J Bangladesh Agril Univ 22(3): **386-395**, 2024 https://doi.org/10.3329/jbau.v22i3.76412

ISSN 1810-3030 (Print) 2408-8684 (Online)

Journal of Bangladesh Agricultural University

Journal home page: http://baures.bau.edu.bd/jbau

Research Article

Evaluation of Trend Models Performance and Forecasting Onion Production: A Comparative Study

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ARTICLE INFO

Article history
Received: 13 June 2024
Accepted: 22 September 2024
Published: 30 September 2024

Keywords
Time series analysis,
Cubic model,
Heatmap,
ARIMA,
Prediction

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ABSTRACT

Onions, a significant spice crop in Bangladesh, frequently experience price surges due to an imbalance between demand and supply, compelling the government to import onions. The volatility of the onion market in Bangladesh and the measures needed to stabilize the situation require intensive policy attention. Therefore, this study was carried out to forecast the onion production over time and to evaluate the efficacy of various trend models. The secondary data was collected from the Food and Agriculture Organization's Statistical Database (FAOSTAT) from 1972 to 2022. The autoregressive integrated moving average (ARIMA) model was used to predict the onion production over time. Additionally, metrics such as modified R^2 and the coefficient of determination (R^2) were used to evaluate the effectiveness of eight trend models comprehensively. The findings indicate that the cubic model is superior to others since it has larger R^2 and adjusted R^2 values. The models' accuracy is also determined utilizing mean absolute percentage error (MAPE) and mean absolute deviation (MAD) metrics. The cubic trend model exhibits lower MAPE and MAD values of 29.43% and 80638.67, respectively. Therefore, it is concluded that the ARIMA (2, 2, 2) model is the best model for forecasting the annual production of onion in Bangladesh. A five-year trend analysis spanning from 2023-2027 indicates an upward trend. Such a result offers a critical insight for stakeholders and policymakers in formulating sustainable onion production strategies.

Introduction

Around the world, people use onions for both food preparation and medical purposes due to their therapeutic properties (Mila and Parvin, 2019). Onion (*Allium cepa* L.) belongs to the *Alliaceae* family and is one of the world's most important spices (Ali et al., 2007). In Bangladesh, onions are a popular spice crop and herbaceous bulb (Bapari et al., 2016; Zafar et al., 2023). Bangladesh's geographical position and meteorological circumstances favor onion cultivation, processing, and marketing (Rahman et al., 2021; Dhatt, 2017). Onion is commercially grown in Bangladesh's major districts, including Faridpur, Rajbari, Manikganj, Jhenaidah, Magura, Meherpur, Madaripur, Shariatpur, Gopalganj, Dinajpur, Pabna, Rajshahi, Kushtia, Jessore, Dhaka, and Rangpur (BBS, 2023). About 507557.05 acres of land in the country is under onion cultivation, and the production is about 2517070.76 M tons (BBS, 2023). The benefit-cost ratio (BCR) for onion is reported as 1.19 (Mila et al., 2022). In addition, the production of onions is considered more profitable than rival spices and functions as a highly commercial, revenue-generating, and employment-generating sector. According to Mila et al. (2022), the Ministry of Agriculture in Bangladesh has documented a yearly demand for onions of around 2.8 million metric tons, denoting a growing need. In 2023, while the demand for onion in Bangladesh was 2.5 million metric tons (MT), domestic production was around 3.4 million metric tons (MT), and onion being highly perishable, around 1 million MT were lost during harvesting and lack of proper storage facilities, resulting only a portion reaching the market which leads to massive demand of onion (Akhter et al., 2023). Bangladesh struggles to fulfill even 15% of its yearly onion demand through domestic cultivation (Hossain et al., 2017). Such a substantial gap creates an imbalance between demand and supply. Therefore, there is a pressing need to

Cite This Article
Jahan, N., Noorunnahar, M. and Parvin, M.T. 2024. Evaluation of Trend Models Performance and Forecasting Onion Production: A Comparative Study. *Journal of Bangladesh Agricultural University,* 22(3):386-395.https://doi.org/10.3329/jbau.v22i3.76412

allocate more resources towards increasing onion production.

Different authors have conducted studies on various crops using time series analysis. Studies have found that multiple models were presented to predict future trends in rice production (Singh et al., 2014). Akhter et al. (2016) analyzed the development and trajectory of essential crops in Bangladesh. Das et al. (2022) compared and contrasted six trend models using tea production data from Bangladesh. Production, yield, and area trends of paddy, wheat, and grams were examined in Chhattisgarh state by Wasnik et al., 2022. Yung and Hu (2013) utilized ARIMA modeling to predict the demand for fresh agricultural products. After looking at onion data from 1971 to 2013, Hossain et al. (2016) found that the ARIMA (0,2,1) model best predicted Bangladesh's onion output.

Despite Bangladesh's significant onion production, there is a considerable gap between demand and supply, and there is a scarcity of literature addressing this topic. Examining trend models and predicting onion output in Bangladesh has received very little attention from researchers. However, there is a significant vacuum in the literature when comparing trend models and evaluating their accuracy in onion production in Bangladesh. Our research aims to fill this gap by investigating several trend models from the most recent research on other crops and employing rigorous statistical diagnostics to ensure their accuracy. Furthermore, while some studies have used the ARIMA model to predict onion production in Bangladesh, current forecast figures are lacking. Our research aims to fill this gap by providing accurate and on-time predictions. Keeping these concerns in mind, the primary goal of this research was to examine and analyze the performance of several trend models to identify the most successful. The government has to prioritize projecting output to address the growing population's nutritional needs while boosting the economy through onion exports. This study investigates current onion production patterns and projects them for the next five years.

