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Full Length Research Paper

A study of auto-regressive integrated moving average (ARIMA) model used for forecasting the production of tomato in Bangladesh

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Tomato is one of the most important and popular vegetables in Bangladesh. It ranks fourth in respect of production and third in respect of area in Bangladesh. It is a good source of Vitamin A and C, and it provides antioxidant elements such as lycopen which prevents cancer. Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. Tomato is also helpful in preventing joint pain problems and the respiratory disorder as well. The main purpose of this research is to identify the Auto-Regressive Integrated Moving Average (ARIMA) model by Box-Jenkin's methodology that could be used to forecast the tomato production in Bangladesh. This study considered the published secondary data of yearly tomato production in Bangladesh over the period of 1971 to 2013. The best selected Box-Jenkin's ARIMA model for forecasting the tomato productions in Bangladesh is ARIMA (0,2,1). The comparison of the original series and forecasted series shows the same manner which indicates that the fitted model is statistically suitable to forecast the tomato productions in Bangladesh, that is, the models forecast well during and beyond the estimation period.

Key words: Tomato, ARIMA model, Box-Jenkin's Methodology, Ljung-Box Test, forecasting, Bangladesh.

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill) is one of the most important and popular vegetables in Bangladesh. It is a good source of Vitamin A and C, and it provides antioxidant elements such as lycopen which prevents cancer (Bhutani and Kallo, 1983). It is cultivated in almost all home gardens and also in the field for its adaptability to wide range of soil and climate in Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (Hossain et al., 2010). In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1995). The best growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi (Sharfuddin and Siddque, 1985) and it ranks fourth in respect of production and third in respect of area (BBS, 2006). Tomato is grown in winter months of Bangladesh as the temperature is congenial at that period of time for optimum growth and yield. But it has great potentiality to grow in summer also. Due to its palatability and vitamin content, its demand in general is growing day by day throughout the year, while its production is far from the requirements especially in summer season. In summer, availability of vegetable is less due to agro-ecological constraints. Cultivation of summer vegetables is affected due to excessive rainfall, wind storm, etc., during the monsoon season (Zaman et al., 2006). Tomato is sensitive to a number of environmental stresses, especially extreme temperature, drought, salinity and inadequate moisture stresses (Kalloo, 1993). In Bangladesh, lack of irrigation and drought resistant cultivars are the central problems for tomato cultivation. In the dry season with high temperature, flower abortion occurs and fruits drop frequently, which causes very poor yield of tomato (Nahir and Ullah, 2012). Year round tomato production in Bangladesh is constrained by many factors of which seasonality and multiple disease problems are the two main factors. Fruit setting in tomato is reportedly interrupted at temperature above 26/20°C day/night respectively and often completely arrested above 38/27°C day/night (Stevens and Rudich, 1978; El-Ahmadi and Stevens, 1979; Kuo et al., 1979). Charles and Harris (1972) stated that fruit setting of tomatoes need night

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temperature of 15 to 20°C, which does not prevail anywhere in Bangladesh during May to September. There is a bright scope of exploitation of heterosis under high temperature in Bangladesh as many tomato lines introduced from abroad are capable enough to produce a large number of small fruits (Patwary, 2013).

Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). Food value of tomato is greatly dependent on its chemical composition such as dry matter, titrable acidity, total sugar, total soluble solids and ascorbic acid, etc. Studies in USA indicate that flavor and taste of tomato are related to free sugars, organic acids and sugar acid ratios (Kader et al., 1978). It is an important condiment in most diets and a very cheap source of vitamins. Tomato is a good source of vitamins A, C and E and minerals that are very good for body and protect the body against diseases (Taylor, 1987). The tomato is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, and vitamins and minerals (Pedro and Ferreira, 2007). Ripe tomatoes have a high content of the antioxidant lycopene, which plays a possible role in the prevention of certain forms of cancer (Agarwal and Rao, 2000). Tomatoes help wash out the toxins and other contaminants from the body and act as a gentle stimulant for kidneys. Tomatoes are also rich in Vitamin A. Regular consumption of tomatoes can prevent short sightedness, night blindness, and other eye diseases. Tomato is also effective in curing morning sickness, excessive gas formation in the intestine, gastro-intestinal diseases, indigestion, etc. Tomato is also helpful in preventing joint pain problems and the respiratory disorder as well (Friedman, 2013).

