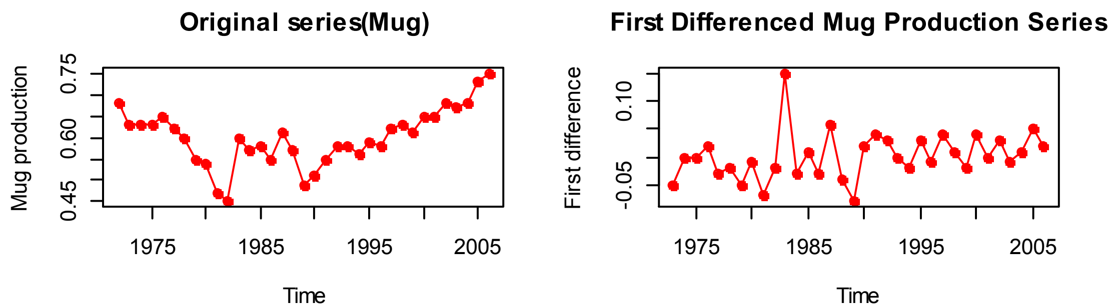
7. Used Climatic Variables in This Study

sun.sum = Sunshine of the Summer Season, sun.dry = Sunshine of the Dry Season , clo.sum = Cloud Coverage of the Summer Season, clo.dry = Cloud Coverage of the Dry Season, max.tem.dry = Maximum Temperature of the Dry Season, max.tem.sum = Maximum Temperature of the Summer Season, min.tem.dry = Minimum Temperature of the Dry Season, min.tem.sum = Minimum Temperature of the Summer Season, rain.dry= Ammount of Rainfall of the Dry Season, rain.sum= Amount Rainfall of the Summer Season, rh.dry = Relative Humidity of the Dry Season, rh.sum= Relative Humidity of the Summer Season, wind.dry = Wind Speed of the Dry Season and wind.sum = Wind Speed of The Summer Season.

8. Results and Discussion

8.1. ARIMAX modeling of Mug Production

At first, it is essential to find out for which order of difference of the time sequence Mug production series satisfies the stationarity condition. From the "Dickey-Fuller" unit root test, it is found that stationarity condition satisfied at the difference order one with p-value < 0.01 which strongly suggests that there is no unit root at the first order difference of Mug production at 1% level of significance. The graphical stationarity test using ACF and PACF are shown in the Figure 1.



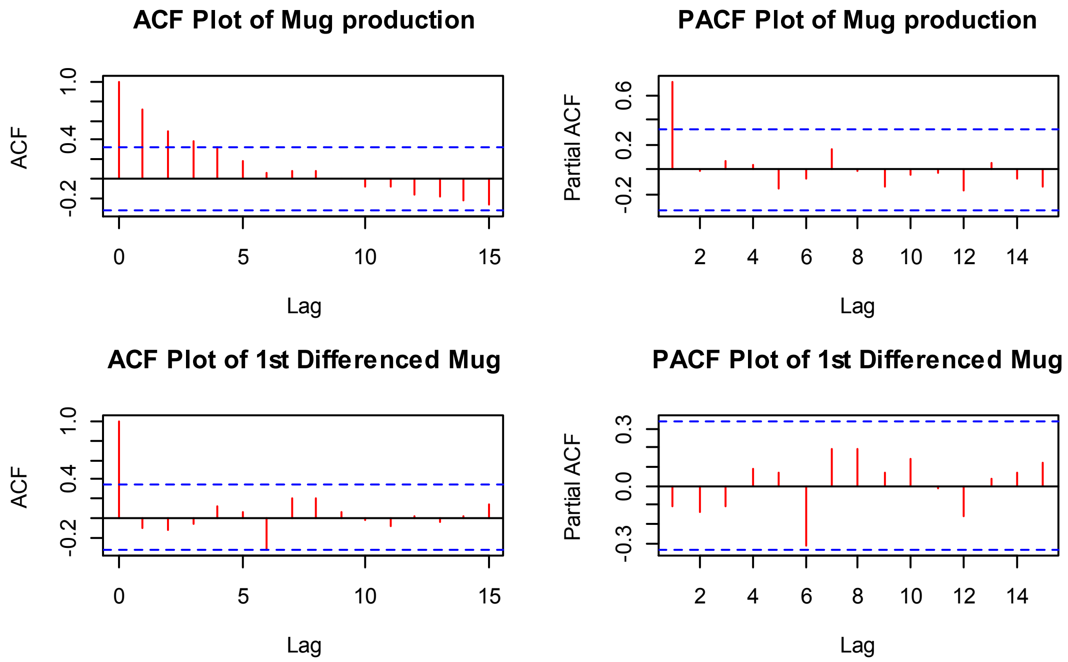


Figure 1: Graphically Stationarity Checking for Mug Production

From the Figure 1, it is clear that the original series does not show constant variance but first order differenced series shows more stable variance than the original series. Again, from the ACF and PACF, it is obvious that there are some significant spikes in the ACF plot indicating existence of Moving Average effects on the original Mug production series, that is, the series is not stationary. At the same time, from the ACF and PACF of first order differenced series, it is clear that there is no significant spike indicating there is no significant effects of Autoregressive and Moving Average order on the first order differenced series which implies that the series is stationary. From the Dickey-Fuller Unit Root Test and graphical representation of Mug-dal production, it is obvious that for the first order difference the series become stationary.