Materials and Methods

Secondary datasets were obtained from the Food and Agricultural Organization website (FAOSTAT, 2023), and statistical analysis and visualization of the data were conducted with the help of the R programming language. The dataset covers the production of onions and shallots, dry (excluding dehydrated), in Bangladesh for 51 years from 1972 to 2022. To scrutinize the performance of trend models, maximum R^2, maximum adjusted R^2, mean absolute percentage error, and mean absolute deviation were employed. ARIMA modeling has been utilized to forecast the series under consideration.

Descriptive Statistics

Descriptive statistics were utilized to leverage the understanding of the quantitative summaries of the nature of a dataset.

Trend Models

The eight most studied parametric trend models were selected statistically for this study. Fifty-one years of time series data from 1972 to 2022 were fitted into each model equation. Eight models (logarithmic, inverse, quadratic, cubic, compound, power, s-curve, and growth) were chosen for performance evaluation.

Selection of a Model

To select the better performing model, maximum R^2 (the coefficient of determination, which quantifies the amount of variability in the dependent variable that is explainable by the independent variable) and maximum adjusted R^2 (the revised form of R^2, which provides a more accurate appraisal of model efficiency) were applied (Imon, 2017 and Das et al., 2023).

Model Evaluation

Evaluation metrics were employed to assess the trend models' effectiveness and performance. In the present study, mean absolute deviation (MAD) and mean absolute percentage error (MAPE) have been employed as the accuracy measures of the estimated models (Raza et al., 2015; Imon, 2017; Das et al., 2023). A lower value from MAD and MAPE denotes a better-fitting model (Karim et al., 2010).

Auto-Regressive (AR) Process

$$Y_t = \beta_0 + \beta_1 Y_{t1} + \beta_2 Y_{t2} + \dots \dots \dots + \beta_p Y_{tp} + \varepsilon_t \dots \dots \dots \dots \text{(i)}$$

Where β_0 is a constant, β_1, β_2, …………, β_p are the parameters of the model, and ε_t is white noise.

Moving (MA) Average Process

$$Y_t = \mu + \varepsilon_t + \phi_1 \varepsilon_{t1} + \phi_2 \varepsilon_{t2} + \dots \dots \dots + \phi_q \varepsilon_{tq} \dots \dots \dots \dots \text{(ii)}$$

Where μ is the expectation of Y_t, ε_t is the error term, and Φ_1, Φ_2, ……, Φ_q are representing the parameters of the model.

ARIMA Model

The general form of the ARIMA (p, d, q) model is as follows-

AR: p = order of the autoregressive part

MA: q = order of the moving average part

I: d = order of differencing involved

$$Y_t' = \mu + \beta_1 Y_{t-1} + \beta_1 Y_{t-2} + \dots\dots\dots + \beta_p Y_{t-p} + \varepsilon_t + \Phi_1 \varepsilon_{t-1} + \Phi_2 \varepsilon_{t-2} + \dots\dots\dots + \Phi_q \varepsilon_{t-q} \dots\dots\dots\dots\dots\dots\dots (iii)$$

Here,
Y'_t= different time series
ε_t = error term at time t
μ = constant

Box-Jenkins Modeling and Forecasting

This study used the Box and Jenkins three-phase process known as the Box-Jenkins methodology (Box and Jenkins, 1976) to find the ideal ARIMA model for the data set.

Results

The cumulative area plot depicted the cumulative sum of onion production from 1972 to 2022, indicating upward total production trends and favorable growth rates (Figure 1).

The heat map showed an increasing trend of onion use in Bangladesh over the years. Especially after 2014, there has been a dramatic increase in onion production, and it might be due to the increase in area under onion production and the adaptation of the yielding variety BARI Piaz-5 in farmers' fields, which can be noticed from the map (Figure 2).

In the 5-year interval box plot (Figure 3) depicting an extreme production value between 2000 and 2004 and between 2010 and 2014, the range of production value was maximum, which means a drastic increase in onion production in Bangladesh (Figure 3).

Performance of Trend Models

The analysis aimed to identify the most appropriate trend model for a dataset of onion production over time. It began by examining descriptive statistics and evaluating the performance of eight different trend models based on metrics like R^2, adjusted R^2, and F-statistics. Furthermore, the accuracy of these models was assessed using metrics such as MAPE and MAD. A scatter plot (Figure 4) depicting the relationship between time (in years) and onion production (in tons) reveals a lack of linearity, suggesting that alternative trend models beyond linear can be considered to capture the underlying patterns in the data better.

