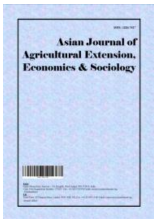

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Forecasting Area, Production and Yield of Onion in Bangladesh by Using ARIMA Model

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

In Bangladesh, onion is the widely used spices both for preparing food and curing diseases as it has medicinal values. As the demand for onion is increasing day by day, it is necessary to make actual projections of onion for undertaking some policies based on it. Therefore, the study investigates the future changes in the area, yield and production of onion in Bangladesh by using the most popular Box-Jenkins methodology. The auto regressive integrated moving average model has been used to understand the pattern of change over a period of 57 years (1961 to 2017) as well as to forecast the changes in the upcoming years. Some information criteria (such as AIC, AICc and BIC) was considered for selecting the best-fitted models of each variable. The forecasted results showed an upward trend for all the variables considered in this study. It implies that the area of onion will increase from 193932.6 hectares in 2018 to 265770.9 hectare in 2027. Again, the amount of onion production will increase from 2073.61 M tons to 3574.06 M tons and for onion yield, it will rise from 10343.17 Kg/ha to 12988.02 kg/ha from 2018 to 2027. These predictions may help the government balancing the demand with the supply and also regulating the price of onion in the domestic markets of Bangladesh.

Keywords: Onion; non stationarity; forecasting; auto regressive integrated moving average; Bangladesh.

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1. INTRODUCTION

Onion (*Allium cepa L*), being one of the major spices and extensively used condiments in Indian Sub-continent, plays an important role in human diet. It is well-known for its nutritional, flavoring, and medicinal characteristics [1,2,3]. Onion production also serves as highly commercial, income earning and employment generating activity and is regarded as more profitable than that of competing spices [4,5]. In terms of production, it is ranked first among all other spice crops in Bangladesh [6]. The benefit-cost ration (BCR) of onion is 2.01 [7].

Bangladesh has favorable agro-climatic conditions for production, processing and marketing of onion. The demand for onion in Bangladesh is growing steadily due to the rapid population growth, changing consumption pattern and diverse ways of using spices in different food items. Yet, many farmers are reluctant to producing onion due to the lack of adequate incentives from government. According to [6], Bangladesh produced approximately 1866 thousand tons of onion during 2016-2017 covering 459 thousand acres of land. Yet, to meet the annual demand of 2400 thousand tons, the country has to imports 700 to 800 thousand tons of onion every year mainly from the world's second largest onion producing country India [8]. Such a big figure indicates that Indian onion dominates the domestic market price of onion to a large extent. Besides, frequent price fluctuation of onion directly affects the real earnings of the consumers and forces them to adjust their consumption budget. In this regard, increasing the domestic production is of utmost importance for reducing the dependency on import in one hand and helping the consumers' balancing their food basket.

According to Hossain et al. [9] it is hard for Bangladesh to meet even 15% of the annual requirements of onion through domestic production. The authors further reported that the yield level is quite low (approximately 370-500 kg/ha) as compared to the higher yield (1000-1200 kg/ha) of onion produced in other countries. The lower yield level is associated with lack of quality seed and improved varieties and improper application of irrigation water at different stages of onion production causing the lower level of production and consequently, the imbalance between demand and supply. Moreover, such imbalance often forces the onion price to hike which have direct impact on the real earnings of the consumers and it induces them to adjust their consumption budget [10]. Therefore, increasing the domestic production in the coming years is of utmost importance for reducing the dependency on import in one hand and helping the consumers' balancing their food basket on the other hand. And, it is only possible through having an accurate information about the future changes in the area, yield and production of onion. Such attempt may enable the government designing appropriate production and trade policy so as to balance demand and supply in the domestic market through self-production than to resort on import.

In the body of literature, numbers of similar studies [10,11,2,12,3] are found which has been conducted in India. However, India is an exporting country which dominates the world market of onion. Therefore, the projection based on Indian context may not be suitable for policy making in the importing countries such as Bangladesh. Among the national studies, Haque et al. [13] and Anjum and Barmon [5] conducted the profitability analysis of onion while Khatun et al. [14] determined the impact of specialized credit for onion and garlic cultivation. Even though a recent study by Hossain et al. [9] is quite similar to the present study, however, the limitation of this study is that it covered only the production data of onion over the periods of 1971-2013. From this pursuit, the present study could be one of the comprehensive ones as it has covered not only the production, but also the area and yield to check whether the expected level of production is compatible with the available land size for onion cultivation in Bangladesh as well as the yield capacity to achieve that level of production. Additionally, effort has also been made in this study for long-term forecasting of onion covering a large dataset spread over 57 years (1961-2017) using the most widely used Auto Regressive Integrated Moving Average (ARIMA) method (elaborated in section 2) model.

