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Future Forecasting of Grain Maize Production in Türkiye with ARIMA Model

ARIMA Modeli ile Türkiye'de Dane Mısır Üretiminin Gelecek Tahmini

ABSTRACT

Maize is an important agricultural product in human and animal nutrition. Its importance is increasing day by day due to its use as raw material in agriculture-based an industry and the added value it produces. The strategic importance of maize due to these reasons has led to the expansion of maize production areas and an increase in production amounts in many countries. This study aims to analyze the changes in grain maize production in Türkiye from past to present and to predict future production trends. Maize is a strategic agricultural product due to its importance in human and animal nutrition, industrial uses and economic value. In this study, changes in grain maize production in Türkiye are analyzed using FAO and TurkStat data covering the period 1961-2023. ARIMA model (0,2,1), one of the Box-Jenkins methods, is preferred for future production projections. Analyses were performed with EVIEWS 10.0 software. In time series analysis, non-stationary data were made stationary by differencing methods. Model selection is based on information criteria and statistical significance tests, and the appropriateness of the ARIMA (0,2,1) model is determined. Forecasting results predict that grain maize production in Türkiye will increase by an annual average of 12.6% between 2024 and 2028. The production amount is estimated to reach 10.91 million tonnes in 2028. These findings indicate that the upward trend in maize production will continue. Research findings provide important information in terms of formulating agricultural policies and supporting farmers' production planning. However, it is emphasized that factors such as climate change, agricultural incentives, infrastructure facilities and market conditions should also be taken into account. By focusing on grain maize production in Türkiye, the study aims to fill the gap in the literature and provide basis for future studies.
Keywords: Maize Production, Future Forecast, ARIMA, Türkiye.

ÖZET

Mısır, insan ve hayvan beslenmesinde önemli bir tarımsal üründür. Tarıma dayalı sanayide hammadde olarak kullanılması ve ürettiği katma değer nedeniyle önemi her geçen gün artmaktadır. Bu nedenlerden dolayı mısırın stratejik önemi, birçok ülkede mısır üretim alanlarının genişlemesine ve üretim miktarlarının artmasına neden olmuştur. Bu çalışma, Türkiye'de dane mısır üretiminin geçmişten günümüze değişimini analiz etmeyi ve gelecekteki üretim eğilimlerini tahmin etmeyi amaçlamaktadır. Mısır, insan ve hayvan beslenmesindeki önemi, endüstriyel kullanımları ve ekonomik değeri nedeniyle stratejik bir tarımsal üründür. Bu çalışmada, 1961-2023 dönemini kapsayan FAO ve TÜİK verileri kullanılarak Türkiye'de dane mısır üretimindeki değişimler analiz edilmiştir. Geleceğe yönelik üretim projeksiyonları için Box-Jenkins yöntemlerinden ARIMA modeli (0,2,1) tercih edilmiştir. Analizler EVIEWS 10.0 yazılımı ile gerçekleştirilmiştir. Zaman serisi analizlerinde durağan olmayan veriler fark alma yöntemleri ile durağan hale getirilmiştir. Model seçimi bilgi kriterleri ve istatistiksel anlamlılık testlerine dayandırılmış ve ARIMA (0,2,1) modelinin uygunluğu belirlenmiştir. Tahmin sonuçları, Türkiye'de dane mısır üretiminin 2024-2028 yılları arasında yıllık ortalama %12.6 oranında artacağını öngörmektedir. Üretim miktarının 2028 yılında 10.91 milyon tona ulaşacağı tahmin edilmektedir. Bu bulgular, mısır üretimindeki artış eğiliminin devam edeceğini göstermektedir. Araştırma bulguları, tarım politikalarının oluşturulması ve çiftçilerin üretim planlamasının desteklenmesi açısından önemli bilgiler sağlamaktadır. Ancak iklim değişikliği, tarımsal teşvikler, altyapı olanakları ve piyasa koşulları gibi faktörlerin de dikkate alınması gerektiği vurgulanıyor. Çalışma, Türkiye'de dane mısır üretimine odaklanarak literatürdeki boşluğu doldurmayı ve gelecekteki çalışmalar için temel oluşturmayı amaçlamaktadır.
Anahtar Kelimeler: Mısır Üretimi, Gelecek Tahmini, ARIMA, Türkiye.