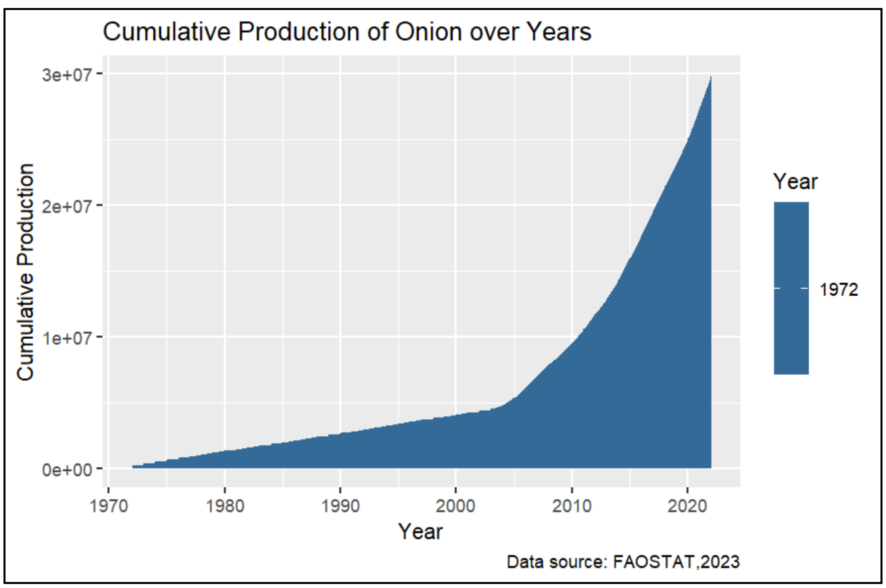


Figure 1. Cumulative production of onion over the years

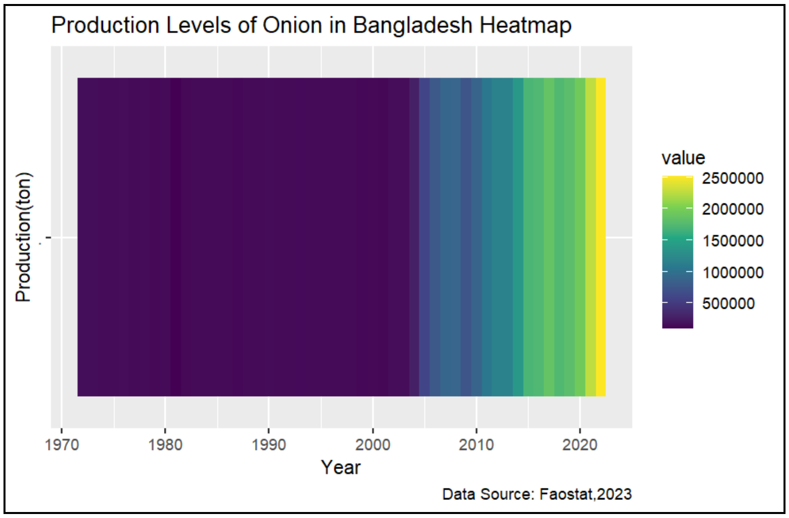


Figure 2. Heatmap of onion production

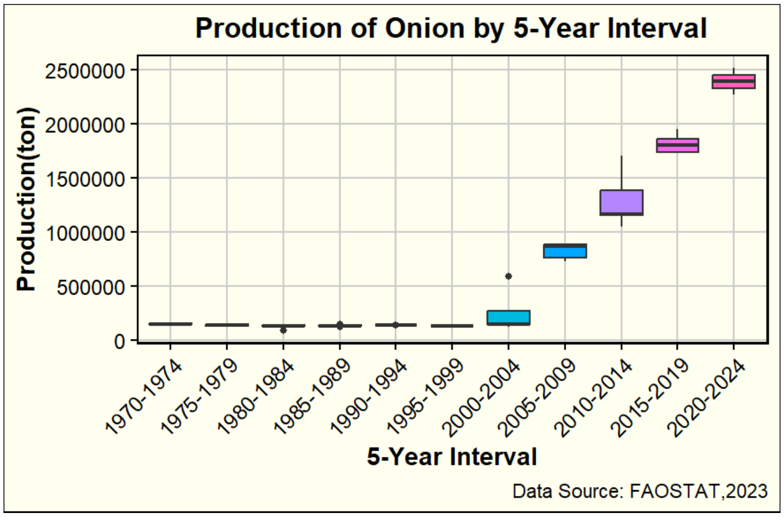


Figure 3. Box-plot of onion production by a 5-year interval

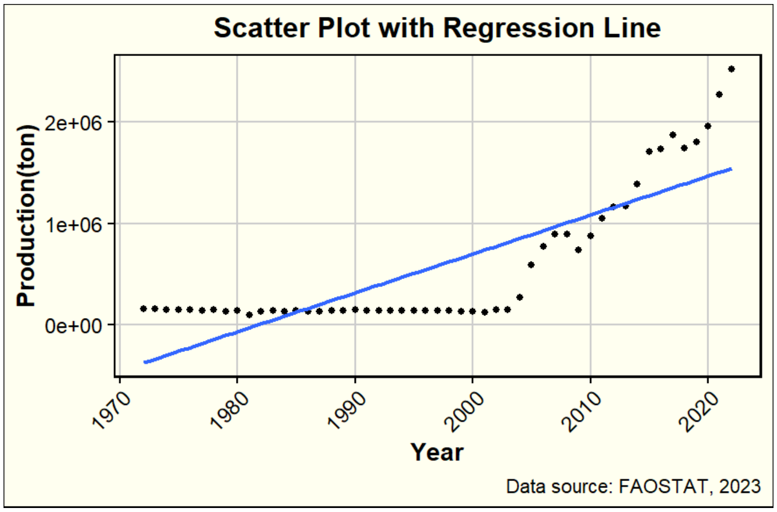


Figure 4. Scatter diagram of onion production with regression line

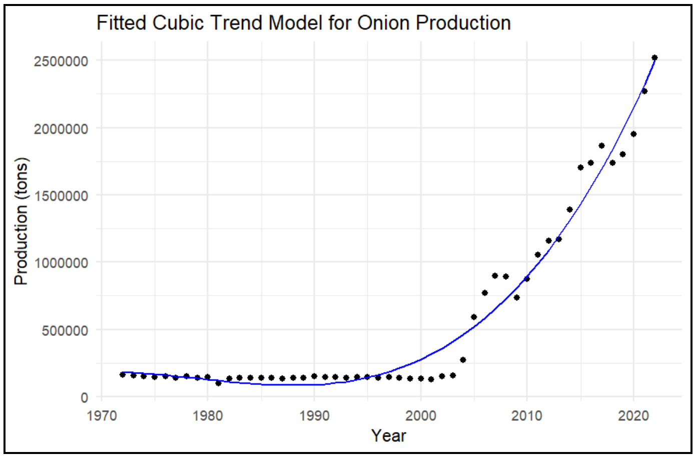


Figure 5. Fitted cubic trend model for Onion Production

Table 1 shows that for all trend models, the F statistic is significant at a 1% significance level except for the growth trend model. Compared to other models, the R^2 and adjusted R^2 values are minimal for the growth model. The R^2 and adjusted R^2 values are the maximum for the cubic model among these eight models. Based on maximum R^2 and maximum adjusted R^2 values, the cubic model is more suitable compared with logarithmic, inverse, quadratic, compound, growth, power, and S-curve models for Bangladesh's onion production data from 1972 to 2022.

Table1. Estimated values for different trend models

Model/ Statistics	**a**	**b_1**	**b_2**	**b_3**	**R^2**	**Adj R^2**	**F**
Logarithmic	-944.84***	125.99***	-	-	0.7335	0.7281	134.9***
Inverse	$3.525e^{-04}$***	$-1.741e^{-07}$***	-	-	0.6959	0.6897	112.1***
Quadratic	$7.311e^{+09}$***	$-7.360e^{+06}$ ***	$1.852e^{+03}$***	-	0.9584	0.9567	553.3***
Cubic	$-2.648e^{+11}$***	$4.015e^{+08}$ ***	$-2.029e^{+05}$ ***	$3.417e^{+01}$ ***	0.9741	0.9724	589***
Compound	$-1.136e^{+02}$ ***	$6.320e^{-02}$ ***	-	-	0.7359	0.730	136.6***
Power	-944.84 ***	125.99 ***	-	-	0.7335	0.7281	134.9***
S	$3.357e^{+06}$ ***	$2.016e^{+03}$ ***	-	-	0.9663725	0.9634483	1321.927***
Growth	$1.042e^{-11}$	$1.000e^{-01}$ **	-	-	$-1.072783e^{+141}$	$-1.117482e^{+141}$	-4.8