2. MATERIALS AND METHODS

2.1 Data Sources

The study used annual time series data of onion area, production and yield in Bangladesh over the period of 1961 to 2017. The data were collected from the website of Food and Agricultural Organization and Bangladesh Bureau of Statistics, Government of the Peoples Republic of Bangladesh [15]. The data were analyzed using R-3.5.3 software. The Box Jenkins autoregressive integrated moving average (ARIMA) models were applied for the observed data. Finally, a forecast was made for the period of 2018 to 2027.

2.2 ARIMA Model

In time series analysis, an auto regressive integrated moving average (ARIMA) is a generalization of an auto regressive moving average model. As there is no seasonal variation in the data, so the study considered non-seasonal ARIMA (p, d, q) models. The model has three parts. The AR (p) parts of the model indicates autoregressive process of order p. It can be written as follows:

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots\cdots\cdots\cdots\cdots + \alpha_p Y_{t-p} + \epsilon_t$$

where,

Y_t= Area, production and yield of onion at time t

$Y_{t-1}, Y_{t-2}, \ldots\ldots\ldots\ldots Y_{t-p}$ = Area, production and yield of onion at time lags $t-1, t-2, \ldots\ldots\ldots t-p$, respectively.

The second part of the model d means difference. That is if the data is non stationary, then it has to be transformed into stationary as it is the main prerequisite for developing ARIMA model. Again, the MA (q) parts of the model is the moving average process of order q and it can be defined as

$$Y_t = \mu + \epsilon_t - \theta_1 \epsilon_{t-1} - \theta_2 \epsilon_{t-2} - \cdots\cdots\cdots - \theta_q \epsilon_{t-q}.$$

where,

μ = Constant terms
ϵ_t = White noise error term at time t
$\epsilon_{t-1}, \epsilon_{t-2}, \cdots\cdots\cdots \epsilon_{t-q}$ = Errors in previous time periods that are incorporated in the response Y_t

Hence, the equation for the non-seasonal ARIMA (p, d, q) model can be written as follows (Anderson, 1971):

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \alpha_2 Y_{t-2} + \cdots\cdots\cdots + \alpha_p Y_{t-p} + \epsilon_t - \beta_1 \epsilon_{t-1} - \beta_2 \epsilon_{t-2} - \cdots\cdots\cdots - \beta_q \epsilon_{t-q}$$

where,

$\alpha_0, \alpha_1, \alpha_2, \cdots\cdots\cdots, \alpha_p$=Coefficients to be estimated
The above equation is the combination of AR (p), I (degree of differencing) and MA (q) process where, Y_t is called the Auto-Regressive Integrated Moving Average (ARIMA) Model.

2.3 The Box Jenkins Methodology

The Box Jenkins methodology is applied both for Univariate or Multivariate ARIMA models in order to find out the best fitted model of the time series data [16]. There are four steps of Box-Jenkins methods. At first, it is required to check the variables if it is stationary or not. Unit Root test is applied for checking the stationarity. Augmented Dickey Fuller (ADF) test and Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test can be used to check the unit root and stationarity of the data. If the data is not stationary, then the data is transformed into stationary by differencing the original data series. The second step is to identify a tentative model to specify the appropriate values of p, d and q. The plots of the Auto Correlation Function (ACF) and Partial Auto Correlation Functions (PACF) help us to recognize the order of MA and AR process respectively. The third step is to estimate the parameters of the model by using the likelihood methods such as AIC, AICc and BIC, Finally, it is necessary to check the best fitted model by testing the parameters and residuals of the chosen model. The residuals are tested through the ACF and PACF plots and the Ljung Box [17] statistics. The forecasted data can be checked the validity of the model through mean absolute percentage error (MAPE). After checking the diagnostics step, the forecast can be generated [18].

3. RESULTS AND DISCUSSION

3.1 Fitting Autoregressive Integrated Moving Average (ARIMA) Model

Stationarity test for original series: At first, the study took unit root test for checking the unit root and stationarity of the original data series. Because the prerequisite of the Box Jenkins ARIMA model is that the series should be stationary to estimate the parameter of the model. The Augmented Dickey Fuller (ADF) [19] test and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) were taken to figures out if the data of onion area, production and yield are stationary around a mean or linear trend or are non-stationary due to a unit root. The null hypothesis for the ADF test is that there is a unit root where alternative hypothesis is that the data is stationary. Again the null hypothesis for KPSS test is that the data is not stationary where the alternative hypothesis is stationary.

From Table 1, it has been found that the P value of the ADF test statistics for onion area, production and yield are greater than 0.05 i.e. the original series has a unit root. Also, the P value of the KPSS test is less than 0.05 i.e. the series is non-stationary at level.

Stationarity test for 1st difference series: The Augmented Dicky Fuller test of the first differenced series presented in Table 2 implies that the P value for onion area, production and yield have unit root (i.e. P value > 0.05). The KPSS test also reveals that the data of first difference series are non-stationary (i.e. P value < 0.05).

