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Forecasting of Wheat Production in Kushtia District & Bangladesh by ARIMA Model: An Application of Box-Jenkin's Method

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Abstract: After independence, in 1971, Bangladesh faced an acute food shortage. Production of rice, the main crop, declined because of the disruption of virtually all agricultural activities during the War of Liberation, and also due to various natural calamities, such as floods, droughts, cyclones, and rapid population growth. It was realized that rice alone could not meet the food requirement of the country. Wheat was therefore chosen as an alternate food crop in the winter season, which remains mostly free from natural calamities. Trend of wheat consumption is increasing over the three decades due to rapid expansion of green revolution technologies, irrigation in dry season, government subsidies in agriculture, improved seeds, increase of arable land, appropriate pesticides use and sufficient fertilizer use. 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. Thus it is essential to estimate the production of food-grains. The main purpose of this paper is to identify the Auto-Regressive Integrated Moving Average (ARIMA) model by Box-Jenkin's methods that could be used to forecast the production of wheat in Kushtia district as well as Bangladesh. The best selected ARIMA model for forecasting the wheat productions in Kushtia district is ARIMA (1,2,1), and, for whole Bangladesh it is ARIMA (0,2,1). This paper makes a comparison between the original series and forecasted series which also shows the same trend in wheat productions, indicating the fitted model are statistically well behaved to forecast wheat productions in Kushtia district as well as Bangladesh.

Keywords: Wheat, ARIMA Model, Box-Jenkin's Method, Bangladesh

1. Introduction:

Wheat cereal plant is of the genus *Triticum*, especially, *T. aestivum*, of the family Graminae. The grain constitutes a major food item and an important commodity on the world grain market. Wheat is an important cereal crop which is cultivated worldwide and was one of the first crops to be domesticated some 10000 years ago. Unlike rice and maize, which prefer tropical environment, wheat is extensively grown in temperate regions occupying 17% of all crop acreage worldwide. It is the staple food for 40% of the world's population (Goyal and Prasad, [1]; Peng *et al.*, [2]). Wheat is the second only to rice which provides 21% of the total food calories and 20% of the protein for more than 4.5 billion people in 94 developing countries (Braun *et al.*, [3]). Global wheat grain production must increase 2% annually to meet the requirement of consistently increasing world population (around 9 billion) till 2050 (Rosegrant and Agcoili, [4]).
After independence, in 1971, Bangladesh faced an acute food shortage. Production of rice, the main crop, declined because of the disruption of virtually all agricultural activities during the War of Liberation, and also due to various natural calamities, such as floods, droughts, cyclones, and rapid population growth. It was realized that though about 80 percent of the total cropped area of Bangladesh is devoted to rice cultivation, rice alone could not meet the food

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requirement of the country. Wheat was therefore chosen as an alternate food crop in the winter season, which remains mostly free from natural calamities. In 1975 the government imported 4000 metric tons of seed. Prior to 1975-76, wheat was grown sporadically and was almost an unknown crop in Bangladesh. Today, among the cereal crops, it is next to rice in importance. Wheat is grown under a wide range of climatic and soil conditions. It however, grows well in clayey loam soils. In Bangladesh it is a crop of Rabi season, requires dry weather and bright sunlight. Well distributed rainfall between 40 and 110 cm is congenial for its growth. Depending on variety and weather conditions, 100-120 days are required from sowing to harvest (Banglapedia, [5]). Rice and Wheat are the principal sources of food, calorie, and protein intake for most of the people of Bangladesh. Once, wheat was a food for the poorer in Bangladesh. Most of the people used to take wheat as ‘Chapati’ (locally known as ruti). The dietary habit of people of Bangladesh has changed to a considerable extent during the past decade. Wheat has now become an indispensable food item of the people of Bangladesh and it continues to fill the food gap caused by possible failure of rice crop. Within a period of 30 years of time, wheat has been firmly established as a secure crop in Bangladesh, mainly due to stable market price and two million farmers are currently involved in wheat production. Wheat cultivation is easier and requires less time and irrigation than other alternative crops like Boro rice, legumes, and potatoes; additionally it has low cultivation costs (Karim *et al.*, [6]). They have identified the appropriate growth model of wheat production in Bangladesh and its three major areas like Dinajpur, Rajshahi, and Rangpur districts during the time periods 1971-72 to 2004-05. They found that the linear model was appropriate for Dinajpur District, while cubic model was appropriate for both Rajshahi and Rangpur districts. Also they found that quadratic model was appropriate for Bangladesh.