Fruits and vegetables usually do not survive in a long storage and similarly tomatoes are vulnerable to damage. Fungal growth is one of the major problems that often arise on the surface of tomatoes. As a seasonal fruit, tomato is widely found in winter season and the price is relatively cheap at the time of harvest. During non-harvesting season, the price of tomatoes rises and goes beyond the affordable limit of the general people. The high price of tomatoes indeed creates the demand of availability of tomatoes during the off season. In Bangladesh, the storage system is not so abundant and plenty of tomatoes are lost every year. Tomato candy making is one of the alternative processes to preserve tomato. Fresh tomatoes usually can be fresh for 3 - 4 days without any preservation system; whereas tomato candies have the endurance for as long as about 6 months. Tomato candy would be more attractive to consumers because it is more practical to live to eat. It contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). Hasanuzzaman et al. (2014) did a research to develop a self-stable dehydrated tomato product using different sugar solutions and to study the effects of the sugar solution on the characteristic of tomato candy. They showed that the best characteristic of tomato candy was found with 40% sugar solution, with highest nutrient and sensory score and lowest microbial load than candy prepared with 50% and 60% sugar solution. The general popularity and health benefits associated with this vegetable crop make it one of the most commercially viable of all agricultural commodities. Cultivation of this high yielding, short duration crop is increasing worldwide. Nowadays, farmers of Bangladesh are very much fascinated to grow hybrid tomato to avoid hormone application, to get early harvest with good quality bigger size fruit. The use of hybrid tomato varieties has increased considerably throughout the world and have many advantages compared to open pollinated ones. Many farmers prefer to grow crops using hybrid seeds in spite of the higher seed cost. Hybrid tomato seed production is relatively a new technology for Bangladesh. However, hybrid tomato seed production is not an easy task (Opena et al., 1993). Maintenance and seed production potentiality of the parental lines is also important in the hybrid seed production programme (Rashid and Singh, 2000). Yesmin et al. (2014) estimated inbred and hybrid seed production potentiality of tomato genotypes and observed the yield performance of the developed hybrids and inbreds during the summer season in Bangladesh. Although production of tomatoes is increasing day by day, but in a land hungry country like Bangladesh, it may not be possible to meet the domestic demand due to increase in population. Moreover, the production of tomato in our country lags behind the demand. One of the main aims of the Millennium Development Goals (MDG) of Bangladesh by the year 2015 is to eradicate hunger, chronic food insecurity, and extreme destitution. To meet the demand of domestic consumption of tomato, it is very much essential to estimate the production of tomato in Bangladesh. The main purpose of this research is to identify the Auto-Regressive Integrated Moving Average (ARIMA) model by Box-Jenkin's methodology that could be used to forecast the production of tomato in Bangladesh.

MATERIALS AND METHODS

Data source

This paper considered the published secondary data of yearly tomato production in Bangladesh which were collected over the period of 1971 to 2013 from the website of FAOSTAT.

ARIMA model

If $\{\zeta_t\}$ is a white noise with mean zero variance σ^2, then $\{Y_t\}$ is defined by $Y_t = \zeta_t + \beta_1\zeta_{t-1} + \beta_2\zeta_{t-2} + ... + \beta_q\zeta_{t-q}$ which is called a moving average process of order q and is denoted by $\mathrm{MA}(q)$. The process $\{Y_t\}$ which is given by $Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \zeta_t$ is called an auto-regressive process of order p and is denoted by $\mathrm{AR}(p)$. Models that are combination of AR and MA models are known as ARMA models. An $\mathrm{ARMA}(p,q)$ model is defined as $Y_t = \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \ldots + \alpha_p Y_{t-p} + \zeta_t + \beta_1 \zeta_{t-1} + \beta_2 \zeta_{t-2} + \ldots + \beta_q \zeta_{t-q}$, where Y_t is the original series, for every t, and assuming that ζ_t is independent of $Y_{t-1}, Y_{t-2}, \ldots, Y_{t-p}$. 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 $\mathrm{ARMA}(p,q)$ model then $\{Y_t\}$ is said to be an $\mathrm{ARIMA}(p,d,q)$ process. Fortunately, for practical purposes, usually taking $d=1$ or at most 2, an $\mathrm{ARIMA}(p,1,q)$ process can be defined as $W_t = \alpha_1 W_{t-1} + \ldots + \alpha_p W_{t-p} + \zeta_t + \beta_1 \zeta_{t-1} + \ldots + \beta_q \zeta_{t-q}$, where $W_t = Y_t - Y_{t-1}$.