Stationarity test for 2nd difference series: Both The ADF test and KPSS test for the second difference series data of onion area, production and yield (Table 3) suggested that there is no unit root (i.e. P value for ADF test < 0.05) and the data is stationary (P value for KPSS test > 0.05). Thus, for all the variables i.e. onion area, production and yield of the data, it would become stationary after 2nd difference.

Furthermore, the time series data of onion area, production, and yield were plotted to identify any unusual observations. In this study, the last 57 years' data were used for the modeling purpose of onion area, production and yield in Bangladesh. The PACF plots of the data was used to identify the AR order and the ACF plots was used to identify the MA order of the ARIMA process.

The plot of the original series of onion area, production and yield (Figs. 1, 2 and 3) showed that there are no significant spikes of both the ACF and PACF.

Table 1. ADF and KPSS test of the original series data

Unit root and stationarity test	Onion	Test statistics	P value
ADF Unit Root Test	Area	0.30	0.99
	Production	1.57	0.99
	Yield	0.15	0.99
KPSS Test	Area	1.00	0.01
	Production	0.89	0.01
	Yield	0.61	0.02

Source: Authors' calculation from Food and Agricultural Organization Data, 2019

Table 2. ADF and KPSS test of the first differenced series

Unit Root and stationarity test	Onion	Test statistics	P value
ADF Unit Root Test	Area	-3.29	0.08
	Production	-3.08	0.14
	Yield	-3.97	0.02
KPSS Test	Area	0.52	0.04
	Production	0.76	0.01
	Yield	0.75	0.01

