Temperature and Rainfall Effects on Spice Crops Production and Forecasting the Production in Bangladesh: An Application of Box-Jenkins ARIMAX Model

Mohammed Amir Hamjah
B.Sc. (Honors), MS (Thesis) in Statistics
Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh.
Email: arif.stat.sust@hotmail.com

Abstract

The objective of this study is to develop the best Box-Jenkins Auto-Regressive Integrated Moving Average with External Regressor, that is, ARIMAX model for measuring the temperature and rainfall effects on major spice crops productions in the Bangladesh and forecasting the production using the same model. Due to time sequence dataset, ARIMAX model is considered as a measuring tool of cause-effect relation among the spice crops and climatic variables (temperature and rainfall) under study. From the study, it is found that ARIMAX(2,1,2), ARIMAX(2,0,1) and ARIMAX(2,1,1) are the best model for Chili, Garlic and Ginger crop respectively. From the comparison between original series and forecasted series, it shows that these fitted model are well representative of the practical situations and both series shows the same manner indicating good forecasting.

Keywords: Temperature, Rainfall, Species Production, Forecasting, ARIMAX Model.

1. Introduction

Agriculture is always vulnerable to unfavorable weather events and climate conditions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors, which play a significant role to agricultural productivity. The impacts of climate change on agriculture food production are global concerns as well as for the matter of Bangladesh, where lives and livelihoods depend mainly on agriculture, is exposed to a great danger, as the country is one of the most vulnerable countries due to climate change.

Chili, Garlic, Ginger, Onion are mostly used and important spice crop in Bangladesh. People of Bangladesh uses theses spices to improve smell in their cooking foods. Chili is a valuable spice and also an important cash crop in Bangladesh. About 170041 hectares of land of Bangladesh is under chili cultivation in both rabi and kharif seasons and the production is about 137,000 M ton (BBS 2004). Though the area and production have been raised but per unit yield of chili is very low.

Ginger is an important commercial spice crop in tropical and subtropical countries including Bangladesh. Among the spices crops, ginger is one of the important cash crops in Bangladesh. In Chittagong Hill tracts region, it is a leading cash crop because of its greater potentiality of growing due to suitable climatic condition. The rhizome is used worldwide as spices for flavoring in a number of foods and food-products and also used in medicines.

Garlic is the most important spice crops of Bangladesh. Consequently, large quantities of this spice (20%) are imported every year at the cost of huge amount of foreign currency. Cultivation of inferior genotypes with traditional production practices are considered to be the main causes for low yield of this spice crops (2.86 ton per hector).

2. Objectives of the Study

The main objective of this study is to develop the best ARIMAX model for measuring the temperature and rainfall effects on major spices crops production in the Bangladesh and production forecasting using the same model. The specific objective of the study is to develop an Autoregressive Integrated Moving Average with external regressors, that is, ARIMAX model for different types of spices crops production such as Chili, Garlic and Ginger in Bangladesh and forecasting these spices crops production under the consideration of the temperature and rainfall effects.

3. Reasons to Choose the ARIMAX 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 is the best model for the time sequence data analysis in this study. At the same time to pursue our research objective, that is, forecasting production, ARIMAX model is the best model ever proposed for time sequence dataset.

4. Review of Literature

There are not enough review of the literature for measuring the effects on agricultural crop productions such as species using ARIMAX model. But some of such relevant study by 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.

5. Data Source and Data Manipulation

The extreme temperature (maximum and minimum) and amount of rainfall information have been collected from the Bangladesh Government's authorized website "www.barc.gov.bd". The species crop productions datasets are also available from Bangladesh Agricultural Ministry's website "www.moa.gov.bd". These dataset are available from 1972 to 2006. Temperature and amount of rainfall information was initially formed in 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 in Bangladesh. 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 has 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" based on the weather and climatic conditions of Bangladesh. Finally, it is take the grand average of seasonal information of 30 climatic stations corresponding to the year from 1972 to 2006 for the purpose of observing seasonal effects of maximum temperature, minimum temperature and amount of rainfall. It is take the average of 30 climatic areas because of focusing the overall country's situation and overall model fitting for whole Bangladesh.

To serve our research objectives, it is divide the dataset two parts, where the first part is made of initial 31 years (1972-2001) to fit the best model based on dataset under study and second part contains last five years (2002-2006) dataset, from which temperature and rainfall variables are used to forecast five years forward forecasting considering the demand of ARIMAX model because we have to give input as regressor variables to forecast using the ARIMAX model.

6. 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

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

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

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

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 $Y_{t-1}, Y_{t-2}, Y_{t-3}, \ldots Y_{t-q}$.