Box-Jenkin's method

The influential work of Box-Jenkins (Box and Jenkins, 1970) shifted professional attention away from the stationary serially correlated deviations from deterministic trend paradigm toward the $ARIMA(p, d, q)$ paradigm. It is popular because it can handle any series, stationary or not with or without seasonal elements. The basic steps in the Box-Jenkins methodology consist of the following five steps:

Preliminary analysis

It creates conditions such that the data at hand can be considered as the realization of a stationary stochastic process.

Identification of a tentative model

It specifies the orders p, d, q of the ARIMA model so that the number of parameters to estimate is clear. Empirical autocorrelation functions play an extremely important role to recognize the model.

Estimation of the model

The next step is the estimation of the tentative ARIMA model identified in step-2. By maximum likelihood method, the parameters of the model were estimated.

Diagnostic checking

It checks if the model is a good one using tests on the parameters and residuals of the model.

Forecasting

If the model passes the diagnostics step, then it can be used to interpret a phenomenon, forecast.

Ljung-Box test

Ljung-Box (Ljung and Box, 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 which is $H_0: \rho_1(e) = \rho_2(e) = \ldots = \rho_k(e) = 0$ is tested with the Ljung-Box statistic, $Q^* = N(N+1)\sum_{i=1}^{k}(N-k)\rho_k^2(e)$, where, N is the number of observation used to estimate the model. This statistic Q^* approximately follows the chi-square distribution with $(k-q)$ degrees of freedom, where q which is the number of parameter should be estimated in the model. If Q^* is large (significantly large from zero), it is said that the residuals of the estimated model are probably auto-correlated. Thus, one should then consider reformulating the model.

Model selection criteria

Before forecasting, it is necessary to estimate the Time Series model and evaluate the performance of the best fitted model. There are many summary statistics available in literature for evaluating the forecast errors of any Time Series or Econometric model. Thus, an attempt is made to identify the best models for tomato production in Bangladesh using the following contemporary model selection criteria, such as RMSPE, MPFE and TIC.

Root Mean Square Error Percentage (RMSPE)

Root Mean Square Error Percentage (RMSPE) is defined as:

$$RMSPE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{Y_t^f - Y_t^a}{Y_t^a}\right)^2}$$

where Y_t^f is the forecast value in time t and Y_t^a is the actual value in time t.

Minimum Phone Frame Error (MPFE)

Minimum Phone Frame Error (MPFE) is defined as:

$$MPFE = \frac{1}{T}\sum_{t=1}^{T}\left(\frac{Y_t^a - Y_t^f}{Y_t}\right)$$

where Y_t^a is the actual value in time t and Y_t^f is the forecast value in time t.

Theil Inequality Coefficient (TIC)

Theil (Theil, 1966) Inequality Coefficient (TIC) is defined as:

$$TIC = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^f - Y_t^a\right)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^a\right)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^f\right)^2}}$$

where Y_t^f is the forecast value in time t and Y_t^a is the actual value in time t.

RESULTS AND DISCUSSION

During the study period, the average tomato production in Bangladesh is around 100350.24 tonnes per annum with a standard deviation of 50383.97 tonnes. In 2012, the maximum production amount was 255430 tonnes and the minimum production was 52545 tonnes which occurred in the year 1974. In this paper, Augmented-Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root test are used to check whether the data series is stationary or not. After first differencing the Augmented-Dickey-Fuller (ADF) test with $\Pr\left(|\tau| \geq -4.7787\right) < 0.01$, Phillips-Perron (PP) test with $\Pr\left(|\tau| \geq -32.907\right) < 0.01$ and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) unit root test with $\Pr\left(|\tau| \geq 0.0601\right) > 0.1$ at 5% level of significance, it adequately showed that the data series is stationary which suggest that there is no unit root. The graphical representations of the original and second differenced series are presented in Figure 1a, b.