From the tentative order analysis, the best selected ARIMAX model is ARIMAX (1,1,3) with the AIC = 193.68 and BIC = 222.69. The parameter estimates are given in the Table 1.

From the Table 1, it is obvious that first order Auto-Regressive Lag; and first, second and third order Moving Average Lag have statistically significant effects on Mug production at 7% level of significance. Again, the regressor variables sun.sum, sun.dry, clo.sum, min.tem.sum and rain.dry have negative effects on Mug production; and clo.dry, max.tem.dry, max.tem.sum, min.tem.dry, rain.sum, rh.dry, rh.sum, wind.dry and wind.sum have positive effects on Mug productions. At the same time, sun.sum, sun.dry, clo.sum, max.tem.sum, min.tem.sum, rain.dry, rh.sum and wind.sum have statistically significant effects on Mug productions at 10% level of significance.

***Table 1**: Summary Statistics of the ARIMAX Model for Mug Production*

Coefficients	Estimates	Std. Error	t-value	p-value
ar1	0.7128	0.151	4.7189	0.0665
ma1	0.9694	0.1464	6.6227	0.0477
ma2	-0.9694	0.1789	-5.417	0.0581
ma3	-1	0.1349	-7.4135	0.0427
sun.sum	-7.6625	1.897	-4.0393	0.0772
sun.dry	-7.9962	1.4677	-5.448	0.0578
clo.sum	-20.9196	1.7609	-11.88	0.0267
clo.dry	1.5343	1.7057	0.8995	0.2668
max.tem.dry	0.7414	1.3711	0.5407	0.3422
max.tem.sum	6.9091	1.1114	6.2167	0.0508
min.tem.dry	2.1655	1.3115	1.6512	0.1733
min.tem.sum	-7.8708	1.229	-6.4043	0.0493
rain.dry	-0.1586	0.0185	-8.5901	0.0369
rain.sum	0.0177	0.0145	1.2155	0.2191
rh.dry	0.2021	0.3864	0.523	0.3466
rh.sum	2.6872	0.4261	6.3065	0.0501
wind.dry	13.416	9.9828	1.3439	0.2036
wind.sum	13.6658	4.2745	3.1971	0.0965

From "Box-Ljung" test of autocorrelation assumption checking, it is found that $\Pr(|\chi^2_{(1)}| \geq 2.7401) = 0.09786$ which suggests that we may accept that there is no autocrrelation among the residuals of the fitted model at 5% level of significance. Again, from the "Jarque-Bera" normality test, it is found that the $\Pr(|\chi^2_{(2)}| \geq 0.2857) = 0.8669$ which refers to accept that the residuals are from normal distribution. Residuals Diagnostic plots are shown in the Figure 2.