Source: Authors' calculation from Food and Agricultural Organization Data, 2019

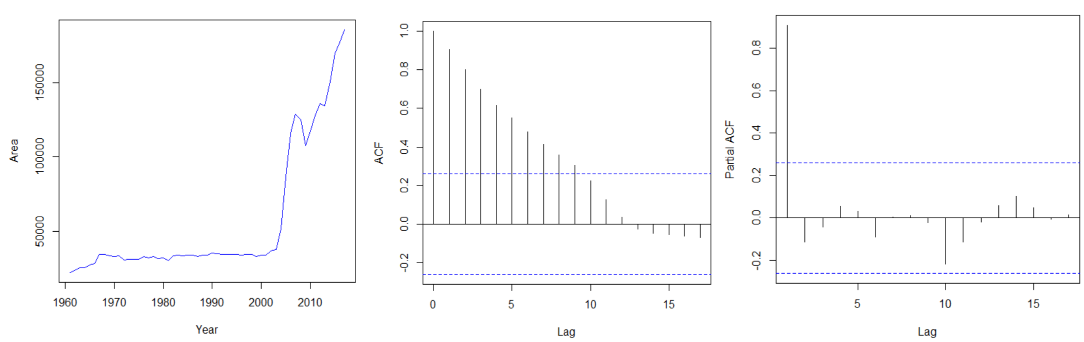

Fig. 1. Correlogram of onion area

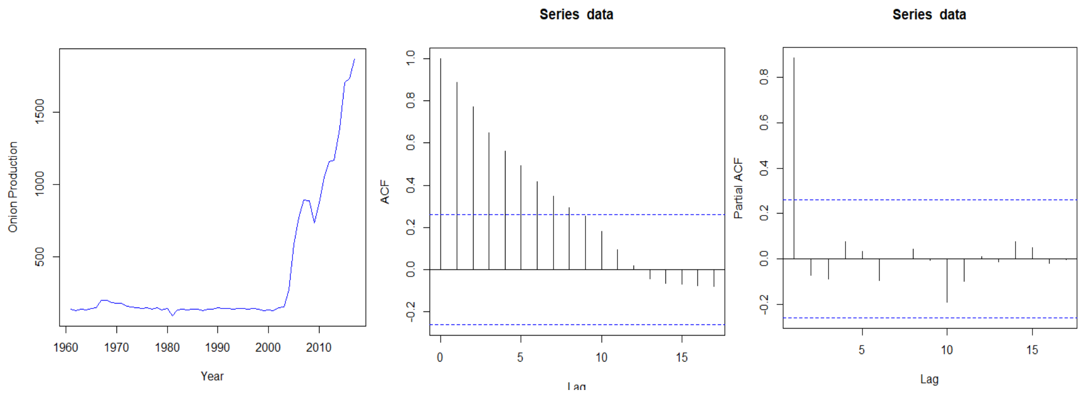

Fig. 2. Correlogram of onion production

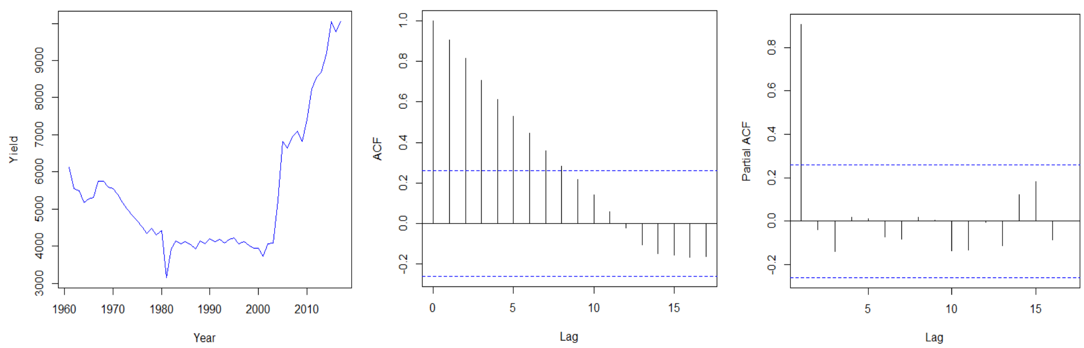

Fig. 3. Correlogram of onion yield

Table 3. ADF and KPSS test of the second differenced series

Unit root and stationarity test	Onion	Test statistics	P value
ADF Unit Root Test	Area	-5.01	0.01
	Production	-5.67	0.01
	Yield	-5.48	0.01
KPSS Test	Area	0.03	0.10
	Production	0.05	0.10
	Yield	0.04	0.10