Table 2 was used to assess the dependability of the fitted model. To determine the accuracy of the estimated model for the dataset, we find that MAPE is 29.4395% for the cubic model. Among these MAPE values, the MAPE for the cubic model is the lowest. The fitted growth model accounts for the highest MAPE value of $2.33e^{+72}$%. The MAD value is lower for the estimated cubic model. The MAD value is 80638.6, which is accounted for by the fitted cubic model. The fitted growth model has the highest MAD value of $1.39e^{+76}$. Finally, the cubic model that is more suitable for onion data will be obtained based on the MAPE and MAD values of the fitted model. So, the estimated cubic model

$Y_t = -2.648e^{+11} + 4.015e^{+08} t_i - 2.029e^{+05} t_i^{\ 2} + 3.417e^{+01} t_i^{\ 3}$.

Here,

Y_t represents the predicted value of the onion production (dependent variable) at time point t. The coefficients ($-2.648e^{+11}$, $4.015e^{+08}$, $-2.029e^{+05}$, and $3.417e^{+01}$) correspond to the intercept and coefficients of the cubic terms, reflecting how t_i (time), the independent variable, influences Y_t. According to this result, in Bangladesh, the compound growth rate of onion production is 5.39%.

Table 2. Accuracy of fitted models

	Logarithmic	**Inverse**	**Quadratic**	**Cubic**	**Compound**	**Power**	**S**	**Growth**
MAPE	99.994	100	57.943	29.439	99.990	99.990	52.030	$2.33e^{+72}$
MAD	585529.9	585542.5	118103.6	80638.670	585529.9	585529.9	110653.20	$1.39e^{+76}$

Modeling and Forecasting of Onion Production

The data set consists of 51 observations on a yearly basis from 1972 to 2022 of onion production. After fitting the model, five years from 2023 to 2027 have been forecasted and compared with actual data.

Variance Stability

A visual plot of onion production in Bangladesh is plotted in Figure 6. The plot depicted no prominent trend; therefore, data transformation to attain stability in variance is not mandatory.