The facts of past three decades indicated the increasing trend of wheat consumption. To meet increasing consumers’ demand, the country has to import, on an average, 1.4 million tons of wheat every year. Moreover, wheat consumption is increasing due to rapid urbanization and industrialization of the country and the consequent increase in the use of numerous bakery products. Moreover, livestock and poultry thrive on wheat grain as a part of the ration and feed channels utilize most of the wheat by-products from flour milling. The straw may be fed as a part of the roughage for ruminants and is used extensively for livestock bedding (Rashid and Islam, [7]). In view of the prevailing situation, rice alone is no more capable of providing balanced and nutritious food for the human, poultry, and livestock. The sufficient quantity of wheat can improve the nutrition situation in the country (Wadud *et al.*, [8]). The government has fixed a target to produce 1.036 million tonnes of wheat in the current financial year (FY'13) on 0.37 million hectares of land. The Household Income and Expenditure Survey (HIES) 2010, conducted by the Bangladesh Bureau of Statistics (BBS) showed daily per capita wheat consumption swelled to 26.1 grams in 2010, marking a 115.7 percent rise from 12.1gm in 2005. Local wheat production has declined gradually over the past one decade after hitting a record high of 1.9 million tonnes in the financial year 1998-99. The condition has improved a little as the country reaped a yield of 0.995 million tonnes in FY'12, a 2.34 percent increase compared to that of FY'11, BBS revealed (The Financial Express, [9]).

In Bangladesh a remarkable progress has performed in achieving its food security, although there were ups and downs in production of food-grains. Since the independence of Bangladesh in 1971, production and consumption of food-grains grew over time. The price hike for agricultural commodities, particularly rice and wheat in 2007 and 2008, has posed a major challenge to food security in Bangladesh. Over the past three decades, rapid expansion of green revolution technologies, irrigation in dry season, government subsidies in agriculture, improved seeds, increase of arable land, appropriate pesticides use and sufficient fertilizer use; have led to a rapid increase in rice and wheat production in Bangladesh. 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. Thus it is to estimate the production of food-grains. Purposively we select a district of Bangladesh namely Kushtia and considered the production wheat in whole Bangladesh. The main purpose of this paper is to identify the appropriate Time Series model by Box-Jenkin’s methodology which is used to forecast the production of wheat in Kushtia district as well as Bangladesh.

2 Materials and Methods

2.1 Data Source

From the publications of “Statistical Yearbook of Bangladesh” [10] published by Statistics division, Ministry of Planning, Dhaka, Bangladesh the secondary data was collected for the wheat production of Kushtia district as well as Bangladesh over the period 1975 to 2012. Recent year data could not be employed due to unavailability of more recent Statistical Yearbook of Bangladesh.

2.2 ARIMA Model

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

2.3 Box-Jenkins Method

The influential work of Box-Jenkins (Box and Jenkins, [11]) shifted professional attention away from the stationary serially correlated deviations from deterministic trend paradigm toward the $\mathrm{ARIMA}(p,d,q)$ 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: Create conditions such that the data at hand can be considered as the realization of a stationary stochastic process.

Identification of a Tentative Model: Specify the orders p,d,q of the ARIMA model so that it is clear the number of parameters to estimate. 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 we estimate the parameters of the model.

Diagnostic Checking: Check 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.

2.4 Jarque-Bera Test

We can check the normality assumption using Jarque-Bera (Jarque and Bera, [12]) 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 sample kurtosis an s is the sample skewness. 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.

2.5 Ljung-Box Test

Ljung-Box (Ljung and Box, [13]) 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 $H_0 : \rho_1(e) = \rho_2(e) = ... = \rho_k(e) = 0$ 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 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. So, one should then consider reformulating the model.

2.6 Model Selection Criteria

Before forecasting it is necessary to estimate the Time Series model and evaluating 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. Here, an attempt is made to identify the best model for wheat production in Bangladesh and Kushtia district using the following contemporary model selection criteria, such as MAE, RMSE, MASE, RMSPE and TIC.

Mean Absolute Error (MAE)

In statistics, the Mean Absolute Error (MAE) is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. The mean absolute error is given by $MAE = \frac{1}{n}\sum_{i=1}^{n}\left| f_i - y_i \right|$, where f_i is the prediction and y_i the true value.