Source: Authors' calculation from Food and Agricultural Organization Data, 2019

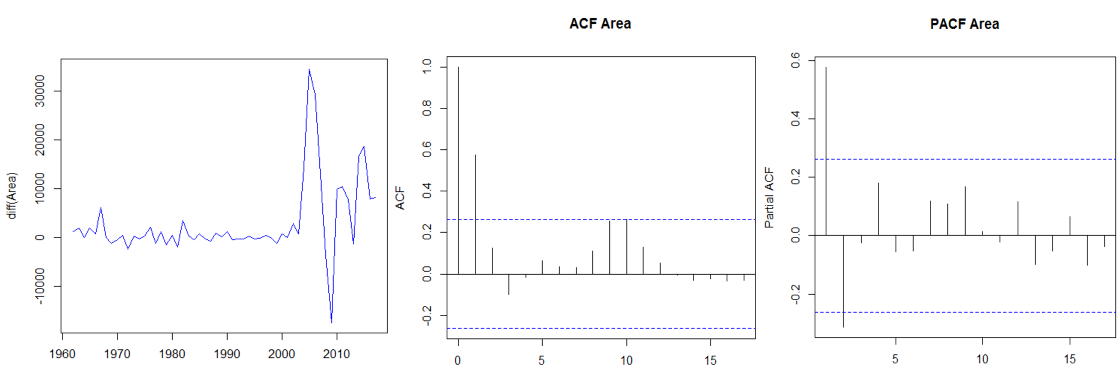

Fig. 4. Correlogram for the 1st differenced series of onion area

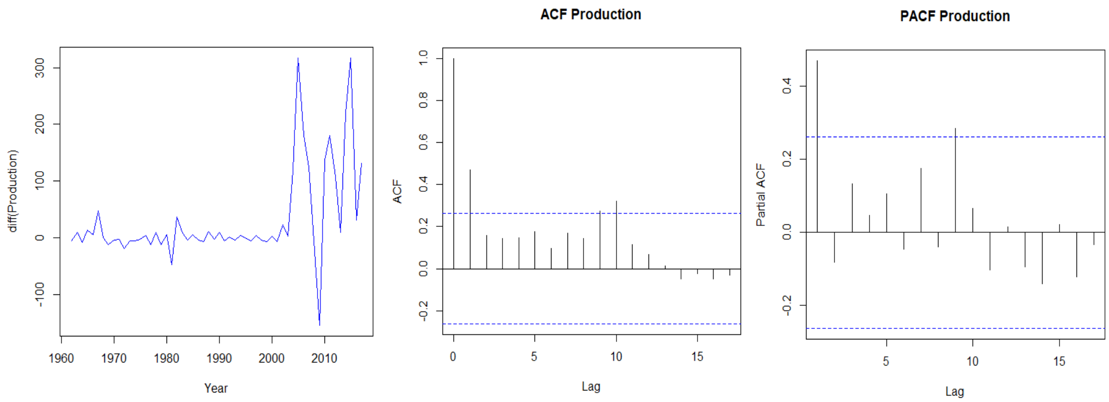

Fig. 5. Correlogram for the 1st differenced series of onion production

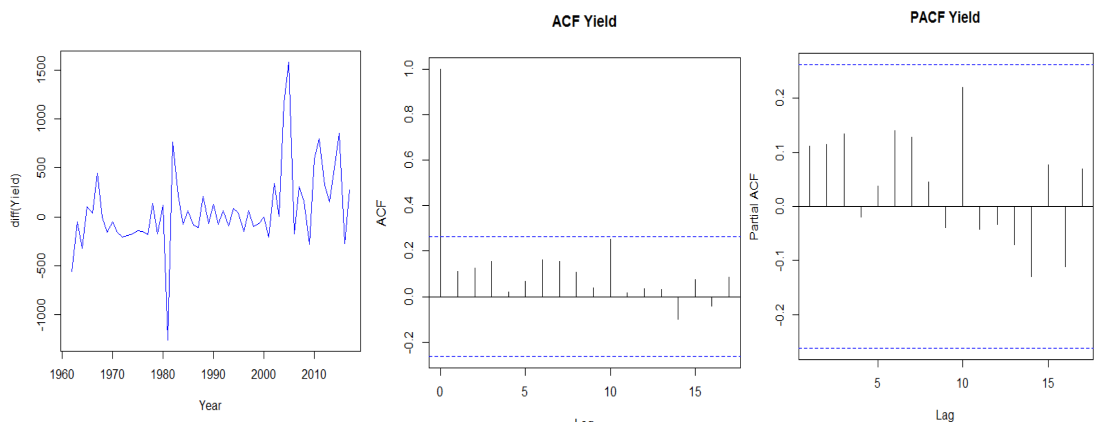

Fig. 6. Correlogram for the 1st differenced series of onion yield

It is evident from Figs. 2, 3 and 4 that the first differenced series of onion area, production and yield of both the ACF and PACF do not die down fast as the value of the lag period has been increased.

However, the 2nd differenced series of all the variables (onion area, production and yield) showed some different pattern in both ACF and PACF. Fig. 7 of the 2nd differenced series of onion area revealed that there is some exponential decay after lag 1 in ACF and exponential decay after lag 2 in PACF plot indicating the AR (2) and MA (1) term. Moreover, Fig. 8 showed that for onion production, there is a significant spike after lag 3 in the ACF and exponential decay in the PACF suggesting that the possible AR order might be 0 and MA order might be within 0 to 3 range. In addition, Fig. 9 revealed that there is a significant spike after 1st lag in ACF and exponential decay in PACF that indicates the possible AR (0) and MA (1) terms for onion yield.

3.2 Diagnostic Checking and Model Estimation

The different models of onion area, production and yield were fitted using different significant values of p, d and q. The minimum values of Akaike Information Criterion (AIC), Correction of Akaike Information Criterion (AICc) and Bayesian Information Criterion (BIC) are used for selecting the values of p, d and q. Because, it implies that the model with minimum AIC, AICc and BIC is closer to the best possible choice because they have residuals with white noise. In this study, it has been found that ARIMA (2, 2, 1), ARIMA (1, 2, 3) and ARIMA (0, 2, 1) for onion area, production and yield were the best selected model based on the minimum values of AIC, AICc and BIC.

3.3 Residual Analysis

The Figs. 10, 11 and 12 showed that both the ACF and PACF plot of the residuals of onion area, production and yield has no significant pattern among the residuals of the fitted ARIMA model. Hence it has been suggested that the residuals are free from autocorrelation.