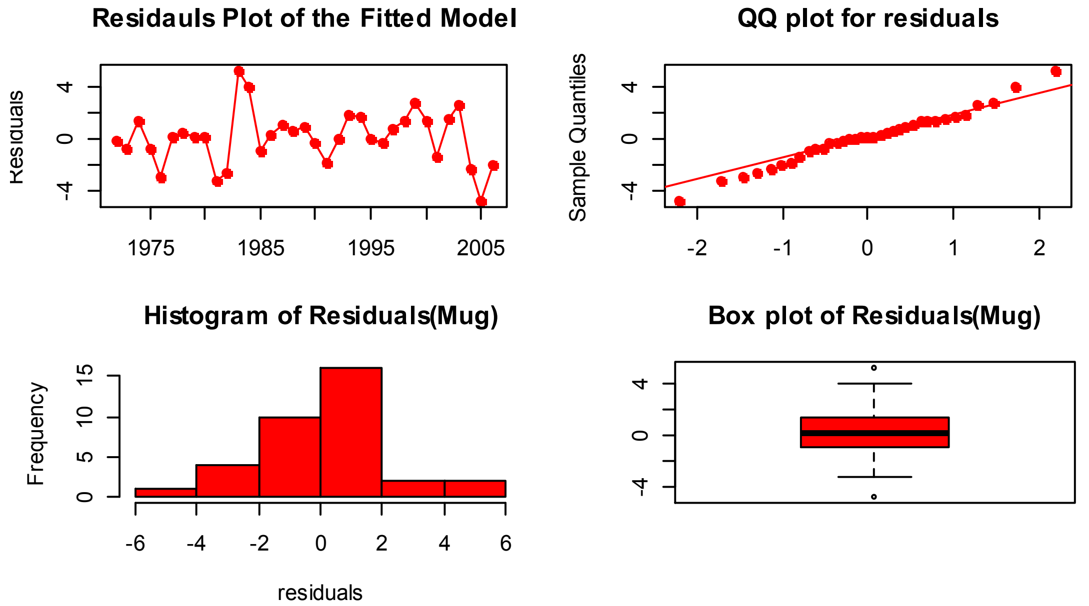


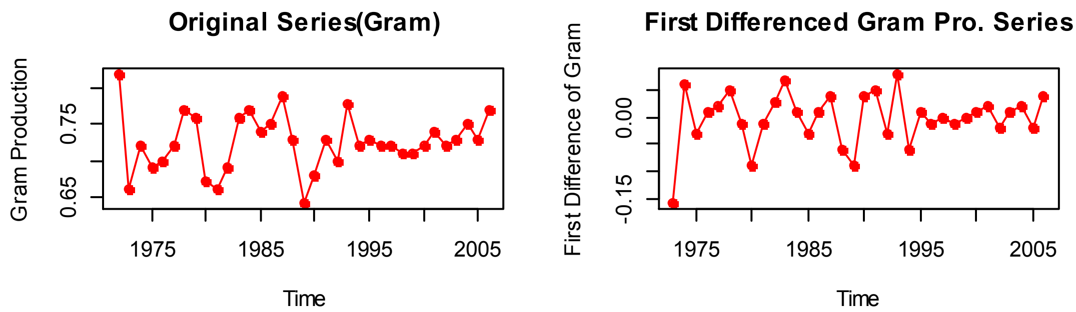
Figure 2: Graphical Diagnostics for ARIMAX Model of Mug Production

From the Figure 2, it is clear that almost all of the points are much closed to the Q-Q line or on the Q-Q line indicating residuals are normally distributed. At the time, from the Histogram of the residuals, it is obvious that residuals are normally distributed. Again, from the Box-Plot, we observe that there are two unusual or outlier observation which may be considerd. Furthermore, from the residual plots, it is transparent that residuals are almost shown constant variance. That is, Mug production is going to make a good decision considering all graphical representation of the residuals of the fitted ARIMAX (1,1,3) model.

Finally, considering all of the Graphical and Formal test, it is obvious that the fitted ARIMAX (1,1,3) model is the best fitted model for measuring the Climatic effects on Mug production in the Bangladesh.

8.2. ARIMAX modeling of Gram Production

From the "Dickey-Fuller" unit root test, it is found that stationarity condition satisfied at the difference order one with p-value < 0.01 which strongly suggests that there is no unit root at the first order differenced Gram production series at 1% level of significance. The graphical stationarity test using ACF and PACF are shown in the Figure 3.



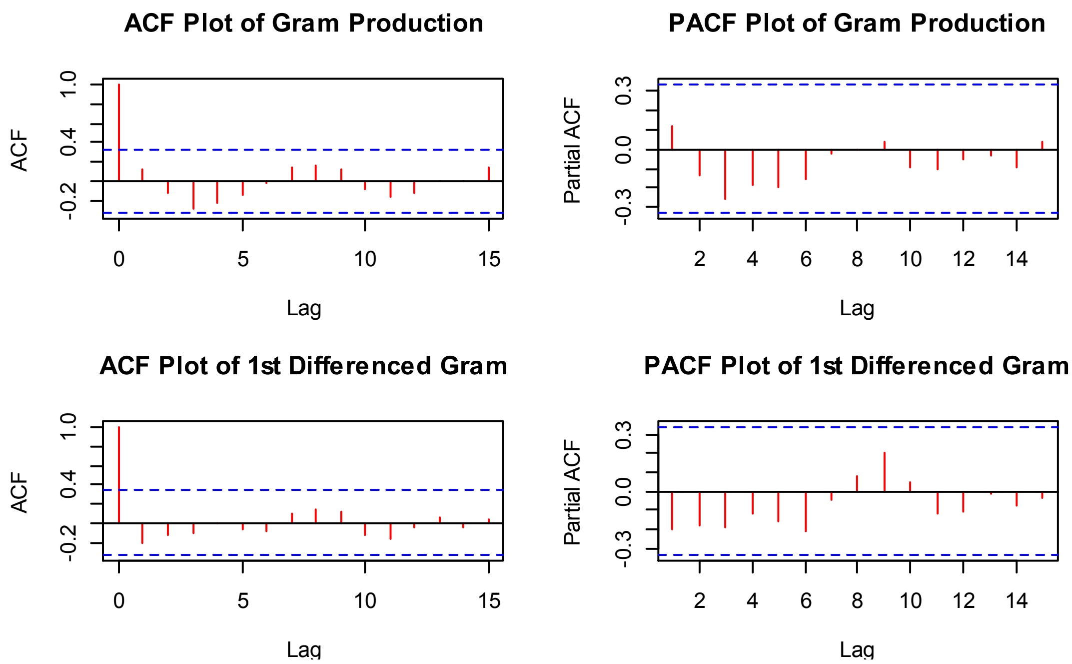


Figure 3: Graphically Stationarity Checking for Gram Production

From the Figure 3, it is clear that first order differenced of Gram production series shows more stable variance than the original series. Again, from the ACF and PACF, it is clear that there is no significant spike in the ACF and PACF in both original and first differenced series indicating there is no significant effects of Autoregressive and Moving Average which implies constant variance. We take difference order one because in this order our best model is found and we don't face any over differencing problem.

From the tentative order analysis, the best selected model is ARIMAX(1,1,3) with the AIC = 257.74 and BIC = 283.68. The parameter estimates are given in the Table 2.

From the Table 2, it is obvious that first and second order Autoregressive Lag have statistically significant effects on Gram productions at 6% level of significance. Again, the regressor variables sun.sum, sun.dry, clo.sum, min.tem.dry, min.tem.sum, rain.dry and rain.sum have negative effects on Gram productions. Similarly, the predictor variables clo.dry, max.tem.dry, max.tem.sum, rh.dry, rh.sum, wind.dry and wind.sum have positive effects on Gram productions. At the same time, clo.sum, clo.dry, max.tem.dry, min.tem.dry and wind.sum have statistically significant effects on Gram productions at 10% level of significance.