Root Mean Square Error (RMSE)

The Root Mean Square Error (RMSE) is certainly the most used measure. It is mainly due to its simplicity and usage in other domains. It is defined as $RMSE = \sqrt{\frac{1}{n}\sum_{t=1}^{n}\left(y_t - \hat{y}\right)^2}$.

Mean Absolute Scaled Error (MASE)

Mean Absolute Scaled Error (MASE) is defined as $MASE = \dfrac{\frac{1}{n}\sum_{t=1}^{n}\left|y_t - \hat{y}_t\right|}{\frac{1}{n-1}\sum_{i=2}^{n}\left|y_i - y_{i-1}\right|}$, where $\hat{y}_t$ is the forecast value in time t and y_t is the actual value in time t .

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 .

Theil Inequality Coefficient (TIC)

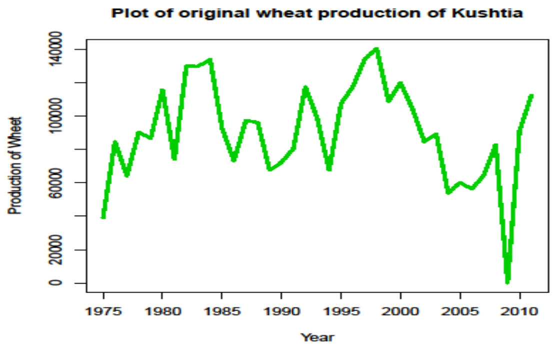
Theil (Theil, [14]) Inequality Coefficient (TIC) is defined as $TIC = \dfrac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^f - Y_t^a\right)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^a\right)^2} + \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(Y_t^f\right)^2}}$, where Y_t^f is the forecast value in time t and Y_t^a is the actual value in time t .

3 Results and Discussion

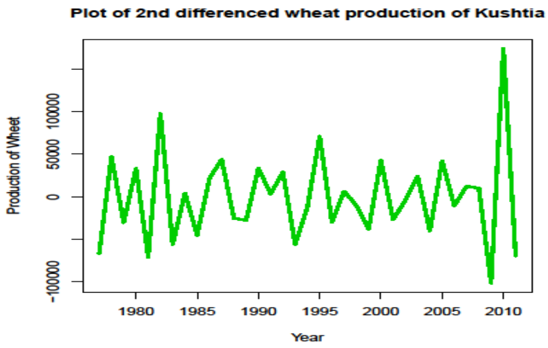
ARIMA Modeling of Wheat Production in Kushtia District

In this paper Augmented-Dickey-Fuller (ADF) test, Phillips-Perron (PP) test and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests are used to check whether the data series is stationary or not. After second differencing the Augmented-Dickey-Fuller (ADF) test with $\Pr\left(\left|\tau\right| \geq \text{-}6.5105\right) < 0.01$, Phillips-Perron (PP) test with

$\Pr\left(|\tau| \geq -51.0822\right) < 0.01$ and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test with $\Pr\left(|\tau| \geq 0.0598\right) > 0.1$ at 5% level of significance adequately declared 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 1*a*,*b***. It is clear that from the starting year, there is an increasing trend up to the year 1985 after that there is a decreasing trend in wheat production. After the year 1999 the production decline gradually (**Figure 1*a***) i.e., the variance is unstable which revealed that the wheat production data series is not stationary. However, the second difference data series of wheat production shows stable variance which makes the data series is stationary (**Figure 1*b***).



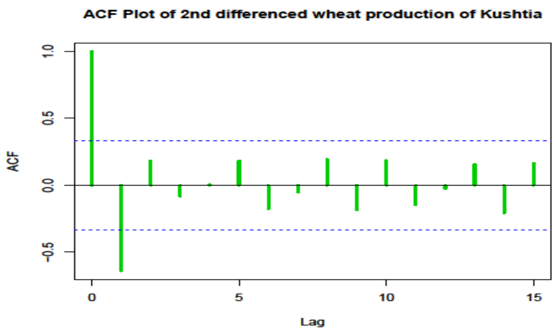
(a)



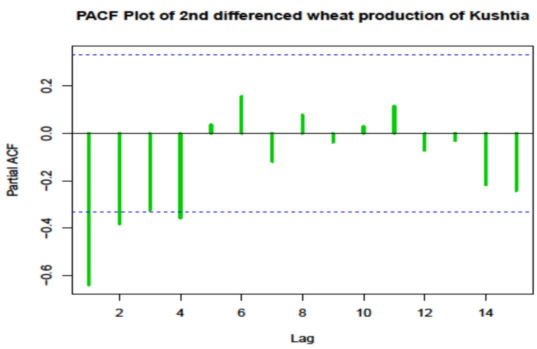
(b)

Figure 1: Time series plot of original series and 2nd differenced what production in Kushtia district.