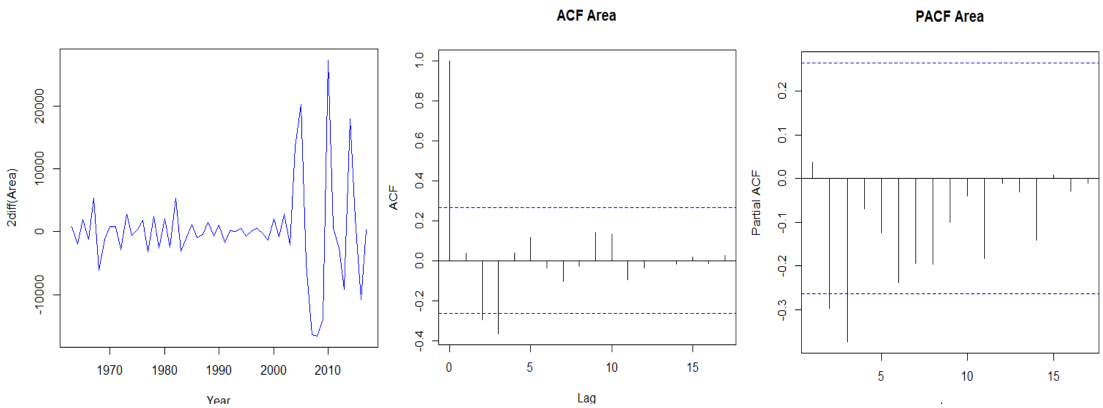

Fig. 7. Correlogram for the 2nd differenced series of onion area

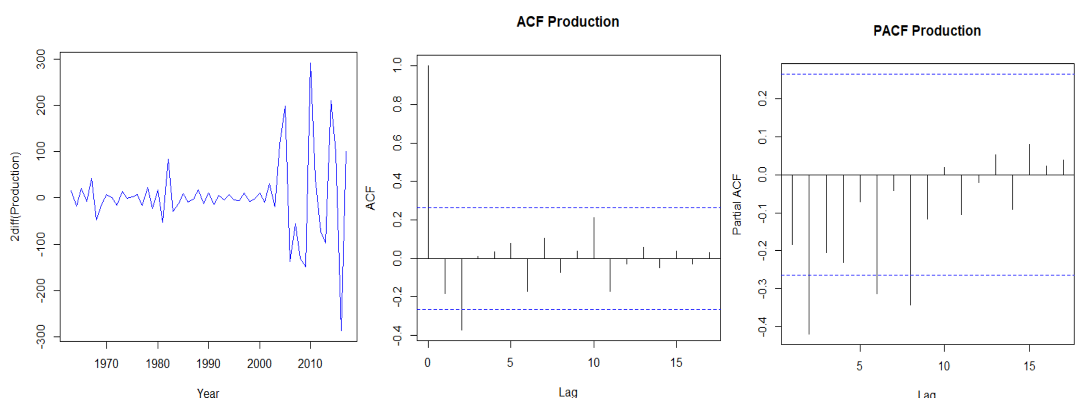

Fig. 8. Correlogram for the 2nd differenced series of onion production

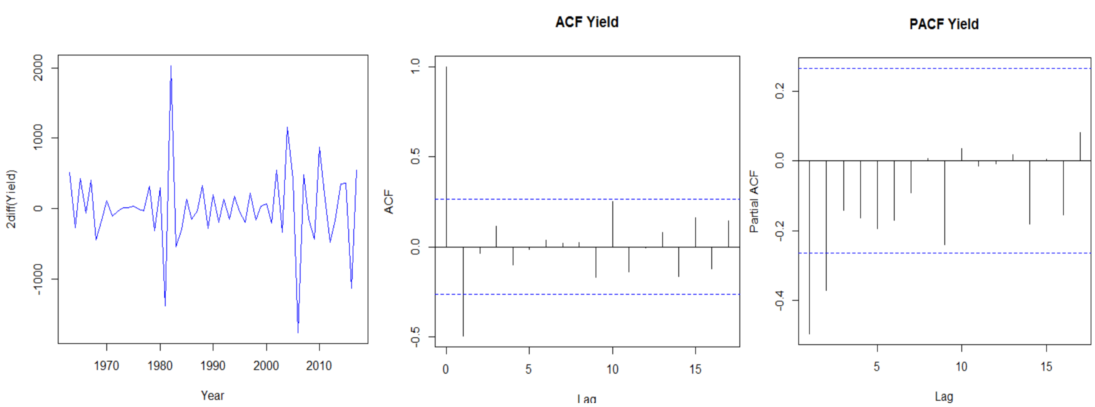

Fig. 9. Correlogram for the 2nd differenced series of onion yield

Table 4. Some best possible fitted ARIMA models with their AIC, AICc and BIC values for onion area, production and yield

Parameters	ARIMA models	AIC	AIC_C	BIC
Area	ARIMA (0, 2, 0)	1134.52	1134.6	1136.53
	ARIMA (0, 2, 1)	1136.36	1136.59	1140.38
	ARIMA (1, 2, 1)	1138.05	1138.52	1144.07
	ARIMA (2, 2, 1)	**1122.97**	**1123.77**	**1130.99**
	ARIMA (2, 2, 2)	1124.61	1125.83	1134.65
	ARIMA (3, 2, 1)	1124.44	1125.66	1134.47
	ARIMA (3, 2, 2)	1125.77	1127.52	1137.82
Production	ARIMA (0, 2, 0)	644.58	644.66	646.59
	ARIMA (1, 2, 0)	644.68	644.91	648.70
	ARIMA (0, 2, 1)	634.45	634.68	638.47
	ARIMA (1, 2, 1)	632.27	632.74	638.29
	ARIMA (0, 2, 3)	**627.04**	**628.34**	**635.57**
	ARIMA (1, 2, 3)	627.41	628.64	637.45
	ARIMA (2, 2, 3)	628.43	630.18	640.47
Yield	ARIMA (0, 2, 0)	851.77	851.54	853.78
	ARIMA (1, 2, 0)	837.99	838.22	842.00
	ARIMA (0, 2, 1)	**821.59**	**821.82**	**825.61**
	ARIMA (1, 2, 1)	823.52	823.99	829.54
	ARIMA (0, 2, 2)	823.51	823.98	829.53
	ARIMA (1, 2, 2)	824.61	825.41	832.63
	ARIMA (2, 2, 2)	827.29	828.51	837.32

Source: Authors' calculation from Food and Agricultural Organization (FAO) Stat Data, 2019