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

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

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

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

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

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

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

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.

6.1. Residuals Diagnostic Checking

6.1.1 Jarque-Bera Test

We can check the normality assumption using Jarque-Bera (Jarque & Bera, 1980) test which is a goodness of fit measure of departure from normality, based on the sample kurtosis (k) and skewness(s). The test statistics Jarque-Bera(JB) is defined as

$$JB = \frac{n}{6}\left(s^2 + \frac{(k-3)^2}{4}\right) \sim \chi^2_{(2)}$$

Where n is the number of observations and k is the number of estimated parameters. The statistic JB has an asymptotic chi-square distribution with 2 degrees of freedom, and can be used to test the hypothesis of skewness being zero and excess kurtosis being zero, since sample from a normal distribution have expected skewness of zero and expected excess kurtosis of zero.

6.1.2 Ljung-Box Test

Ljung-Box (Box and Ljung, 1978) Test can be used to check autocorrelation among the residuals. If a model fit well, the residuals should not be correlated and the correlation should be small. In this case the null hypothesis is $H_0 : \rho_1(e) = \rho_2(e) = \ldots\ldots = \rho_k(e) = 0$ is tested with the Box-Ljung statistic

$$Q^* = \mathrm{N}(\mathrm{N}+1) \sum_{i=1}^{k} (N-k)\, \rho_k^2(e)$$

Where, N is the no of observation used to estimate the model. This statistic Q* approximately follows the chi-square distribution with (k-q) df, where q is the no of parameter should be estimated in the model. If Q* is large (significantly large from zero), it is said that the residuals autocorrelation are as a set are significantly different from zero and random shocks of estimated model are probably auto-correlated. So one should then consider reformulating the model.

7. Used Software

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 **forecas**t, **TSA** and **tseries**.

8. Used Regressors Variables Under Study

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.