To stabilize the variance and make the data stationary, second difference is enough i.e., the difference order is two that is it is integrated of order two. The alternative positive and negative ACF (**Figure 2*a***) and exponentially decay PACF (**Figure 2*b***) indicates the wheat production in Kushtia district follows an autoregressive moving average process. The PACF with significant spike at lag 1 and ACF with significant spike at lag 1 suggest that first order autoregressive and first order moving average are effective on wheat production in Kushtia.



(a)



(b)

Figure 2: ACF and PACF plot of 2nd differenced what production in Kushtia district.

Using the tentative procedure, it is clear that ARIMA(1,2,1) is the best selected model for forecasting the wheat production in Kushtia with $\text{AIC} = 830.63$, $\text{AIC}_\text{C} = 831.41$ and $\text{BIC} = 835.3$. The estimates of the parameters of the fitted ARIMA(1,2,1) model are shown in Table 1.

Table 1. *Summary Statistics of the fitted ARIMA(1,2,1) model*

Coefficients	Estimates	Std. Error	t-value	p-value
AR(1)	-0.3702	0.1595	-2.321003	0.1294928
MA(1)	-0.9999	0.0930	-10.75161	0.02952086

Several graphical representations of the residuals of the fitted ARIMA(1,2,1) model are presented in **Figure 3**, and suggest no significant pattern and hence it is said to be there is no autocorrelation among the residuals. Also, the

"Box-Pierce" test with $\Pr\left(\left|\chi_1^2\right| \geq 0.2269\right) = 0.6338$ and the "Box-Ljung" test with $\Pr\left(\left|\chi_1^2\right| \geq 0.2458\right) = 0.6201$ at 5% level of significance strongly suggest that there is no autocorrelation among the residuals of the fitted ARIMA(1,2,1) model. Here "Jarque-Bera" test is used to check the normality assumption of the residuals of the fitted model. The "Jarque-Bera" test with $\Pr\left(\left|\chi_2^2\right| \geq 0.0558\right) = 0.9725$ at 5% level of significance strongly suggests that the residuals of the fitted ARIMA(1,2,1) model are normally distributed. Therefore, it is clear that the fitted ARIMA(1,2,1) model is the best fitted model and adequately used to forecast the wheat production in Kushtia district.

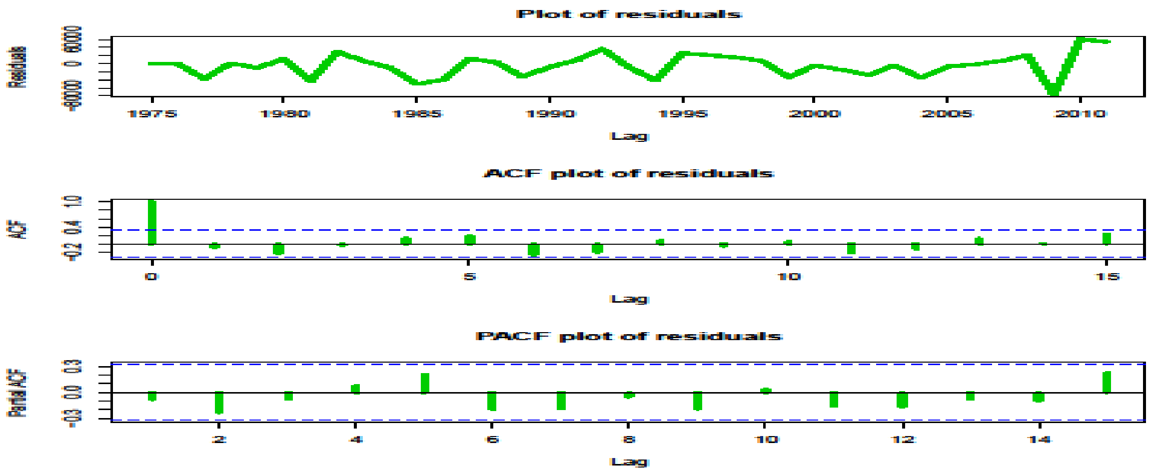


Figure 3: Several plots of residuals of the fitted model.