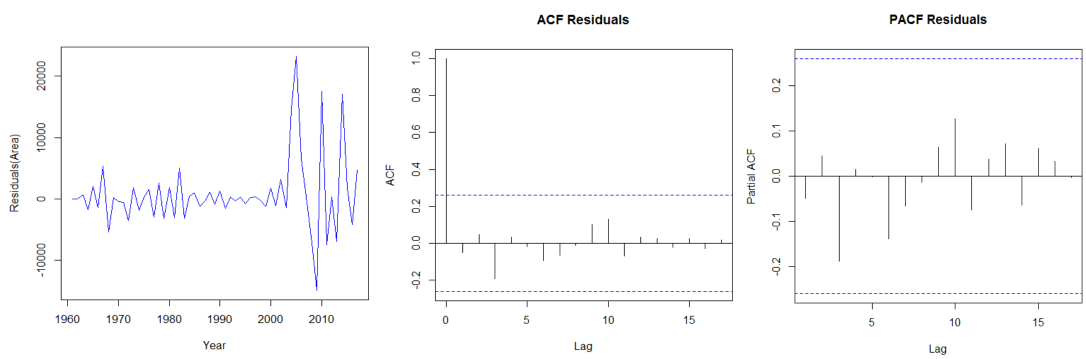

Fig. 10. Residual plots of onion area

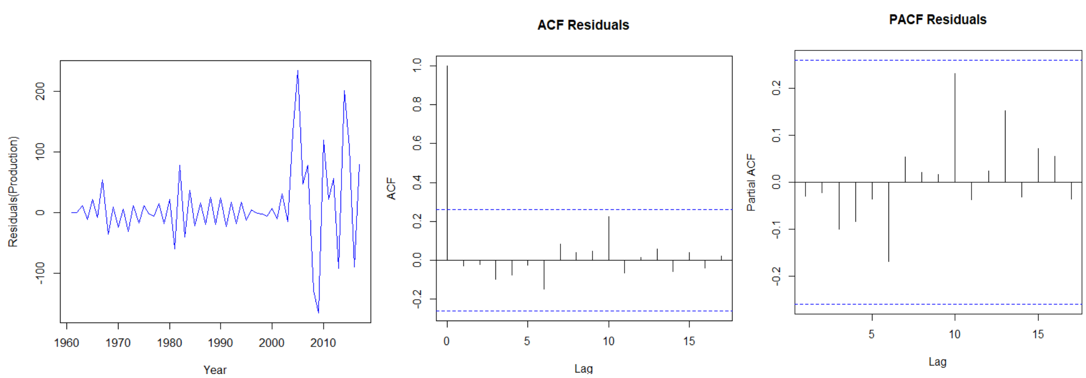

Fig. 11. Residual plots of onion production

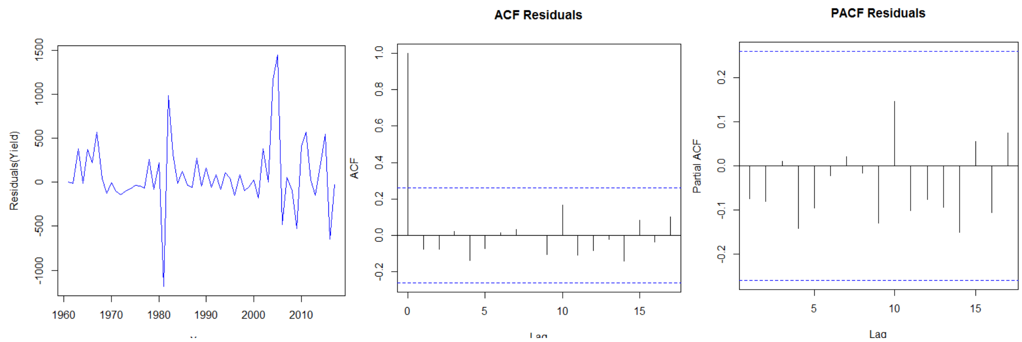

Fig. 12. Residual plots of onion yield

Box-Ljung test is also used to check the autocorrelations in the residuals of the fitted ARIMA models. Table 5 showed that the P value is greater than 0.05 which strongly suggested that there is no autocorrelation among the residuals of the fitted ARIMA (2,2,1) for area, ARIMA (1, 2, 3) for production and ARIMA (0, 2, 1) for yield of onion.

3.4 Forecast Using ARIMA Model

Table 6 indicates the actual and forecasted values for onion area, production and yield along with percentage deviation and Mean Absolute Percentage Error (MAPE). Here, in most cases the predicted values were smaller than the actual values.