Stationary Checking

To test stationary, we consider the ACF and PACF (Figure 7) of the production data of onions. Autocorrelation is decaying, and some spikes fall outside the two standard error limits (Figure 7 (a)). It indicated that the data set is non-stationary. To check the stationary, the Ljung-Box test was done. This test shows that the estimated value of p is < 2.2e-16(essentially zero), which is much smaller than typical significance levels of 0.05. Therefore, there is significant evidence to reject the null hypothesis of no autocorrelation, which suggests that autocorrelation is present in the data. As a result, it confirms that the series is non-stationary.

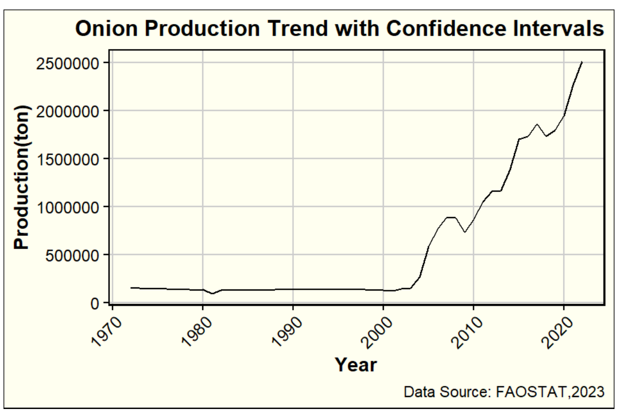
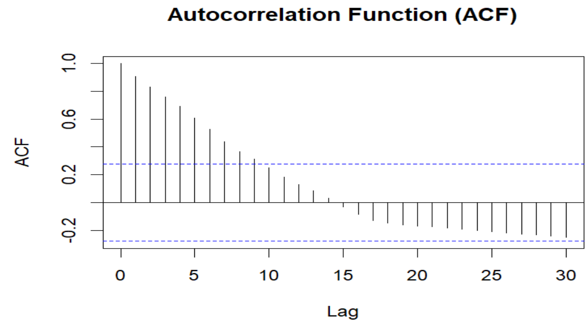


Figure 6. The time plot of onion production.

(a) Autocorrelation function (ACF)



(b) Partial autocorrelation function (PACF)

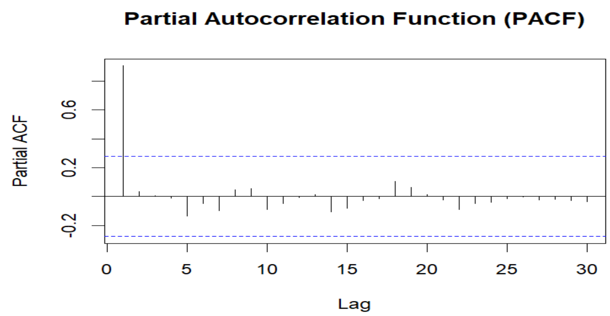


Figure 7. The (a) ACF and (b) PACF of onion production

Model Selection

The function 'auto. Arima' in the R programming language, specifically in the 'forecast' package, was utilized to figure out the best model. For the onion data set, ARIMA (2,2,2) results in the best model with the lowest Akaike information criterion (AIC) value of 1260.47.

Estimation and Diagnostic Checking

The estimated value of the coefficients and the corresponding value of the Z-statistic are presented in Table 3. The P-values of ar1, ar2, ma1, and ma2 are less than 0.05 at the 0.05 significance level. Figure 8 represents the behavior of the residuals left over after fitting the ARIMA (2,2,2) model. The plot of the standardized residuals shows that most of the standardized residuals are within the 95% limits. The plot of the ACF of residuals has been given, and all the spikes are within the 95% limits and near zero. The plot of p-values from the Ljung box test with 5 degrees of freedom shows that residuals remaining after fitting the model are white noise. These diagnostic checks indicate that the model chosen is appropriate, with a minor akaike information criterion (AIC) value and better-behaved residuals.

Table 3. The significance test of the parameters of ARIMA (2,2,2): Onion Production data

Coefficients	Parameters	Standard error	Z-value	P-value
ar1	1.0710	0.1647	6.5027	0.00
ar2	-0.5367	0.1401	-3.8308	0.00
ma1	-1.6564	0.1513	-10.945	0.00
ma2	0.7541	0.1315	5.7340	0.00

Figure 9 compares the actual and fitted values of onion production. Figure 10 shows the actual (1972 -2022) and forecasted (2023-2027) values of onion production. Figures 9 and 10 are intended to visually compare and represent the analysis of onion production trends. Figure 9 compares the actual onion production data with the values predicted by our fitted model, demonstrating the model's effectiveness in capturing historical trends. Figure 10 extends this analysis by presenting historical data (1972-2022) and our forecasts for future onion production (2023-2027), illustrating the projected trends based on our model. The forecasted values of yearly data of onion production from 2023 to 2027 are presented in Table 4.