9. Analysis and Results Discussion

9.1. ARIMAX Modeling of Chili Crop Production

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

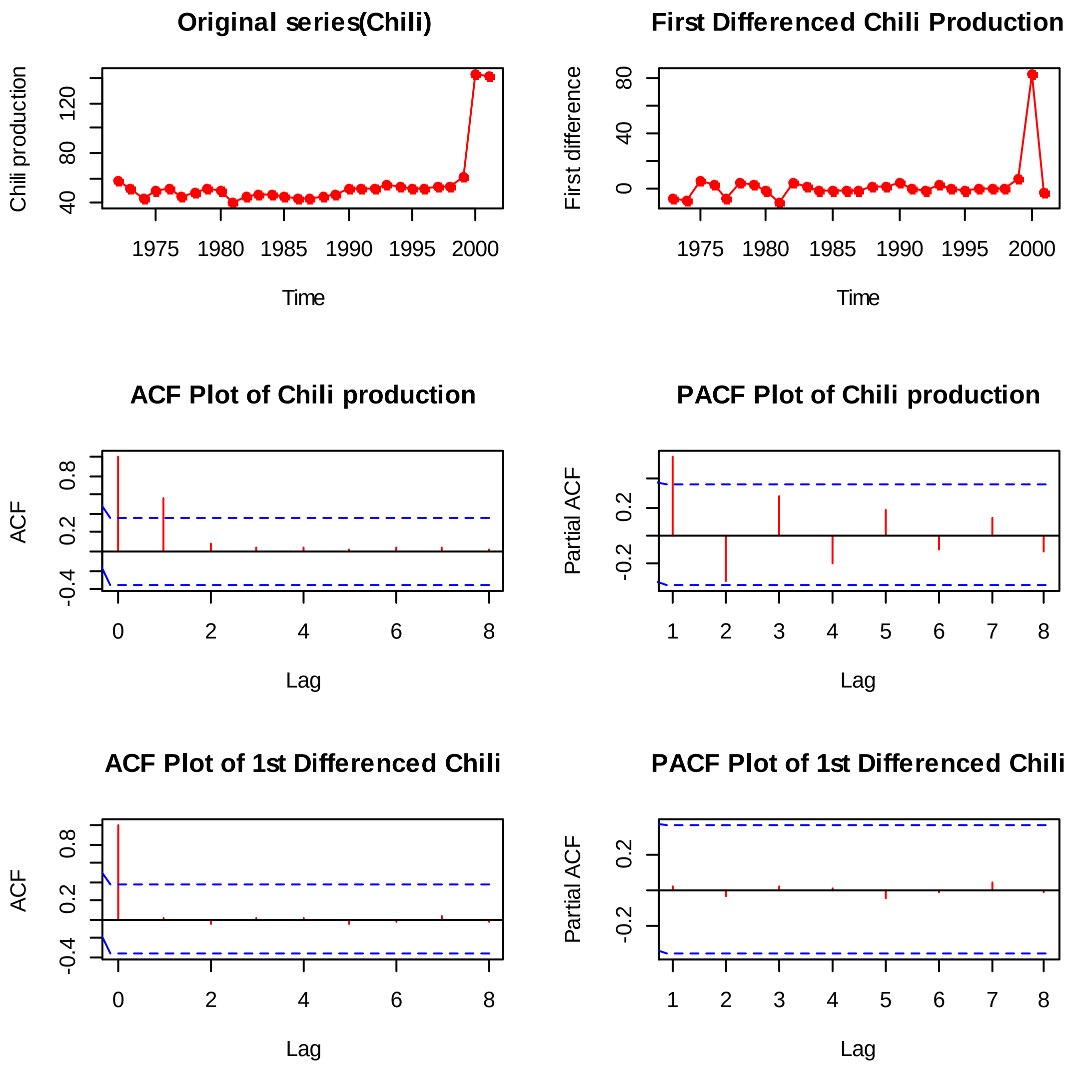


Figure 1: Graphically Stationarity Checking for Chili Production

From the Figure 1, it is obvious that the first order differenced Chili production series shows more stable variance than the original series. Again, from ACF and PACF, it is clear that there is a single significant spike in the ACF plot indicating the existence of Moving Average effects on the original Chili 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 spikes which also tell us that the series is stationary with first order difference; and implies that there is no significant effects of Autoregressive and Moving Average order at first order differenced series. So, from the formal test (Dickey-Fuller Unit Root Test) and graphical representation of Chili production, it is transparent that at the difference order one the series become stationary.

From the tentative order analysis, the best selected ARIMAX model for Chili production is ARIMAX (2,1,2) with AIC = 251.98 and BIC = 267.02. The parameter estimates are given in the Table 1.

Table 1: Summary Statistics of the ARIMAX (2,1,2) Model for Chili Production

Coefficients	Estimates	Std. Error	t-value	p-value
bar1	-0.9492	0.216	-4.3953	0.0712
ar2	-0.0087	0.2237	-0.0387	0.4877
ma1	1.7343	0.1762	9.8437	0.0322
ma2	0.9986	0.1402	7.1217	0.0444
max.tem.dry	-19.4349	4.5631	-4.2591	0.0734
max.tem.sum	-7.7363	5.4212	-1.4271	0.1946
min.tem.dry	5.3993	4.5999	1.1738	0.2246
min.tem.sum	6.6771	5.3135	1.2566	0.214
rain.dry	-0.1012	0.0589	-1.7173	0.1678
rain.sum	0.0619	0.0794	0.7791	0.2893

From the Table 1, it is obvious that first order Auto-regressive Lag; and first and second order Moving Average Lag have statistically significant effects on Chili production at 7% level of significance. The second order autoregressive Lag has not highly significant effects on Chili production but we have kept this autoregressive term in model because this is the best model and we select it using model selection criteria and only this model satisfies the all criterion for a good model at the diagnostic stage. Again, max.tem.dry, max.tem.sum, and rain.dry have negative and min.tem.sum, min.tem.dry and rain.sum have positive effects on the Chili production. At the same time, max.tem.dry has statistically more significant effects on the Chili production at 7% level of significance and others variables have significant effects on the Chili production at 29% level of significance.

From the "Box-Ljung" autocorrelation test, it is found that $\Pr(|\chi^2_{(1)}| \geq 0.0167) = 0.8972$ which strongly suggests that there is no autocrrelation among the residuals of the fitted ARIMAX model at 5% level of significance. Again, from the "Jarque-Bera" normality test, it is found that $\Pr(|\chi^2_{(2)}| \geq 3.2315) = 0.1987$ which refers to accept the normality assumption that the residuals are from normal distribution.

Residuals diagnostics plots are shown in the Figure 2.

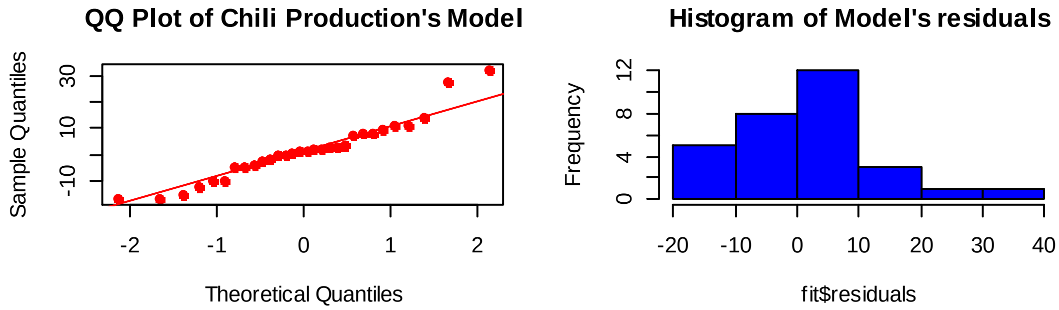


Figure 2: Graphical Residuals Diagnostics Checking for ARIMAX Model of Chili Production