1. INTRODUCTION

Maize is one of the main sources of nutrition for the food sector, as well as an important raw material for industry and feed industry. Due to its versatile use and the economic value it creates, maize is one of the strategic products in the agricultural sector and plays an influential role in shaping global agricultural policies (Gözel, 2024; Tipi & Erdal, 2021).

Maize is an important plant that has been cultivated for thousands of years in the history of humanity. It is known to have originated in the Americas and is thought to have spread from there to different regions. In archaeological excavations, 5,000 to 7,000-year-old remains of sweet corn and ear fragments have been identified in the U.S. state of New Mexico. These discoveries reveal that maize has a history dating back to some 8,000 to 10,000 years ago. In the early 16th century, maize was transported by Portuguese sailors to the west coast of Africa, India and China, from where it spread throughout Asia. It is estimated that it probably reached Turkey via North Africa. The name 'maize' is thought to be associated with the fact that it was brought to Anatolia via Egypt and Syria (Babaoğlu, 2024).

The maize plant has an important place in human and animal nutrition worldwide thanks to its high yield and wide range of uses. Today, about 11% of people's daily caloric intake is derived from maize and maize products. Especially in Mexico and South American countries, maize is consumed intensively. It is seen that 73% of the maize cultivated in the world is used in animal nutrition and 27% in human consumption (Paksoy & Ortasöz, 2018).

Risks and uncertainties arising from the structural problems of the agricultural sector make it difficult for producers to plan long-term production. These uncertainties complicate the sustainability of agricultural production and negatively affect the decision-making processes of producers. However, analyzing the future production trends of agricultural products plays an important role in determining which crops should be prioritized by guiding producers to make more accurate decisions (Khalili, 2023).

In this study, the statistics on grain maize production in Türkiye were analyzed comparatively and it was aimed to forecast the future trend of grain maize production in Türkiye based on these data. At the same time, the research findings are aimed to contribute to the production planning processes of farmers.

2. MATERIAL AND METHOD

2.1. Material

In this study, the changes in the amount of grain maize production in Türkiye have been analyzed from past to present. The production data used in the study were evaluated in the analysis to determine the future trends of grain maize production. In the analysis, 63 years of production data covering the years 1961-2023 were used. These data were obtained from FAO and TurkStat databases. National and international reports and literature sources were utilized to evaluate the developments in maize production.

2.2. Method

Basic statistical methods such as ratio, index and comparison were used to evaluate the statistics on maize production. ARIMA model, one of the Box-Jenkins methods (Makridakis & Hibon, 1997; Naylor et al., 1972), was applied to predict the course of grain maize production in Türkiye for the next five years (2024-2028). ARIMA (0,2,1) model was preferred for forecasting the production amount and the analysis of the model was carried out using EVIEWS 10.0 software.

Agricultural production is a dynamic process that is shaped by climatic conditions and includes many variables such as trends and seasonal fluctuations. In order to achieve reliable and accurate results, it is critical to take these factors into account and select the appropriate model in the analysis. In this respect, it is important to make agricultural data stationary by removing deviations that may adversely affect the results of the analysis.

The estimation process consists of 3 main stages. In the first stage, the stationarity of the time series of maize production is tested and stationarity is ensured by using the differencing method. In the second stage, the appropriate ARIMA forecasting model is determined for the analysis. In the third stage, the coherency of the selected model is evaluated by analyzing the error distributions of the time series and future forecasts are made (Makridakis & Hibon, 1997; Naylor et al., 1972; Tipi & Erdal, 2021).

2.2.1. Stationarity Analysis

Stationarity is the condition where observations in a time series around a constant mean and variance remain stable over time. Usually time series are non-stationary because they contain trends or seasonal fluctuations. Therefore, in order to obtain accurate and reliable analysis results, it is of great importance to make time series stationary. Moreover, ensuring stationarity plays a critical role in preventing spurious regression problems. One of the most important indicators that a time series is stationary is the absence of a unit root (Bawdekar et al., 2022; Shen & Wirjanto, 2019).