The values of the most useful "forecasting criteria" of the fitted model are shown in Table 2.

Table 2. *The forecasting criteria of the fitted ARIMA(1,2,1) model*

Model	MAE	RMSE	MASE	RMSPE	TIC
ARIMA(1,2,1)	21875.46	28903.41	0.9546343	2085.865	0.1492531

By using the best fitted model ARIMA(1,2,1), the forecasted wheat production in Kushtia district for ten years are shown in Table 3. Also, the graphical comparison of the original and the forecasted data series is shown in **Figure 4**.

Table 3. *Forecasted Wheat production in Kushtia district*

Year	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Forecasted Production	106765.9	111055.2	111607.4	113543	114966.5	116579.6	118122.5	119691.4	121250.6	122813.4

It is observed that the forecasted series (blue-color) fluctuated from the original series (pink-color) with a very small amount which shows the fitted series has the same manner of the original series (**Figure 4**). Therefore, the forecasted series is really better representation of the original wheat production in Kushtia district.

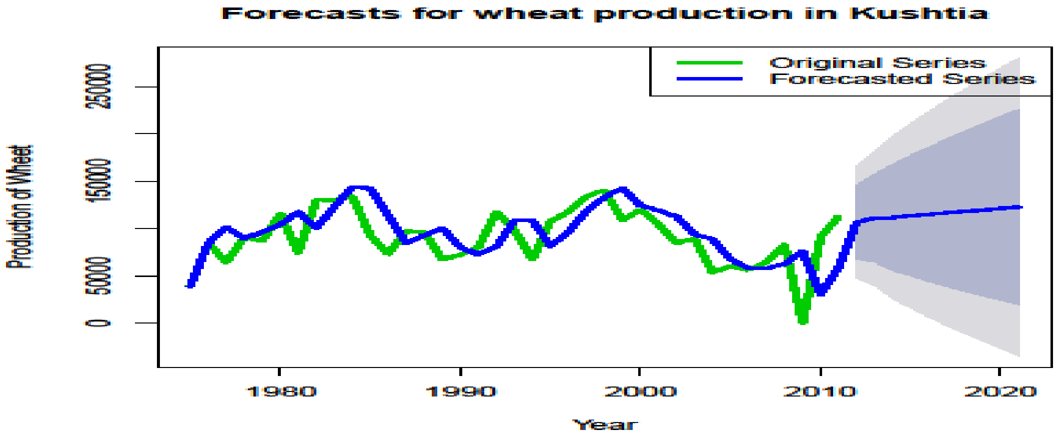
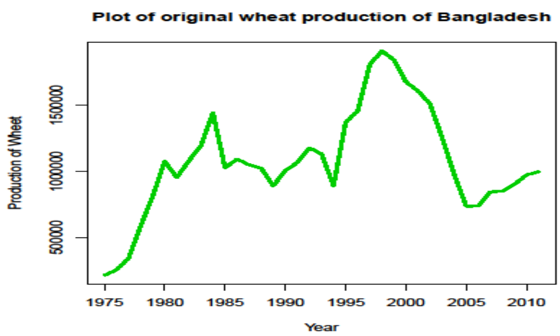


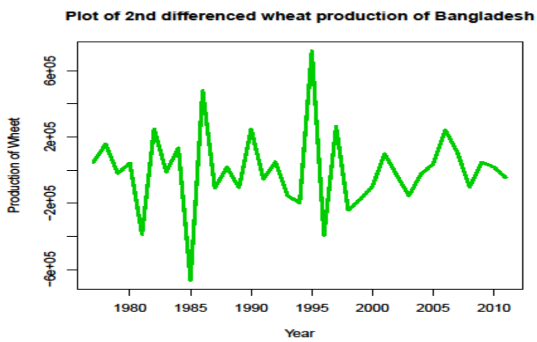
Figure 4: Comparison between original and forecasted wheat production in Kushtia district.