Table 4. The forecasted value of yearly data of Onion Production from 2023 to 2027

Year	Forecasted Value
2023	2645959
2024	2715338
2025	2785076
2026	2887134
2027	3023617

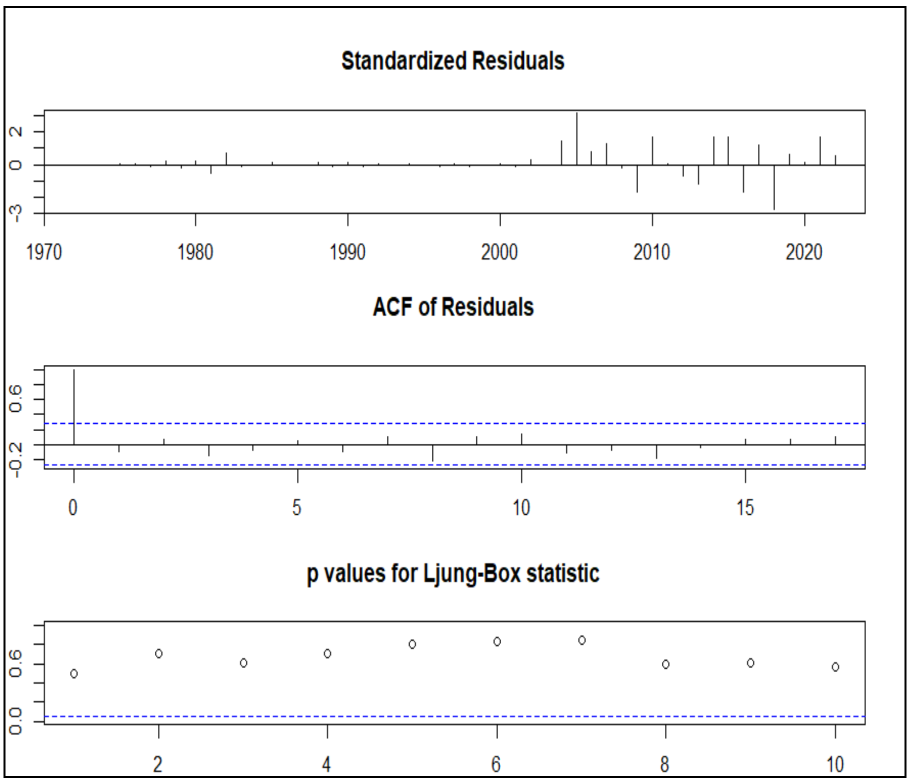


Figure 8. The Diagnostic Checking of ARIMA (2,2,2) Model.

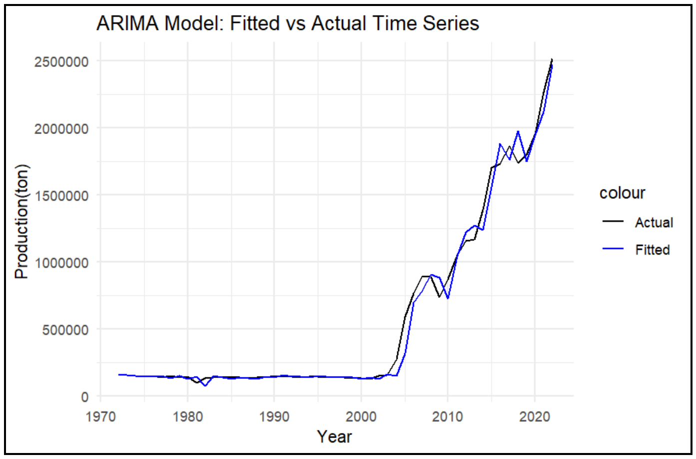


Figure 9. The comparison of Actual and Fitted values of Onion Production

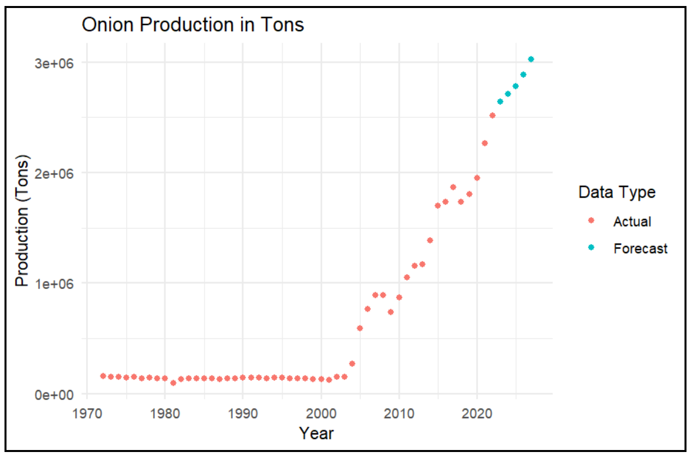


Figure 10. Actual (1972-2022) and forecasted (2023-2027) value of Onion Production

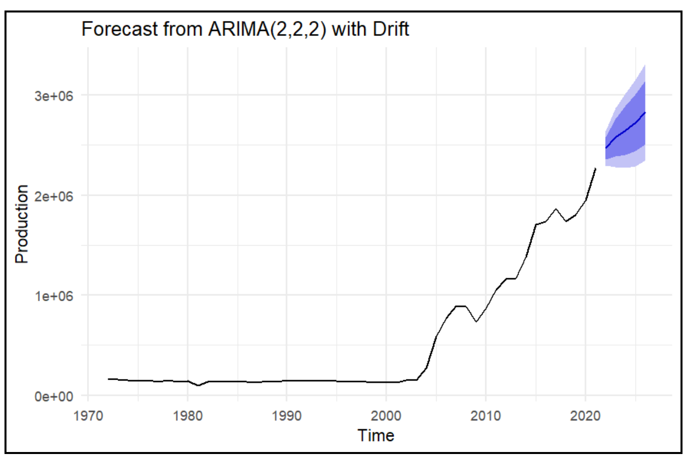


Figure 11. Onion forecasts from ARIMA (2,2,2) with Drift

Figure 11 shows a long-term upward trend in the future in the time series, which denotes a positive drift for the future production value of onion in Bangladesh. A positive drift suggests that the time series value will increase over time, reflecting future expansion and growth of onion production in Bangladesh.