From the Figure 2, it is clear that almost all points are closed to the Q-Q line or on the Q-Q line which indicates that residuals of the Chili production's model are normally distributed. At the time, from the Histogram of the residuals of Chili production's model, it is obvious that residuals are normally distributed.

Finally, considering all of the Graphical and Formal test, it is obvious that our fitted ARIMAX (2,1,2) model is the best fitted model to measure the temperature and rainfall effects on Chili production in Bangladesh.

9.2. ARIMAX Modeling of Garlic Production

At first, it is very essential to find out for which order of difference of the time sequence Garlic production data satisfies the sationarity condition. From the Dickey-Fuller unit root test, it is found original series is stationary with the p-value = 0.01 which strongly suggests that there is no unit root in the Garlic production series at 1% level of significance. The graphical sationarity test using ACF and PACF can be shown in the Figure 3.

From the Figure 3, it is obvious that original Garlic production series shows constant variance. Again, from the ACF and PACF, it is clear that there is no significant spikes at any lag order which also tell us that the original series is stationary; and implies that there is no significant effects of Autoregressive and Moving Average order on the original Garlic production series. So, from the formal test and graphical representation of Garlic production, it is obvious that original Garlic production series is stationary.

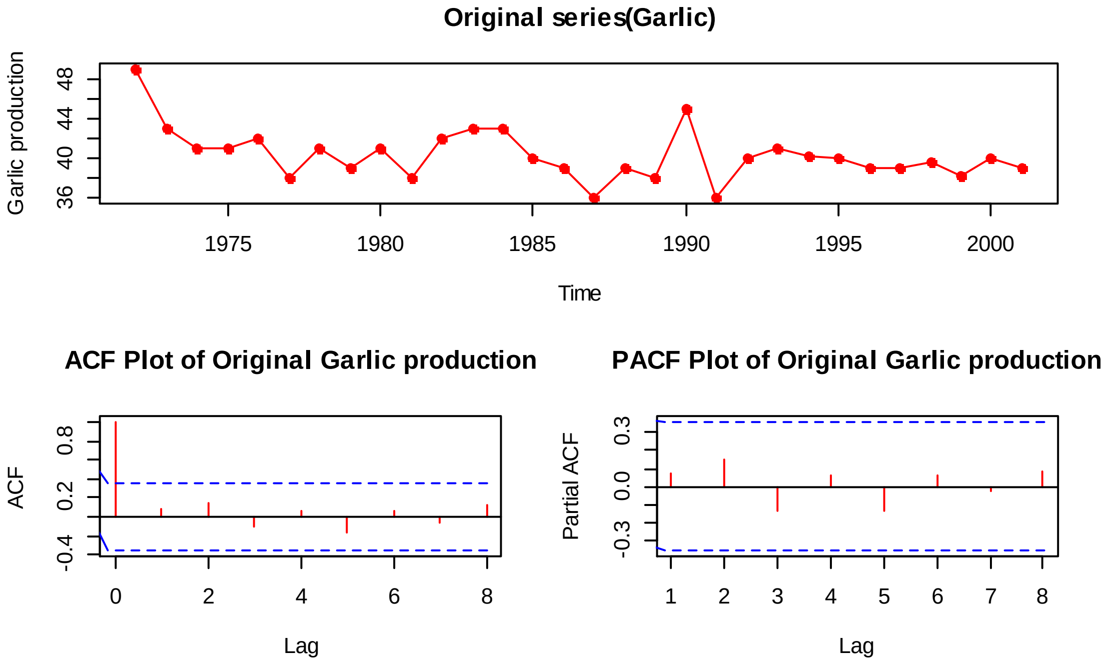


Figure 3: Graphically Sationarity Checking for Garlic Production

From the tentative order analysis, the best selected model for Garlic production is ARIMAX (2, 0, 2) with AIC = 146.14 and BIC = 161.55. The parameter estimates are given in the Table 2.