From the 'Box-Ljung' autocorrelation test, it is found that the Pr($|\chi^2_{(1)}| \geq 0.0004$) = 0.983 which strongly suggests that we may accept the assuption that there is no autocrrelation among the residuals at 5% level of significance. Again, from "Jarque-Bera" normality test, it is found that the Pr($|\chi^2_{(2)}| \geq 0.2826$) = 0.8682 which refers to accept that the residuals are normally distributed.

***Table 2**: Summary Statistics of the ARIMAX Model for Gram Production*

Coefficients	Estimates	Std. Error	t-value	p-value
ar1	0.7487	0.1328	5.636	0.0559
ar2	-0.8469	0.1103	-7.6764	0.0412
sun.sum	-14.0792	6.1309	-2.2964	0.1307
sun.dry	-13.0072	5.2127	-2.4953	0.1213
clo.sum	-32.5492	8.9763	-3.6261	0.0857
clo.dry	30.1487	5.9552	5.0626	0.0621
max.tem.dry	39.2619	4.5448	8.6388	0.0367
max.tem.sum	19.6479	13.5714	1.4477	0.1924
min.tem.dry	-18.4329	4.8918	-3.7681	0.0826
min.tem.sum	-15.4473	8.0037	-1.93	0.1522
rain.dry	-0.3203	0.0523	-6.1226	0.0515
rain.sum	-0.0116	0.0289	-0.4	0.3789
rh.dry	1.1549	1.0695	1.0799	0.2378
rh.sum	2.1729	3.0254	0.7182	0.3017
wind.dry	50.3957	20.7813	2.425	0.1245
wind.sum	45.8110	11.3086	4.0510	0.0770

Residuals Diagnostic plots are shown in the Figure 4.

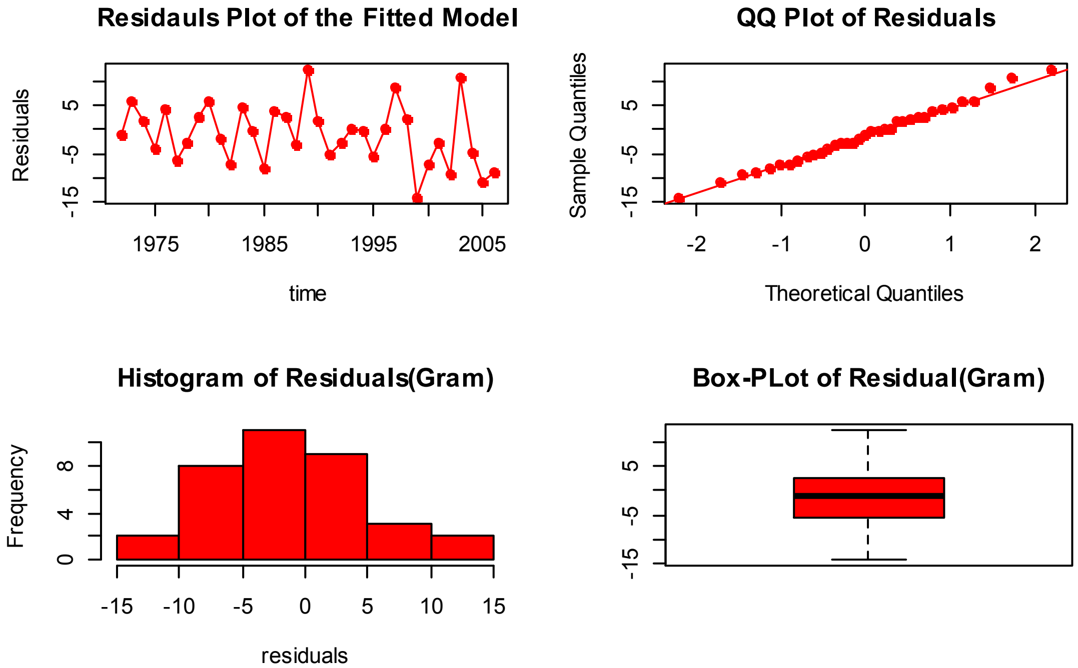


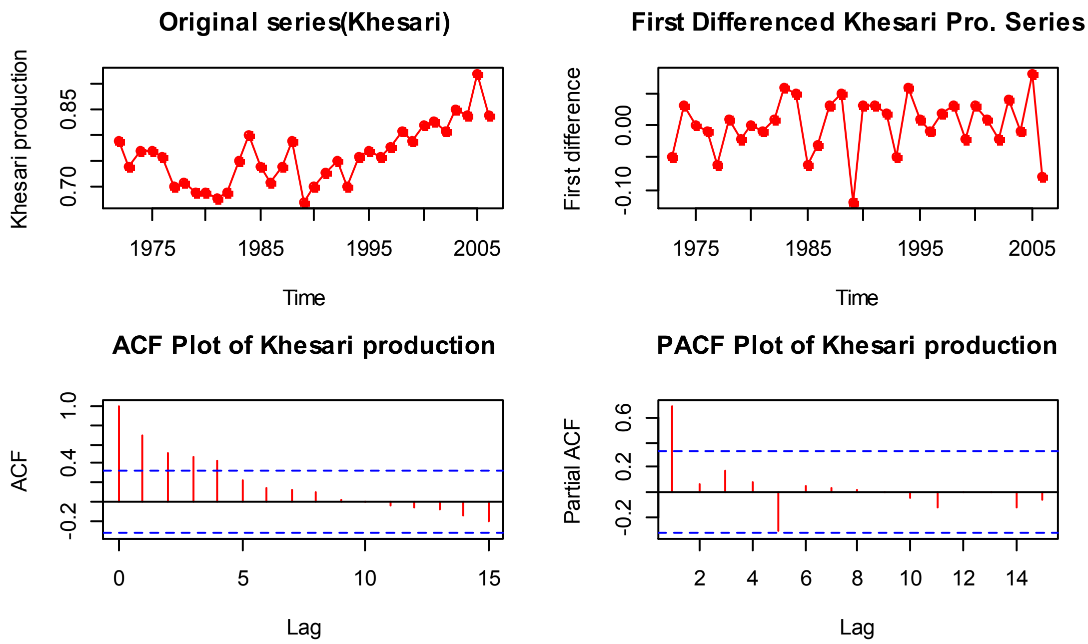
Figure 4: Graphical Diagnostics for ARIMAX Model of Gram Production