The tomato production data series shows gradual increasing trend over the study period, which implies that the variance of tomato production in Bangladesh was not stable over time thus leading the tomato production data series as non-stationary (Figure 1a). However, it is clear that the second differenced tomato production data series shows stable variance which indicates that the data have become stationary. To stabilize the variance and to make the data stationary second difference to be enough, the difference order is 2 and is said to be integrated in order 2 (Figure 1b). The alternative positive and negative ACF (Figure 1c) and PACF (Figure 1d) indicates that the tomato production data follows an autoregressive moving average process. Using the tentative procedure, it is clear that ARIMA (0,2,1) model with $\mathrm{AIC} = 849.36$, $\mathrm{AIC_C} = 849.69$ and $\mathrm{BIC} = 852.74$ is the best selected model for forecasting the tomato production in Bangladesh. The estimates of the parameters of the fitted ARIMA (0,2,1) model are shown in Table 1. Also, the value of the most useful "forecasting criteria" of the fitted ARIMA (0,2,1) model are shown in Table 1.

Several graphical representations of the residuals for the fitted ARIMA (0,2,1) model are presented in Figure 2 and they suggest no significant pattern and hence it is said that there is no autocorrelation among the residuals. Also, the "Box-Pierce" test with $\Pr\left(|\chi_1^2| \geq 1.5977\right) = 0.2062$ and the "Ljung-Box" test with $\Pr\left(|\chi_1^2| \geq 1.7146\right) = 0.1904$ at 5% level of significance strongly suggest that there is no autocorrelation among the residuals of the fitted ARIMA (0,2,1) model. Here, "Histogram with Normal Curve" is used to check the normality assumption of the residuals of the fitted model. The Histogram with Normal Curve of the residuals of the fitted ARIMA (0,2,1) model is given in Figure 2. Histogram with Normal Curve approximately suggests that the residuals of the fitted ARIMA (0,2,1) model are statistically normally distributed. Therefore, it is clear that the fitted ARIMA (0,2,1) model is the best fitted model and adequately used to forecast the tomato production in Bangladesh.

By using the best fitted model ARIMA (0,2,1), the forecasted tomato production for ten years along with 95% confidence level are presented in Table 2. The graphical comparison of the original series and the forecast series is shown in Figure 3. It is apparent that the original series (dark-green-color) gradually shows an upward tendency. The forecast series (blue-color) fluctuated from the original series with a very small amount, that is, it shows the production in the same manner as the original series (Figure 3). The forecasted tomato production in Bangladesh also has an increasing trend. Therefore, the forecasted series is really a better representation of the original tomato production series in Bangladesh.

CONCLUSION

Although production of tomatoes is increasing day by day, in a land hungry country like Bangladesh it may not be possible to meet the domestic demand due to