Table 2: Summary Statistics of the ARIMAX (2,0,1) Model for Garlic Production

Coefficients	Estimates	Std. Error	t-value	p-value
ar1	0.8663	0.3549	2.4408	0.1238
ar2	-0.4283	0.2861	-1.4971	0.1875
ma1	-1	0.0898	-11.1415	0.0285
intercept	159.5469	32.1085	4.969	0.0632
max.tem.dry	1.6848	1.5194	1.1088	0.2336
max.tem.sum	-1.2177	1.6765	-0.7263	0.3
min.tem.dry	-0.0071	2.1423	-0.0033	0.4989
min.tem.sum	-4.8974	1.869	-2.6204	0.116
rain.dry	0.017	0.0242	0.7025	0.3051
rain.sum	-0.0325	0.0171	-1.9001	0.1542

From the Table 2, it is obvious that first, second order Auto-regressive Lag; and first order Moving Average Lag have statistically significant effects on Garlic production at 18% level of significance. Again, max.tem.dry and rain.dry have positive; and max.tem.sum, min.tem.sum, min.tem.dry and rain.sum have negative effects on the Garlic production. At the same time, min.tem.sum and rain.sum have statistically more significant effects on the Garlic production at 15% level of significance and others variables have significant effects on the Chili production at 50% level of significance.

To check Autocorrelation assumption, “Box-Ljung” test is used from which it is found that $\Pr(|\chi^2_{(1)}| \geq 0.2788) =$ 0.5975 which suggests that there is no autocrrelation among the residuals of the fitted ARIMAX model at 5% level of significance. Again, to check the normality assumption, “Jarque-Bera” test is used, from which it is found that $\Pr(|\chi^2_{(2)}| \geq 0.0747) = 0.9634$ which refers to accept the normality assumption that the residuals are from normal distribution.

Residuals diagnostics plots are shown in the Figure 4.

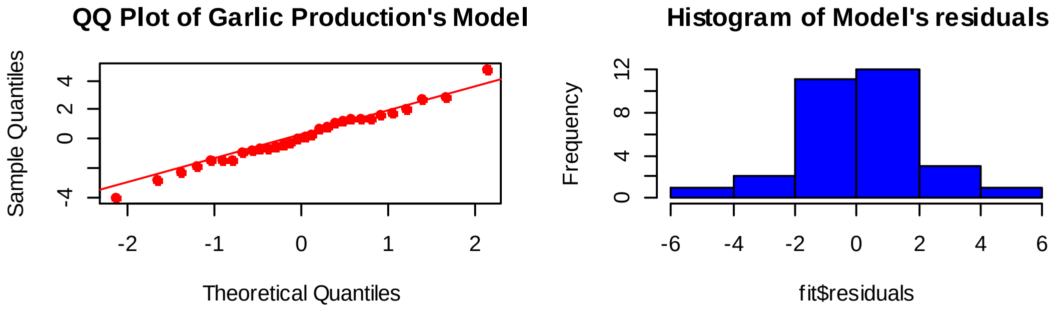


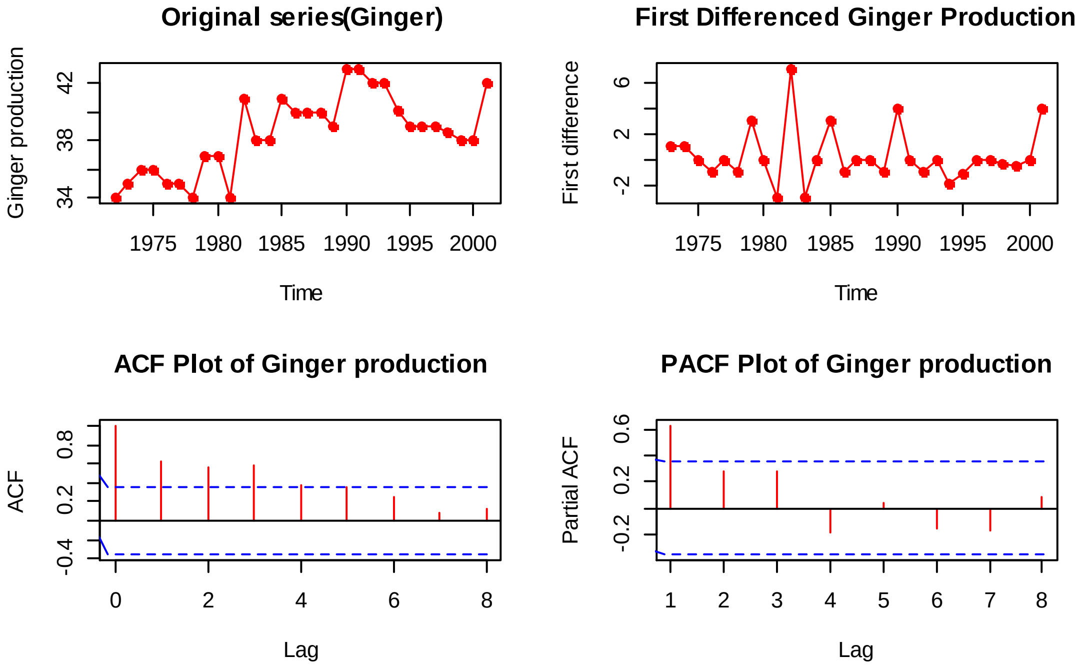
Figure 4: Graphical Residuals Diagnostics Checking for ARIMAX Model of Garlic Production