From the Figure 4, it is obvious that almost all of the points are much closed to the Q-Q line or on the Q-Q line which indicates that residuals are normally distributed. Again, from the Histogram of the residuals of Gram production model, it is clear that residuals are symmetrically normally distributed. At the time, from the Box-Plot, we observe that residuals are symmetrically normally distributed and there is no unusual or outlier observation. Furthermore, from the residual plots, it is clear that residuals are shown constant variance.

Finally, considering all of the Graphical and Formal test, it is obvious that our fitted model ARIMAX (2,1,0) is the best fitted model for measuring the Climatic effects on Gram production in the Bangladesh.

8.3. ARIMAX modeling of Khesari Production

From the "Dickey-Fuller" unit root test, it is found that the p-value = 0.01 which implies that there is no unit root in the Khesari production series at first difference, that is, the Khesari production series becomes stationary for difference order one at 1% level of significance. The stationarity test is graphically shown in the Figure 5.



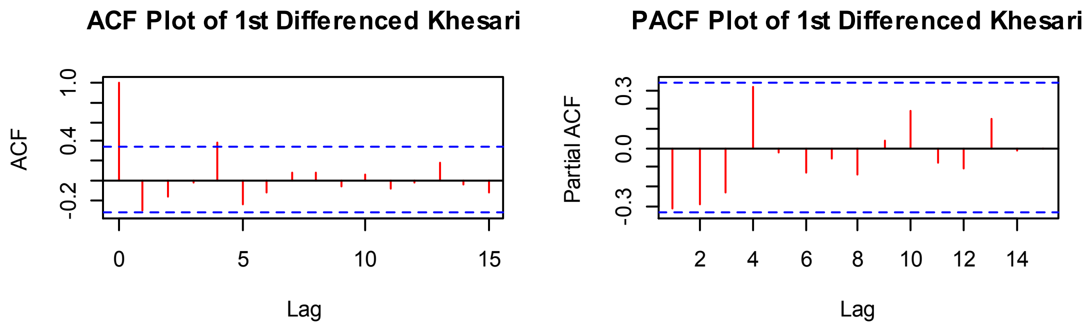


Figure 5: Graphically Stationarity Checking for Khesari Production

From the Figure 5, it is clear that the original series does not show constant variance but first order differenced of Khesari production series shows more stable variance than original series. Again, from the ACF and PACF, it is clear that there are some significant spikes in the ACF plot indicating existence of Moving Average effects on the original Khesari production series, that is, the original Khesari production series is not stationary. At the same time, from the ACF and PACF of first differenced series, it is obvious that there is no significant spike which also indicate that there is no significant effects of Autoregressive and Moving Average order at first order difference series, that is, the series is stationary with first order difference.

From the tentative order analysis, the best selected model is ARIMAX (1,1,2) with the AIC = 300.71 and BIC = 328.19. The parameter estimates are given in the Table 3.

From the Table 3, it is obvious that first order Auto-Regressive Lag; and first and second order moving Average Lag have statistically significant effects for measuring the climatic effects on Khesari productions at 5% level of significance. Again, the regressor variables clo.dry, min.tem.dry, rain.dry and rh.sum have negative effects on Khesari production; and sun.sum, sun.dry, clo.sum, max.tem.dry, max.tem.sum, min.tem.sum, rain.sum, rh.dry, wind.dry and wind.sum have positive effects on Khesari productions. At the same time, sun.dry, sun.sum, clo.sum, rain.dry and rh.dry have statistically significant effects on Khesari production at 10% level of significance.

From the "Box-Ljung" autocorrelation test, it is observed that the Pr($|\chi^2_{(1)}| \geq 1.3337$) = 0.2481 which suggests that we may accept the assuption that there is no autocrrelation among the residuals at 5% level of significance. Again, from the "Jarque-Bera" normality test, it is found that the Pr($|\chi^2_{(2)}| \geq 0.3565$) = 0.8367 which refers to accept that the residuals are normally distributed.