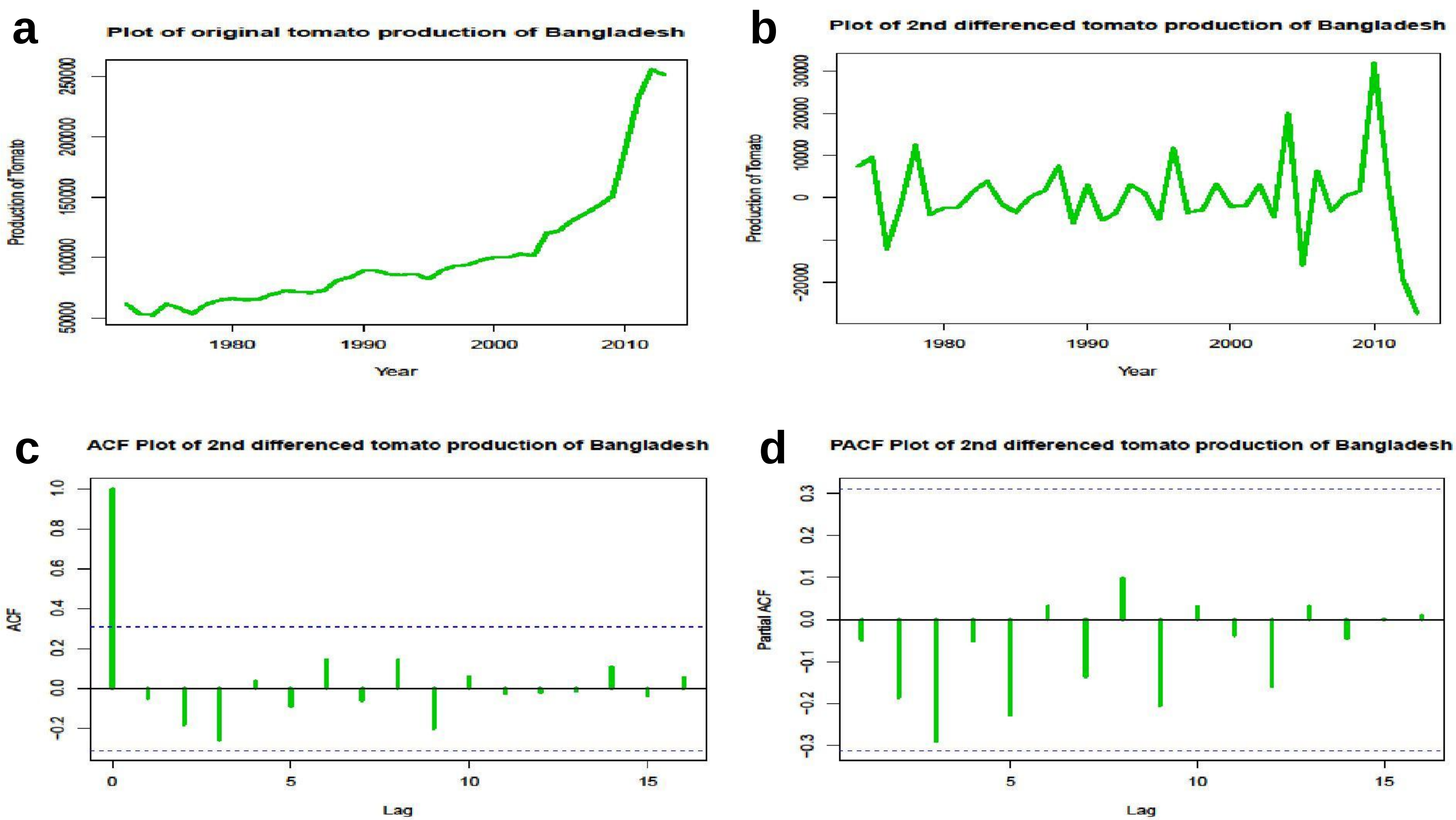

Figure 1. (a) Time series (original series) plot, (b) Time series (2nd differenced) plot, (c) ACF and (d) PACF of 2nd differenced tomato production in Bangladesh.

Table 1. Summary statistics and forecasting criteria of the fitted ARIMA (0,2,1) model.

Coefficient	Estimate	Std. Error	t-value	p-value
ma1	-0.7287	0.1327	-5.491334	0.05733755
Forecasting criteria	MASE	RMSPE	MPFE	TIC
	0.8169672	0.06967291	0.01582523	0.04084457