From the Figure 4, it is clear that almost all points are closed to the Q-Q line or on the Q-Q line indicating residuals of the Garlic production's model are normally distributed. At the time, from the Histogram of the residuals, it is obvious that residuals are symmetrically normally distributed.

Finally, considering all of the Graphical and Formal test, it is obvious that our fitted ARIMAX (2,0,1) model is the best fitted model to measure the temperature and rainfall effects on Garlic production in Bangladesh**.**

9.3. ARIMAX Modeling of Ginger Production

From the Dickey-Fuller unit root test of sationarity checking, it is found that first differenced series is stationary with the p-value = 0.01, which strongly suggests that there is no unit root at first ordered Ginger production series at 1% level of significance. The graphical sationarity test using ACF and PACF are shown in the Figure 5.



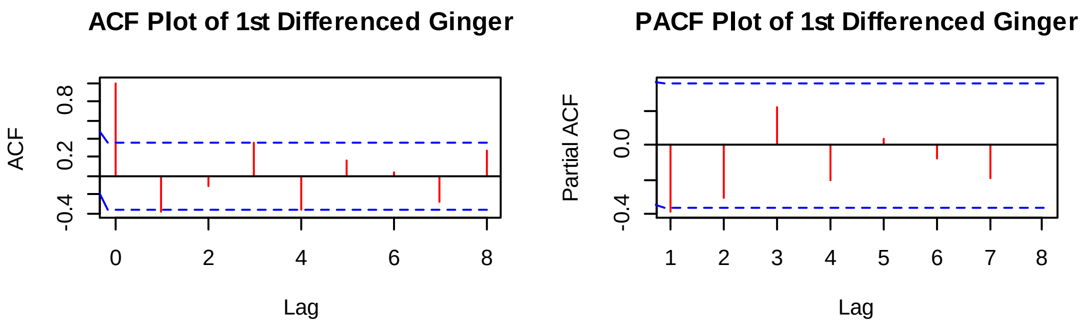


Figure 5: Graphically Stationarity Checking for Ginger Production

From the Figure 5, it is clear that the first order differenced Ginger production series shows more stable variance than the original series. Again, from the ACF and PACF, it is clear that there are some significant spikes in the ACF plot indicating the existence of Moving Average effects on the original Ginger 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 spikes at any lag which tell us that the series is stationary with first order difference; and implies that there is no significant effects of Autoregressive and Moving Average order at first order difference series. Therefore, from the formal test (Dickey-Fuller Unit Root Test) and graphical representation of Ginger production series, it is clear that at the difference order one the series become stationary.

From the tentative order analysis, the best selected ARIMAX model for Ginger production is ARIMAX (2, 1, 1) with AIC = 124.35 and BIC = 138.03. The parameter estimates are given in the Table 3.

Table 3: Summary Statistics of the ARIMAX (2,1,1) Model for Ginger Production

Coefficients	**Estimates**	**Std. Error**	**t-value**	**p-value**
ar1	-1.3015	0.1074	-12.1232	0.0262
ar2	-0.8144	0.0977	-8.3316	0.038
ma1	1	0.127	7.8751	0.0402
max.tem.dry	-1.1169	1.0474	-1.0664	0.2398
max.tem.sum	2.3722	1.0721	2.2125	0.1351
min.tem.dry	0.8758	0.9664	0.9062	0.2657
min.tem.sum	-4.2023	0.78	-5.3875	0.0584
rain.dry	0.0154	0.0198	0.7799	0.2892
rain.sum	-0.0088	0.0061	-1.4326	0.194

From the Table 3, it is clear that first and second order Auto-regressive Lag; and first order Moving Average Lag have statistically significant effects on Ginger production at 4% level of significance. Again, max.tem.dry, min.tem.sum and rain.sum have negative and max.tem.sum, min.tem.sum and rain.dry have positive effects on the Ginger production. At the same time, all regressor variables have statistically significant effects on Ginger production at 29% level of significance.