Table 3: *Summary Statistics of the ARIMAX Model for Khesari Production*

Coefficients	Estimates	Std. Error	t-value	p-value
ar1	-0.937	0.0557	-16.8292	0.0189
ma1	1.1795	0.1882	6.2675	0.0504
ma2	0.9963	0.1078	9.2402	0.0343
sun.sum	48.3212	15.3063	3.157	0.0976
sun.dry	3.3054	10.4907	0.3151	0.4028
clo.sum	134.3938	25.7669	5.2157	0.0603
clo.dry	-14.2826	17.5273	-0.8149	0.2824
max.tem.dry	2.3959	10.8299	0.2212	0.4307
max.tem.sum	25.7946	24.9979	1.0319	0.245
min.tem.dry	-10.3535	14.5809	-0.7101	0.3035
min.tem.sum	17.7215	20.7867	0.8525	0.2753
rain.dry	-0.4333	0.1064	-4.0723	0.0766
rain.sum	0.1554	0.0697	2.2283	0.1343
rh.dry	8.8991	2.8434	3.1297	0.0984
rh.sum	-11.7103	6.4873	-1.8051	0.161
wind.dry	66.8645	42.5432	1.5717	0.1804
wind.sum	74.1483	27.3033	2.7157	0.1123

Residuals Diagnostic plots are shown in the Figure 6.

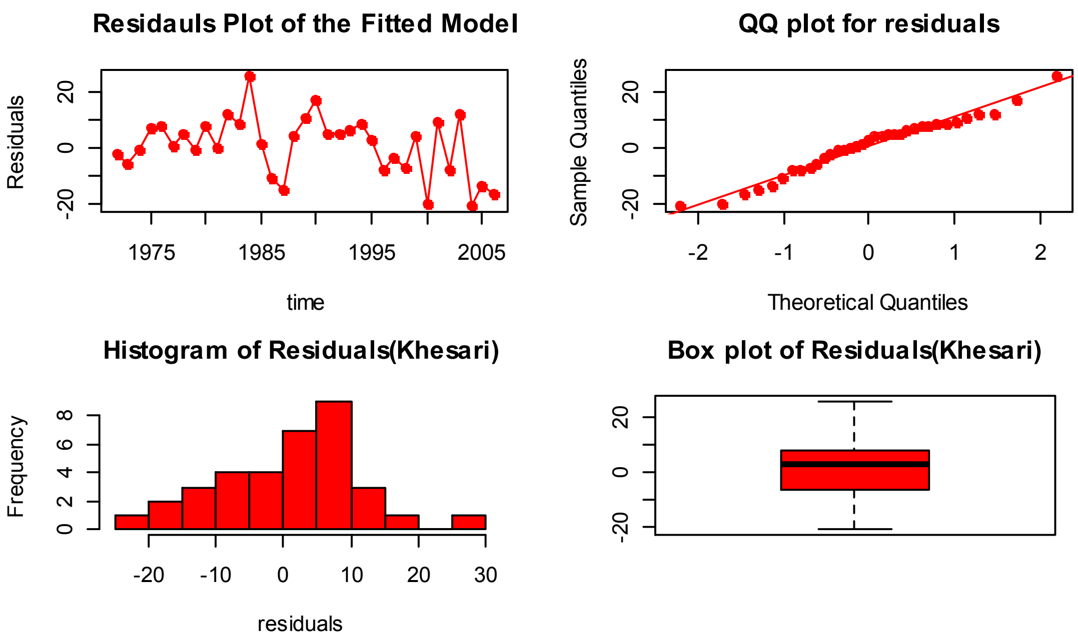


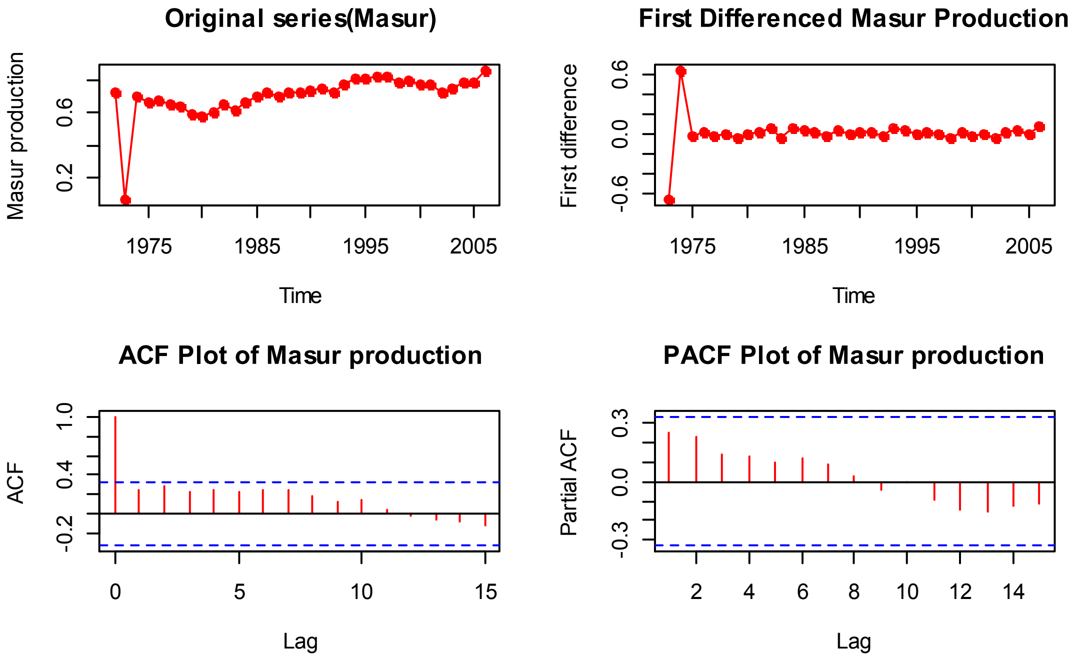
Figure 6: Graphical Diagnostic for ARIMAX Model of Khesari Production