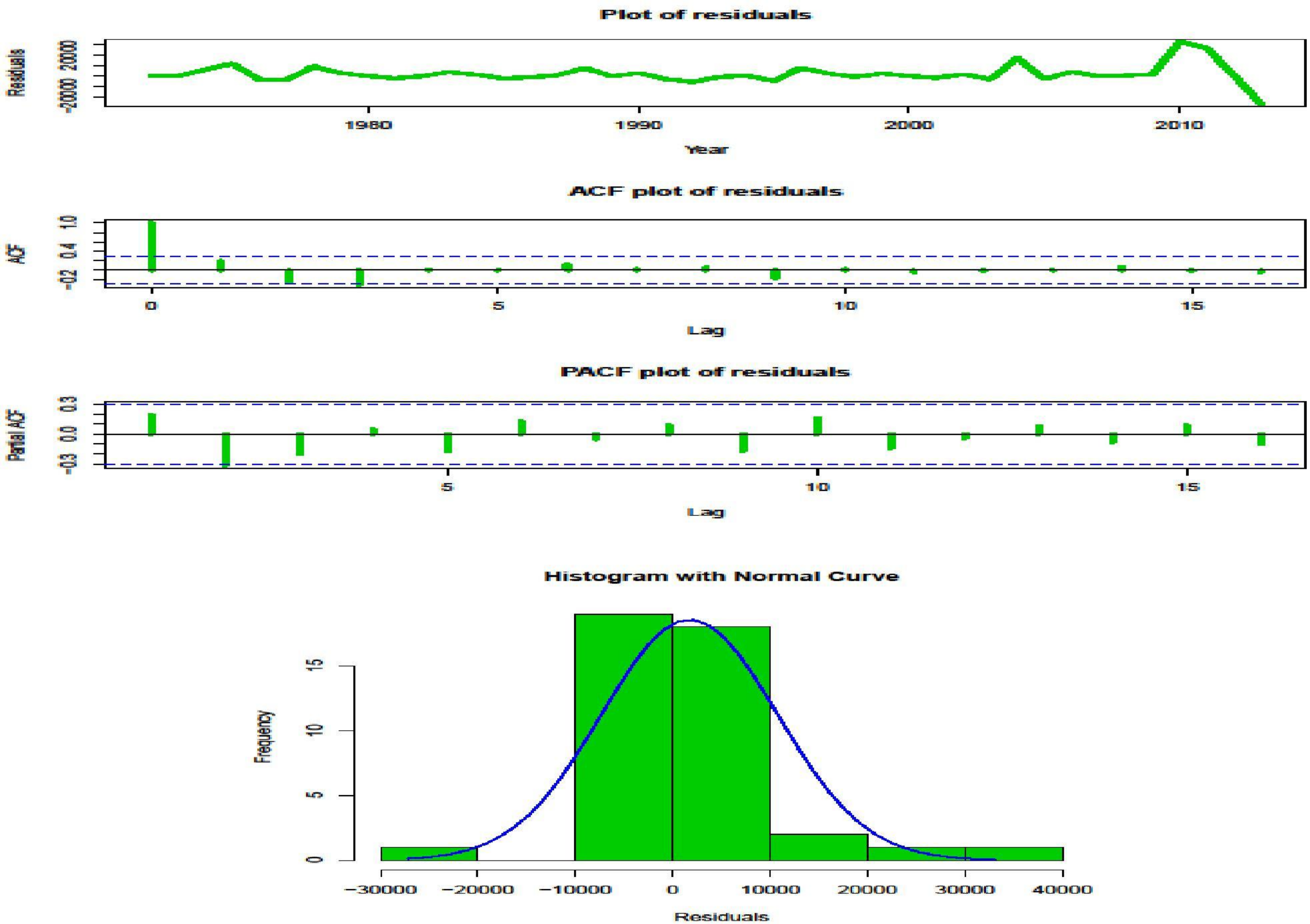

Figure 2. Several graphical representations and Histogram with Normal Curve of residuals.

Table 2. Forecasted tomato production in Bangladesh.

Tomato production (tonnes)			
Year	**Forecast**	**LCL**	**UCL**
2014	266379.1	248136.1	284622.1
2015	281758.2	252250.4	311265.9
2016	297137.3	256361.1	337913.5
2017	312516.4	260001.8	365030.9
2018	327895.4	263049.9	392741.0
2019	343274.5	265472.2	421076.9
2020	358653.6	267266.8	450040.4
2021	374032.7	268444.0	479621.4
2022	389411.8	269018.8	509804.8
2023	404790.9	269007.7	540574.1

Note: LCL= Lower Confidence Limit and UCL=Upper Confidence Limit.