ARIMA Modeling of the Wheat Production in Bangladesh

In this paper, Augmented-Dickey-Fuller (ADF) test, Phillips-Perron (PP) test and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) tests are used to check whether the data series is stationary or not. After second differencing the Augmented-Dickey-Fuller (ADF) test with $\Pr(|\tau| \geq -4.1126) = 0.0169$, Phillips-Perron (PP) test with $\Pr(|\tau| \geq -47.0675) < 0.01$ and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test with $\Pr(|\tau| \geq 0.0364) > 0.1$ at 5% level of significance adequately declared 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 5*a,b***. It is clear that from the starting year, there is an increasing trend with fluctuations up to the year 1999 after that there is a decreasing trend in wheat production of Bangladesh **Figure 5*a***) i.e., the variance is unstable which revealed that the wheat production data series is not stationary. However, the second difference data series of wheat production shows stable variance which makes the data series is stationary (**Figure 5*b***).



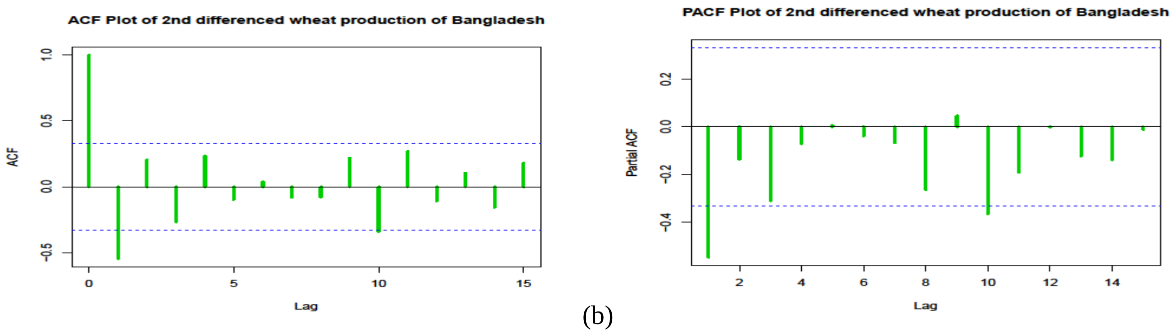
(a)



(b)

Figure 5: Time series plot of original series and 2nd differenced wheat production in Bangladesh.

To stabilize the variance and make the data stationary, second difference is enough that is difference order is two i.e., it is integrated of order two. The exponentially decay PACF (**Figure 6*b***) indicates the wheat production in Bangladesh follows a moving average process. The ACF (**Figure 6*a***) with significant spike at lag 1 suggest that first order moving average is effective for wheat production in Bangladesh.



(a) (b)

Figure 6: ACF and PACF plot of 2nd differenced wheat production in Bangladesh.

Using the tentative method, it is clear that ARIMA(0,2,1) model with $\text{AIC} = 955.3$, $\text{AIC}_\text{C} = 955.68$ and $\text{BIC} = 958.41$ is the best selected model for forecasting the wheat production in Bangladesh. The estimates of the parameters of the fitted ARIMA(0,2,1) model are shown in Table 4.

Table 4. *Summary Statistics of the fitted ARIMA(0,2,1) model*

Coefficients	Estimates	Std. Error	t-value	p-value
MA(1)	-0.8814	0.1579	-5.582014	0.05642565

Several plots of the residuals of the fitted ARIMA(0,2,1) model are presented in **Figure 7**, suggest that there is no significant pattern and hence there is no autocorrelation among the residuals. Also, the "Box-Pierce" test with $\Pr\left(\left|\chi_1^2\right| \geq 0.1641\right) = 0.6854$ and the "Box-Ljung" test with $\Pr\left(\left|\chi_1^2\right| \geq 0.1777\right) = 0.6733$ at 5% level of significance strongly suggest that there is no autocorrelation among the residuals of the fitted ARIMA(0,2,1) model. The "Jarque-Bera" test with $\Pr\left(\left|\chi_2^2\right| \geq 2.5596\right) = 0.2781$ at 5% level of significance moderately suggests that the residuals of the fitted ARIMA(0,2,1) model are 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 wheat production in Bangladesh.