From the Figure 6, it is clear that almost all of the points are much closed to the Q-Q line or on the Q-Q line indicating residuals are normally distributed. Again, from the Histogram of the residuals of Khesari production model, it is clear that residuals are normally distributed. At the time, from the Box-Plot, we observe that there is no unusual or outlier observation. Furthermore, from the residual plots, it is obvious that residuals are shown constant variance.

Finally, considering all of the Graphical and Formal test, it is obvious that our fitted ARIMAX(1,1,2) is the best fitted model for measuring the Climatic effects on Khesari production in the Bangladesh.

8.4. ARIMAX modeling of Masur Production

From the "Dickey-Fuller" unit root test, it is found that p-value = 0.01 which implies that there is no unit root in the Masur production series at first order difference, that is, the Masur production series becomes stationary for the first order difference at 1% level of significance. The stationarity test is graphically shown in the Figure 7.



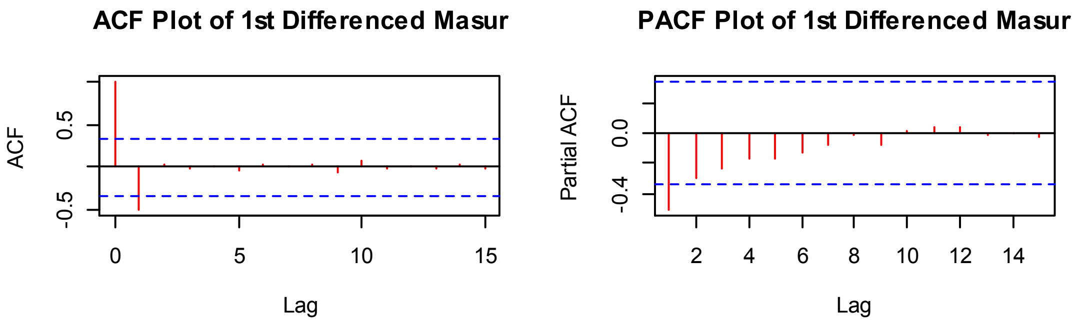


Figure 7: Graphically Stationarity Checking for Masur Production

From the Figure 7, it is obvious that the original series does not show constant variance but first order differenced Masur production series shows more stable variance than original series. Again, from the ACF and PACF, it is clear that there is no significant spike in the ACF plot indicating there is no effects of Moving Average or Autoregressive order on the original Masur production series. At the same time, from the ACF and PACF of first differenced series, it is obvious that there is a significant spike which also indicate that the series is not stationary with first order difference. But from the formal test, that is, "Dickey-Fuller" Unit Root Test, it is obvious that at the difference order one the series become stationary and that is why we take difference order one to make the series stationary. At the same time, only for this order the model have strongly passed the diagnostic stage.

From the tentative order analysis, the best selected model is ARIMAX (2,1,1) with the AIC = 287.61and BIC = 315.08. The parameter estimates are given in the Table 4.

From the Table 4, it is obvious that first and second order Auto-Regressive Lag; and first order Moving Average Lag have statistically significant on Masur production at 10% level of significance. Again, the regressor variables sun.sum, sun.dry, clo.sum, min.tem.sum, rain.dry and rh.dry have negative effects on Masur production; and clo.dry, max.tem.dry, max.tem.sum, min.tem.dry, rain.sum, rh.sum, wind.dry and wind.sum have positive effects on Mug production. At the same time, sun.dry, sun.sum, clo.sum, clo.dry, max.tem.dry, max.tem.sum, min.tem.sum, rain.dryrh.sum and wind.sum have statistically significant effects on Masur production at 10% level of significance.

From the "Box-Ljung" autocorrelation test, it is observed that the Pr($|\chi^2_{(1)}| \geq 1.501$) = 0.2205 which indicates that we may accept the assuption that there is no autocrrelation among the residuals at 5% level of significance. Again, from "Jarque-Bera" normality test, it is found that the Pr($|\chi^2_{(2)}| \geq 0.0853$) = 0.9582 which refers to accept that the residuals are normally distributed.

***Table 4:** Summary Statistics of the ARIMAX Model for Masur Production*

Coefficients	Estimates	Std. Error	t-value	p-value
ar1	0.4945	0.149	3.3181	0.0932
ar2	-0.8951	0.0817	-10.9615	0.029
ma1	1	0.0779	12.8413	0.0247
sun.sum	-4.5677	8.235	-0.5547	0.3388
sun.dry	-46.866	12.5088	-3.7466	0.083
clo.sum	-62.3539	12.4931	-4.9911	0.0629
clo.dry	30.1905	9.6568	3.1263	0.0985
max.tem.dry	36.696	5.0347	7.2887	0.0434
max.tem.sum	111.117	27.3024	4.0699	0.0767
min.tem.dry	2.6	7.0213	0.3703	0.3871
min.tem.sum	-87.6404	15.6258	-5.6087	0.0562
rain.dry	-0.5679	0.1071	-5.2999	0.0594
rain.sum	0.1374	0.0561	2.4505	0.1233
rh.dry	-2.3475	1.8388	-1.2766	0.2115
rh.sum	23.513	5.7212	4.1098	0.076
wind.dry	69.1069	44.8865	1.5396	0.1834
wind.sum	121.176	17.9369	6.7557	0.0468

Residuals Diagnostic plots are shown in the Figure 8.