From the "Box-Ljung" autocorrelation test, it is found that $\Pr(|\chi^2_{(1)}| \geq 0.3511) = 0.5535$ which suggests that there is no autocorrelation among the residuals of the fitted ARIMAX model at 5% level of significance. Again, from the "Jarque-Bera" normality test, it is found that $\Pr(|\chi^2_{(2)}| \geq 0.2392) = 0.8873$ which refers to accept the normality assumption that the residuals are from normal distribution.

Residuals diagnostics plots are shown in the Figure 6.

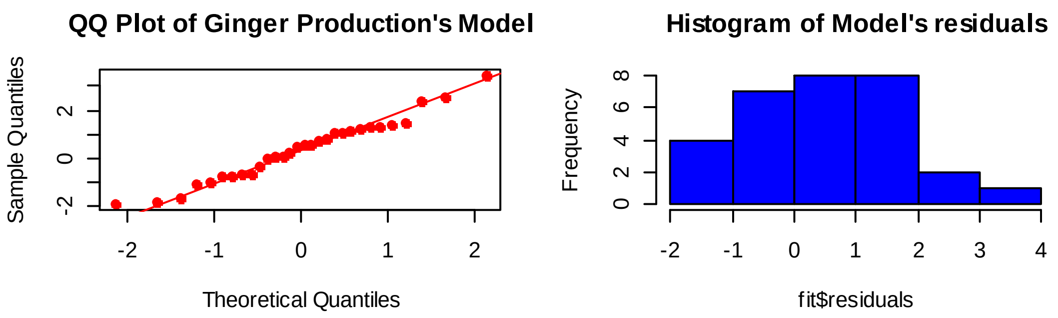


Figure 6: Graphical Residuals Diagnostics Checking for ARIMAX Model of Ginger Production

From the Figure 6, it is clear that almost all points are closed to the Q-Q line or on the Q-Q line indicating residuals of the Ginger production's model are normally distributed. At the time, from the Histogram of the residuals, it is obvious that residuals are normally distributed.

Finally, considering all of the Graphical and Formal test, it is obvious that our fitted ARIMAX(2,1,1) model is the best fitted model to measure the temperature and rainfall effects on Ginger production in Bangladesh.

10. Forecasting Cash Crop Production Using Fitted ARIMAX Model

After selecting the best model, now we are going to use these models to forecast species crop productions in Bangladesh under consideration of temperature and rainfall effects. To forecast the species crop productions, following modern "Forecasting Criteria" are considered. The most useful forecast evaluation criteria are Root Mean Square Error (RMSE) proposed by Ou and Wang (2010), Mean Absolute Error(MAE), Root Mean Square Error Percentage(RMSPE), Mean Absolute Percentage Error (MAPE) proposed by Sutheebnjard and Premchaiswadi (2010). The results of these criteria for forecasting species crop productions in Bangladesh are shown in the Table 4.

Table 4: Forecasting Criteria for the Best Selected Model

Species Crop	Selected Model	Forecasting Criterion			
		ME	RMSE	MAPE	MAE
Chili	ARIMAX(2,1,2)	1.420293	11.27518	14.57435	8.241679
Garlic	ARIMAX(2,0,1)	0.1537435	1.817675	0.1747029	1.454215
Ginger	ARIMAX(2,1,1)	0.3802592	1.32114	2.785421	1.076563

11. Comparison between Original and Forecasted Series

It is tried make a comparison between the original series and forecasted series from the fitted ARIMAX model. These forecasted results are shown in the Figure 7.

From the Figure 7,

- From the Chili production forecasting plot (top), it is clear that the original series of the cotton production (red color), which show initially almost constant tendency but at ending of the in-sample part shows increasing tendency which is continued in the forecasting part. So, it can be said that forecasting the Chili production may well under consideration of temperature and rainfall effects.
- From the Garlic production forecasting plot (middle), both original and forecasted series are shown same manner. So, it is also a good forecasted series.
- From the Ginger production forecasting plot, both original and forecasted series are shown same manner. So, it is also another good forecasted series.

Finally**,** all of the fitted models clearly explain the practical situation which implies that these fitted models are statistically good fitted model for measuring temperature and rainfall effects on spices crops production and forecasting the spices crops under consideration of these effects covering the whole Bangladesh.