Here, in most cases the predicted values were smaller than the actual values. The deviation of the forecasted values of onion area for the years 2014, 2015, 2016 and 2017 were 10.51%, 1.03%, 2.50% and 2.28% respectively. Similarly, the deviation of the forecasted values for onion production were 12.76%, 7.51%, 8.07% and 5.62% for the years 2014, 2015, 2016 and 2017 respectively. Again, the deviation of the forecasted values of yield of onion were 2.08%, 5.37%, 6.24%, and 0.63% respectively in the same consecutive years. Additionally, from the Mean Absolute Percentage Error (MAPE) it has been clear that about 95.32% of onion area, 90.55% of onion production and 95.43% of onion yield are accurately predicted by the fitted models.

Table 5. Ljung-box test of the residuals

Test	Onion	χ-squared Statistic	P value
Ljung-Box	Area	2.65	0.75
Test	Production	0.67	0.95
	Yield	2.23	0.82

Source: Authors' calculation from Food and Agricultural Organization (FAO) Stat Data, 2019

Table 6. Comparison of actual and forecasted values of onion area, production and yield in Bangladesh using the different best fitted ARIMA model

Parameters	Years of prediction	Actual values	Forecasted values	% error in prediction (±)	MAPE in Prediction (%)
Area	2014	150915	135055	10.51	
(Hectare)	2015	169609	167854	1.03	
	2016	177492	181934	-2.50	4.68
	2017	185735	181492	2.28	
Production	2014	1387	1210	12.76	
(000 M	2015	1704	1576	7.51	
tons)	2016	1735	1875	-8.07	9.45
	2017	1867	1762	5.62	
	2014	9190	8999	2.08	
Yield	2015	10049	9509	5.37	
(Kg/Ha)	2016	9777	10387	-6.24	4.57
	2017	10049	10113	-0.63	

Source: Authors' calculation from Food and Agricultural Organization (FAO) Stat Data, 2019

Table 7. Forecasted values of onion area, production and yield in Bangladesh at 95% confidence interval

Year of prediction	Onion area (Hectare)			Onion production (000 M tons)			Onion yield (kg/ha)		
	Forecasted values	LCL	UCL	Forecasted values	LCL	UCL	Forecasted values	LCL	UCL
2018	193932.60	181771.40	206093.80	2073.61	1941.61	2205.61	10343.17	9545.20	11141.14
2019	201969.12	176999.31	226938.96	2220.26	1975.13	2465.38	10637.04	9440.75	11833.34
2020	209912.90	174329.52	245496.38	2375.96	2065.57	2686.34	10930.92	9381.55	12480.28
2021	217852.20	173977.28	261727.25	2538.15	2173.61	2902.69	11224.79	9337.37	13112.21
2022	225821.91	174818.36	276825.56	2705.00	2287.21	3122.80	11518.66	9297.39	13739.93
2023	233814.04	175855.65	291772.39	2875.20	2400.32	3350.08	11812.53	9256.56	14368.51
2024	241810.13	176619.84	307000.40	3047.79	2509.42	3586.15	12106.40	9212.17	15000.64
2025	249800.93	177062.08	322539.98	3222.09	2612.48	3831.71	12400.28	9162.63	15637.92
2026	257786.71	177289.77	338283.67	3397.64	2708.41	4086.86	12694.15	9107.01	16281.28
2027	265770.93	177382.59	354159.23	3574.06	2796.73	4351.39	12988.02	9545.20	11141.14

Source: Authors' calculation from Food and Agricultural Organization (FAO) Stat Data, 2019

Table 7 presents the forecasted value of onion area, production and yield in Bangladesh from 2018 to 2027. From the graph it seems that the area, production and yield of onion are increasing day by day in Bangladesh. In 2008, the area of onion will be 193932.6 hectares and it will be 265770.9 in 2027 hectares. Again, the production and yield of onion will increase from 20173.61thousands metric tons and 10343.17 kg per hectare in 2008 to 3574.06 thousands metric tons and 12988.02 metric tons in 2027 respectively. But the growth of area, production and yield is not so much compared to the growth rate of population.

4. CONCLUSION

A forecasting of onion area, production and yield model were formulated. Based on the forecasting and validation results, the study showed that there will be lesser supply of onion in future compared to domestic demand of onion in Bangladesh. Because, at present the domestic demand for onion is 24 lakh tons that might be doubled after 10 years because of larger population growth. Thus, it needs to increase the yield for meeting the huge demand of onion in the country. To overcome this situation, the onion producers can change its cropping pattern by bringing additional area under onion production. The onion producers can adopt advance methods and technology for accelerating the yield of onion. Government can give subsidy and provide high yielding seeds of onion for the growers. Also government can provide better storage facility for reducing the post-harvest loss and reining the over price hike of onion through syndication of dishonest traders in Bangladesh. Again, the onion production can be increased through efficient use of existing resources. For that, adequate capital needs to invest in research and development related to spices crops in Bangladesh. In this way, the scenario analyses under this study may boost up the productivity and fulfill the domestic demand of onion in near future.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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