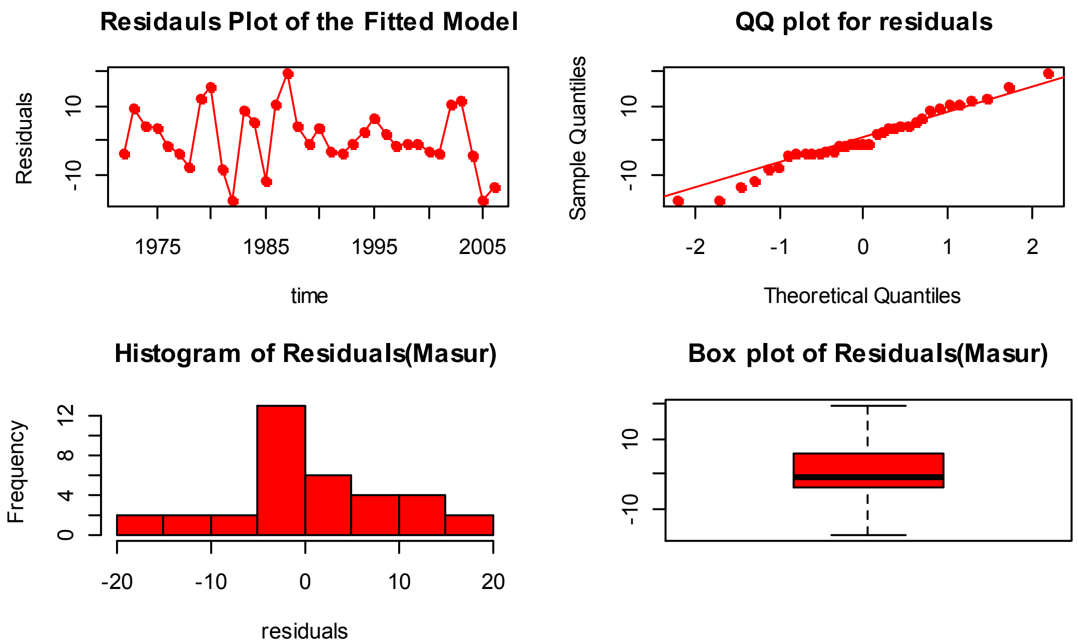


Figure 8: Graphical Diagnostics for ARIMAX Model of Masur Production

From Figure 8, it is observable that almost all of the points are much closed to the Q-Q line or on the Q-Q line indicating residuals are normally distributed. Again, from the Histogram of the residuals, it is clear that residuals are normally distributed. At the time, from the Box-Plot, there is no unusual or outlier observation. Furthermore, from the residual plots, it is obvious that residuals are almost shown constant variance.

Finally, considering all of the Graphical and Formal test, it is obvious that the fitted ARIMAX (2,1,1) model is the best model for measuring the Climatic effects on Masur production in the Bangladesh.

Conclusion and Recommendations

In this study, it is tried to fit an appropriate by using Box-Jenkins Auto-Regressive Integrated Moving Average with external regressor, that is, ARIMAX model because of time sequence pulse crop dataset, where climatic variables are used as regressor variables. In this study, it is tried to fit the best model to measure the climatic effects on different types of pulse crops production named as Masur, Mug, Khesari and Gram covering whole Bangladesh. To select the best model for measuring the climatic effects on different types of pulse crops production, the latest available model selection criteria such as AIC, BIC, ACF and PACF are used. Again, to select the fitted model, it is tried to fit the best simple model because the model contains less parameters give the good representative results. The best selected Box-Jenkins ARIMAX model for measuring the climatic effects on pulse productions are ARIMAX (1,1,3), ARIMAX (2,1,0), ARIMAX (1,1,2) and ARIMAX (2,1,1) for Mug, Gram, Khesari and Masur productions respectively. From all of the Graphical representation and Formal test, it is transparent that all model are good representation of practical situations based on the sample data. From the study, it is found that sun.sum, sun.dry, clo.sum, max.tem.sum, min.tem.sum, rain.dry, rh.sum and wind.sum have statistically significant effects on Mug production. Again, clo.sum, clo.dry, max.tem.dry, min.tem.dry and wind.sum have statistically significant effects on Gram production. Similarly, sun.dry, sun.sum, clo.sum, rain.dry and rh.dry have statistically significant effects on Khesari production. At the same time, sun.dry, sun.sum, clo.sum, clo.dry, max.tem.dry, max.tem.sum, min.tem.sum, rain.dry, rh.sum and wind.sum have statistically significant effects on Masur production.

After conducting these analyses, the following recommendations can be made

- The policy makers and researchers could use these model to make a decision for agricultural crops production under consideration of temperature and rainfall effects on agricultural productions especially for spices production.
- Similar regional models could be further studied to find variations of the models.
- The climatic zone similar to Bangladesh could also be compared in the future studies.

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