Discussion

This study applied various time series models for analyzing onion production in Bangladesh and attempted to identify a suitable model for precise forecasting. In general, the data visualizations (figure 1, figure 2, and Figure 3) showed that Bangladesh produces more onions day by day. However, Hossain et al. (2016) claimed in their study that despite Bangladesh's growing onion production, the country's overpopulation will prevent it from meeting domestic demand. The cubic trend model emerged as the most effective model in the study. The study evaluates seven trend models to understand their effectiveness in tracking changes in Onion production over time. A similar study was conducted in the recent year, 2022, by Das et al., where six trend models were used to properly check the performance of the trend models for tea production in Bangladesh (Das et al., 2022). On the other hand, Das et al. (2023) suggested that a compound and growth trend model was more appropriate for the ginger data from Bangladesh, while Karmokar and Imon in 2008 showed that the compound trend model was suitable for rice cultivation in Bangladesh. The Cubic model emerges as the most suitable choice based on its low MAPE of 29.43% and MAD value of 80638.67, whereas Das showed in her research that the fitted compound and growth models had lower MAPE and MAD values of 12.14% and 6057.54, respectively, for ginger production in Bangladesh. For our research on forecasting onion output, the most appropriate model is ARIMA (2, 2, 2). However, Amir et al. (2021) recommended using ARIMA (2, 1, 2) with the lowest AIC value for forecasting onion production in Pakistan. A similar time series model, ARIMA, was used by Mishra et al. (2013) and Mila et al., 2022, to predict the area, productivity, and production of onions in Bangladesh and India.

On the other hand, Hossain et al. (2016) found that the ARIMA (0,2,1) model is the most accurate model for predicting onion production in Bangladesh after analyzing onion data from 1971 to 2013 manually. This study utilized an automated approach ('auto.arima' in R), which automatically selects the appropriate model. The variation is mainly due to the length of the time series and structural changes examined for analysis.

Conclusion

Given the escalating demand for spices to cater to diverse culinary requirements and capitalize on their health benefits, a comprehensive examination of onion production assumes significance. In this regard, we used onion production data, compared eight trend models, and discovered that the cubic trend model provides a better-fitted model. The compound growth rate of onion production is 5.39%. Although the growth rate is noticeable, it will not be stable in the coming years due to the shrinking of land and population growth. Therefore, researchers and policymakers should focus on developing onion production technologies from an economic and scientific point of view to meet the increasing demand in this study, forecasting onion production five years ahead done by the ARIMA (2,2,2) model. Validating the model across various periods is imperative, as the validity and suitability of forecasts may diminish over time.

Furthermore, the current growth trajectory of onion production is subject to variability, suggesting an imminent instability. Consequently, there is a pressing need for researchers and policymakers to innovate and devise novel approaches to onion cultivation to meet the burgeoning demand effectively. The findings of this study highlight the need for more investments in infrastructure development, such as cold storage facilities, irrigation systems, and transportation networks, to ensure the growing trend of onion. Capacity-building initiatives such as training programs, access to credit, and extension services should also be made available to the farmers. Additionally, fostering collaboration among government agencies, research organizations, industry stakeholders, and farmers groups may help to withstand potential challenges and promote sustainable growth in Bangladesh's onion production.

Acknowledgments

The authors acknowledge FAOSTAT for the availability of secondary data in this study.

References

Ahmed, A. U., Ahmad, K. 2013. Sudden onion price surge in Bangladesh: A situation analysis for policy. *Securing food for all in Bangladesh*, 375.

Akhter, S., Sarker, J. R., Das, K. R. 2016. Growth and trend in area, production and yield of major crops of Bangladesh. *International Journal of Economics, Finance and Management Sciences*, 4(1): 20-25. (Doi: 10.11648/j.ijefm.20160401.13).

Akter, S., K, T. Rahman., A, R. Anik., M, R. Amin., 2023. Growth and trend analysis of onion production in Bangladesh. *Ann. Bangladesh Agric*, 27(2): 201-210. Doi: 10.3329/aba.v27i2.72547.

Ali, M. K., Alam, M. F., Alam, M. N., Islam, M. S., Khandaker, S. M. 2007. Effect of nitrogen and potassium level on yield and quality of seed production of onion. *Journal of Applied Science Research*, 3(12): 1889-1899.

Amir, M. W., Amin, M., Nazir, H. Z., 2021. Statistical modeling and forecasting for onion production of Pakistan. *Journal of Agricultural Research, 59*(2).

Bapari, M. Y., Chowdhury, M. K. I., Haque, M. E., Al-Mamun, A. 2016. Economic analysis of onion production in Sujanagar and Santhia areas of Pabna, Bangladesh. *International Journal of Humanities and Social Science Invention*, 5(10): 5-12.

BBS. 2023. Year Book of Agricultural Statistics of Bangladesh, Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

Box, G. E. P., Jenkins, G. M., 1976. Time Series Analysis: Forecasting and Control. San Francisco, CA: Holden-Day.