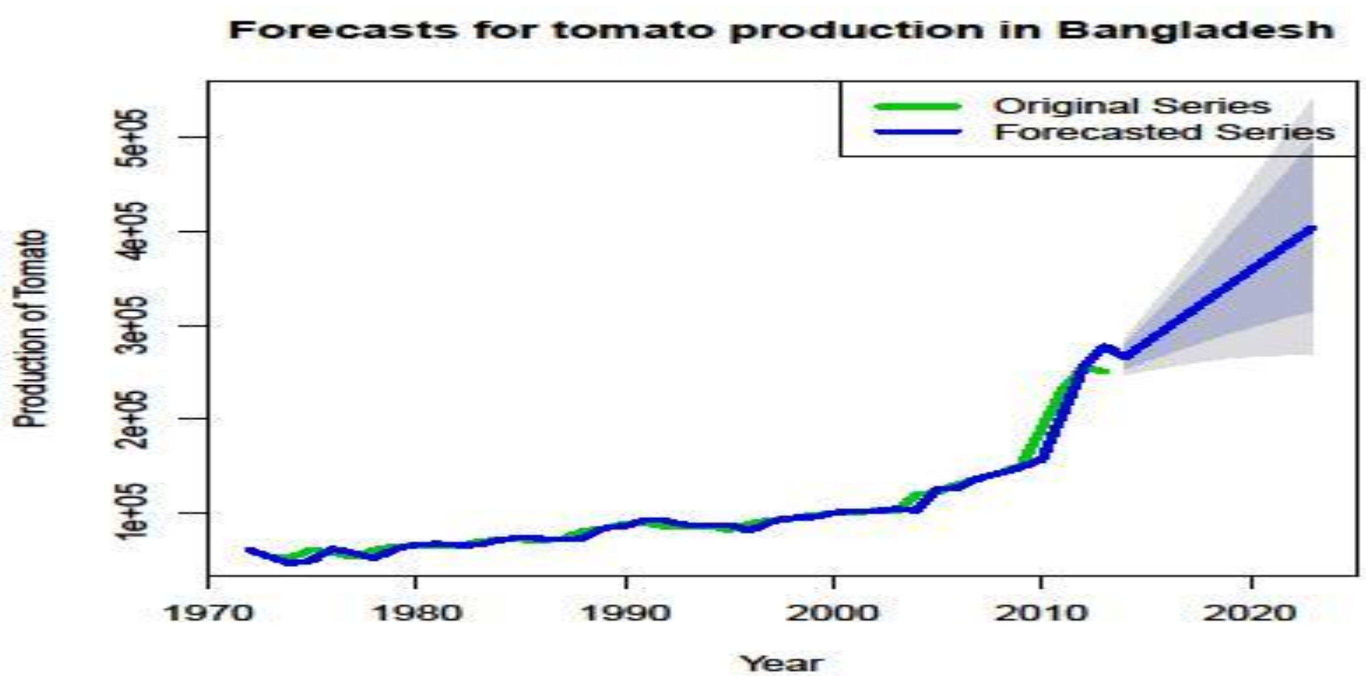

Figure 3. Comparison between the original and forecasted tomato production in Bangladesh.

increase in population. Moreover, the production of tomatoes in Bangladesh lags behind the demand. So, to meet the demand of domestic consumption of tomato, it is very much essential to estimate the future production of tomato in Bangladesh which is done by forecasting. During the study period, the average tomato production in Bangladesh was around 100350.24 tonnes per annum with maximum production 255430 tonnes occurred in the year 2012 and the minimum production was 52545 tonnes in the year 1974. The aim of this paper was to find the best model to forecast tomato production in Bangladesh with the help of the latest available model selection criteria such as AIC, AIC_C , etc. According to the model selection criteria used in this paper, the best selected ARIMA model for forecasting tomato productions in Bangladesh is ARIMA (0,2,1). Several graphical representations of residuals, Box-Pierce and Ljung-Box test suggest that there is no autocorrelation among the residuals of the fitted model. Furthermore, the Histogram with Normal Curve approximately suggests that the residuals of the fitted model are normally distributed.

In addition, the comparison of the original series and forecasted series shows the same manner which indicates that the fitted model is statistically suitable to forecast tomato productions in Bangladesh, that is, the models forecast well during and beyond the estimation period which reached a satisfactory level. Thus, the fitted model can be used for policy purposes as far as used to forecasts the tomato production in Bangladesh.

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