12. Conclusion and Recommendations

The main objective of this study is to develop the best Box-Jenkins Auto-Regressive Integrated Moving Average with External Regressor, that is, ARIMAX model for measuring the temperature and rainfall effects on major spices crops production in the Bangladesh and forecasting the production using the same model. Due to time sequence dataset, ARIMAX model is considered as a measuring tool of cause-effect relation among the spices crops production and climatic variables (temperature and rainfall) under study. It can be done using Multiple Regression but our dataset used in this study is a time sequence data and for time sequence dataset Multiple Regression model is not a suitable approach and that is why we try to fit the model using ARIMAX model. For most of crops production, temperature is the most vital climatic factor and some crops need optimum temperature and some need extreme temperature. Amount of rainfall is an important factor for any crop productions. In this study, it is tried to fit the model to measure the impact of these two climatic variables seasonally. To serve this purpose, the grand average of the month October, November, December, January and February is considered as a "dry season" and that of March, April, May, June, July, August, September is taken as a "summer season" considering the weather and climatic situation of Bangladesh. From the study, it is found that ARIMAX(2,1,2), ARIMAX(2,0,1) and ARIMAX(2,1,1) are the best model for Chili, Garlic and Ginger production respectively. From the comparison between original series and forecasted series, it shows that these fitted model are well representative of the practical situations and both series shows the same manner. From the study, it is obvious that ARIMAX model is well behaved to short time study and also forecasting criterion are very well satisfied. From the study, it is also noticeable that temperature and rainfall have most vital component of the climates and have significant effects on different types of species crop productions under study.

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.

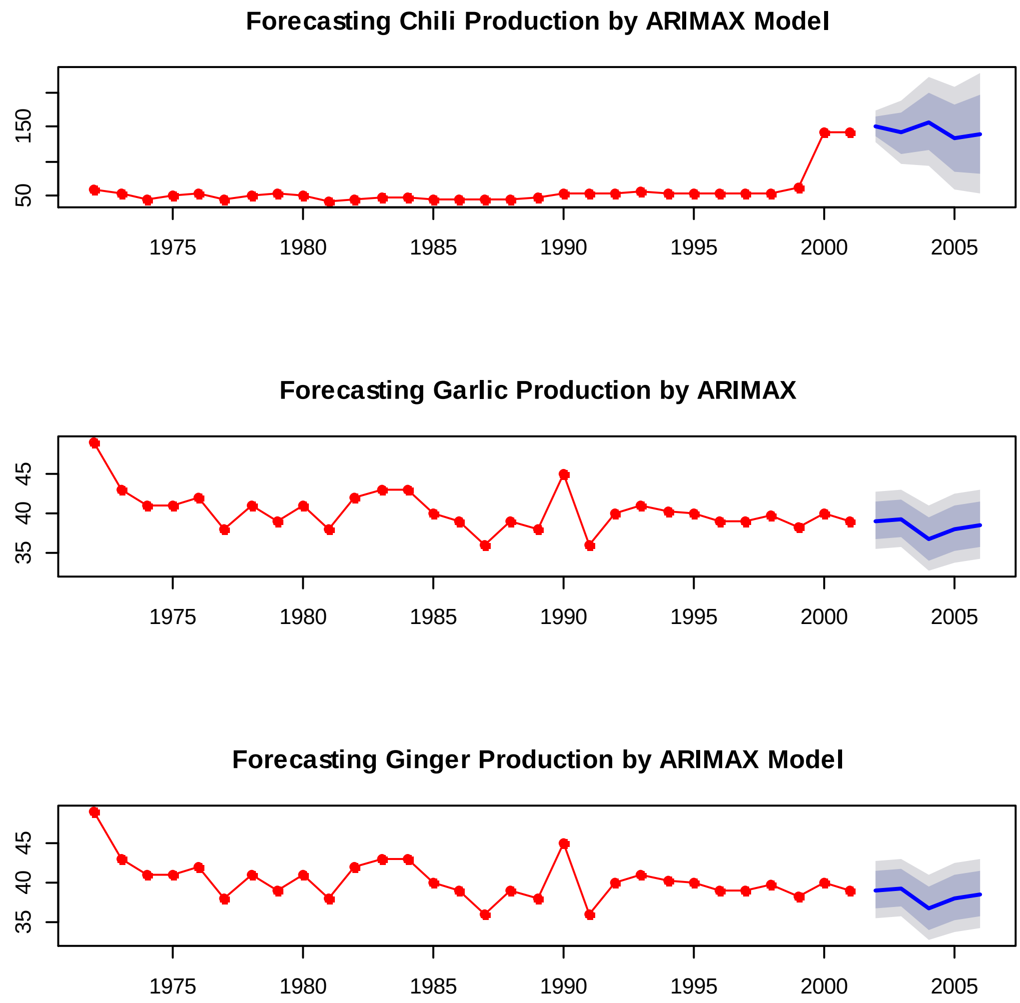


Figure 7: *Graphical Comparison between Original and Forecasted Series*

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