Das, K. R., Jahan, M., Noorunnahar, M., 2023. Performance of trend models of ginger production. *Journal of Bioscience and Agriculture Research*, 30(1): 2508-2512.

Das, K. R., Sultana, N., Karmokar, P. K., Hasan, M. N., 2022. A comparison of trend models for predicting tea production in

Bangladesh. *Nepalese Journal of Statistics*, 6: 51-62. Doi: 10.3126/njs. v6i01.50804.

Dhatt, A. S., 2017. Production technologies for cultivation of onion. *Advances in production technology of commercial vegetable crops. Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Solan*, 42-52.

Food and Agriculture Organization of the United Nations. 2023. FAOSTAT online database. Crops and livestock products (Onion), Concatenated, 1972 to 2022. Rome, Italy: Food and Agricultural Organization. Available at: https://www.fao.org/faostat/en/#data/QCL

Hossain, M. M., Abdulla, F., Parvez, I., 2016. Time series analysis of onion production in Bangladesh. *Innovative Journal of Agricultural Science*, 4(2): 1-10.

Hossain, M. M., Abdulla, F., Parvez, I., 2017. Time series analysis of onion production in Bangladesh. *Innovate Journal of Agricultural Science*, 5(1): 2–6.

Huda, F. A., Islam, M. S., Biswas, H., Islam, M. S., 2008. Impact assessment study on selected spice crops under action plan in Bangladesh. *Progress in Agriculture*, 19(2): 229-241.

Hung, R., Lee, S., 2022. Analyzing the Effectiveness of COVID-19 Mitigation Policies Using ARIMA Forecasting. *Journal of Student Research*, 11(3).

Imon, A. H. M. R. 2017. Introduction to Regression Time Series and Forecasting. Bangladesh: *Nandita Prokash*, 111.

Islam, Q. M. S., Matin, M. A., Hossain, S., 2012. Economic performance of ginger (Zingiber officinale Rose.) cultivation in some selected locations of Bangladesh. *Bangladesh Journal of Agricultural Research*, 37(1): 109-120. Doi: 10.3329/bjar.v37i1.11182.

Karim, R., Awala, A., Akhter, M. 2010. Forecasting of wheat production in Bangladesh. *Bangladesh Journal of Agricultural Research*, 35(1): 17-28. Doi: 10.3329/bjar.v35i1.5863.

Karmokar, P. K., Imon, A. H. M. R., 2008. Trend analysis of the production of rice in Bangladesh. *International Journal of Statistical Sciences*, 8: 103-110.

Mila, F., Noorunnahar, M., Nahar, A., Acharjee, D., Parvin, T., Culas, R., 2022. Modelling and forecasting of tea production, consumption and export in Bangladesh. *Current Applied Science and Technology*, *22*(2), 1-20. https://doi.org/10.55003/cast.2022.02.22.009

Mila, F. A., Parvin, M. T., 2019. Forecasting Area, Production and Yield of Onion in Bangladesh by Using ARIMA Model. Asian Journal of Agricultural Extension, Economics & Sociology, 37(4): 1-12. DOI: 10.9734/AJAEES/2019/v37i430274

Mishra, P., Sarkar, C., Vishwajith, K. P., Dhekale, B. S., Sahu, P. K., 2013. Instability and forecasting using ARIMA model in area, production, and productivity of onion in India. *Journal of Crop and Weed*, 9(2): 96-101.

Noorunnahar, M., Chowdhury, A. H., Mila, F. A., 2023. A tree based eXtreme Gradient Boosting (XGBoost) machine learning model to forecast the annual rice production in Bangladesh. PloS one, 18(3): e0283452. https://doi.org/10.1371/journal.pone.0283452

Rahman, M. A., Mondal, M. S., Huq, H., Mukherjee, N., Rahman, M. R., 2021. Crop Production Patterns and Marketing in Char Areas: Adapting to Hazards and Vulnerability. Living on the Edge: Char Dwellers in Bangladesh, 291-305.

Rashid, M. H. A., Rasel, M., 2018. Morphological characterization of bulb formation for local onion cultivars in Bangladesh. *Journal of the Bangladesh Society for Agricultural Science and Technology,* 15 (1-4): 31-36.

Raza, I., Naheed, S., Anwar M. Z., Masood, M. A., 2015. Trend Analysis of Tea Import in Pakistan. *Global Journal of Researches in Engineering*, 15(3): 8-14.

Singh, D. P., Kumar, D., Paikra, M. S., Kusro, P. S., 2014. Developing statistical models to study the growth rates of paddy crops in different districts of Chhattisgarh. *American International Journal of Research in Formal, Applied & Natural Science*, 5(1): 102-104.

Wasnik, S., Pandey, S., Patel, P., Patel, M., Choudhary, V., 2022. Trends in area, production, and yield of paddy, wheat and gram in Chhattisgarh state: A critical analysis. *The Pharma Innovation Journal*, 11(6): 1397-1402.

Yang, H., Hu, J., 2013. Forecasting of fresh agricultural products demand based on the ARIMA model. *Advance Journal of Food Science and Technology*, 5(7): 855-858. Doi: 10.19026/ajfst.5.3172.

Zafar, S., Aslam, N., Kausar, A., Perveen, S., Riaz, M., 2023. Onion. In Essentials of Medicinal and Aromatic Crops (pp. 431-458). Cham: Springer International Publishing.