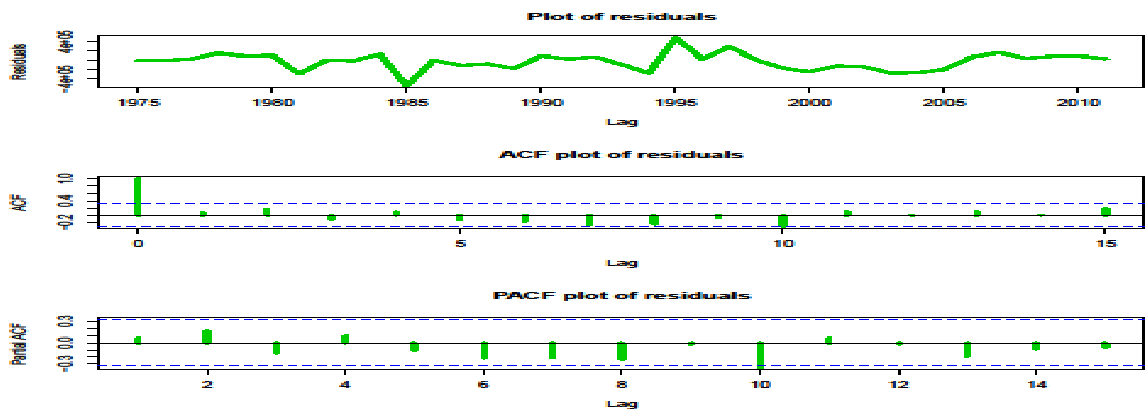


Figure 7: Several plots of residuals of the fitted model.

The values of the most useful "forecasting criteria" of the fitted model are shown in Table 5.

Table 5. *The forecasting criteria of the fitted ARIMA(0,2,1) model*

Model	MAE	RMSE	MASE	RMSPE	TIC
ARIMA(0,2,1)	134379.2	183855.9	0.4583181	0.17269	0.07907823

By using the best fitted model ARIMA(0,2,1), the forecast value for ten years are shown in Table 6. The graphical comparison of the original and the forecasted data series is shown in **Figure 8**.

Table 6. *Forecasted wheat production in Bangladesh*

Year	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Forecasted production	986289.1	977222.1	968155.2	959088.2	950021.3	940954.3	931887.4	922820.4	913753.5	904686.5

It is observed that the forecasted series (blue-color) fluctuated from the original series (pink-color) with a very small amount which shows the fitted series has the same manner of the original series (**Figure 8**). Therefore, the forecasted series is really better representation of the original wheat production in Bangladesh.

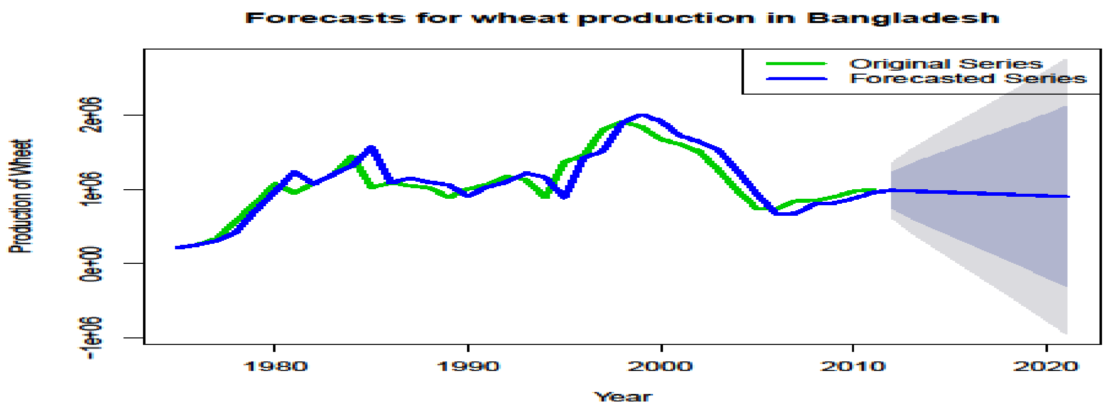


Figure 8: Comparison between original and forecasted wheat production in Bangladesh.

4 Conclusion

This paper tried to find and fit the best model to forecast the wheat production in Kushtia district as well as 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 Box-Jenkins ARIMA model for forecasting the wheat productions in Kushtia district is ARIMA (1,2,1), whereas, for whole Bangladesh it is ARIMA (0,2,1). The comparison between the original series and forecasted series indicate the fitted models behaved statistically well. Thus, the fitted models forecast well during and beyond the estimation period to a satisfactory level for both the cases. Therefore, these models can be used for policy purposes as far as forecasts the wheat production.

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