The Augmented Dickey-Fuller (ADF) unit root test developed by Dickey and Fuller in 1979 and the Phillips-Perron (PP) unit root test developed by Phillips and Perron in 1988 were used to test the stationarity of time series (Çağlayan & Saçaklı, 2006; Dickey & Fuller, 1979).

These tests aim to determine whether there is a unit root in time series. In ADF and PP tests, according to the null hypothesis, the hypothesis H_0 is rejected if the test statistic is greater than the specified critical value. This implies that the time series does not contain a unit root and is stationary. On the other hand, if the test statistic is less than the critical value, H_0 is accepted and the H_1 is rejected, which implies that the time series contains a unit root and is non-stationary (Khalili et al., 2024; Makridakis & Hibon, 1997; Naylor et al., 1972).

2.2.2. Box Jenkins Method (ARIMA)

The ARIMA (Autoregressive Integrated Moving Average) model, also known as the Box-Jenkins method, is a powerful and effective model widely used in the forecasting of univariate time series. This model provides an understanding and forecasting of the behavior of time series by analyzing trends, seasonal effects and other dynamic elements in the series. By taking into account the effects of the values of past periods on the current period and the distributions of error terms in previous periods, ARIMA enables the prediction of future values (Caner & Engindeniz, 2020; Khalili, 2023; Ulaş, 2023).

The ARIMA (p,d,q) model consists of autoregressive (AR), integrated (I) and moving average (MA) components. While the (AR) component generates estimations based on observations from previous periods, the (I) component ensures that the series is stationary to correct for trend and seasonality effects, and the (MA) component improves the accuracy of the model by taking into account the effects of previous forecast errors. The combined use of these components enables the ARIMA model to make coherent and reliable estimations (Hyndman & Athanasopoulos, 2018; Palabıçak & Binici, 2023; Shumway & Stoffer, 2017). The general mathematical representation of the ARIMA model can be written as follows;

$$x_t = \theta_0 + \phi_1 x_{t-1} + \cdots + \phi_p x_{t-p} + \varepsilon_t - \theta_1 \varepsilon_{t-1} - \cdots - \theta_q \varepsilon_{t-q} \quad (1)$$

Right here;

x_t	: Estimated time series value,
θ_0	: Constant term,
ε_t	: Error term,
$\phi_{1,} \dots \phi_p$	: Autoregressive (AR) parameters,
$\phi_{1,} \dots \phi_q$	: Moving average (MA) parameters,
$x_{t-1,} \dots x_{t-p}$	: Lagged time series values
$\varepsilon_{t-1,} \dots \varepsilon_{t-q}$	: Lagged error terms

Stationarized time series are analyzed in two main stages. The first stage involves determining the most appropriate forecasting model and the second stage involves testing the reliability of the selected ARIMA model. These processes are explained step by step below.

Primarily, in determining the forecasting model, the model with the highest Log Likelihood (LogL) value and the lowest Hannan-Quinn Information Criterion (HQ), Akaike Information Criterion (AIC) and Schwarz Information Criterion (BIC) values is accepted as the most appropriate forecasting model (Burnham & Anderson, 2004; Ma et al., 2018).

In addition to these criteria, parameters such as the explanatory power (R^2) and statistical significance levels (F and t statistics) of the obtained ARIMA models are also taken into account. Furthermore, the Mean Absolute Percentage Error (MAPE) value should be taken into account to evaluate the forecasting performance of the preferred ARIMA model. If the MAPE value is greater than 50%, it indicates that the forecast results are not reliable; if it is in the range of 20-50%, the forecast is at an acceptable level; if it is in the range of 10-20%, it is considered a good forecast; and if it is below 10%, it indicates that the forecast is quite accurate and precise (Caner & Engindeniz, 2020; Chen et al., 2009; de Myttenaere et al., 2016; Palabıçak & Binici, 2023).

3. RESEARCH FINDINGS AND DISCUSSION

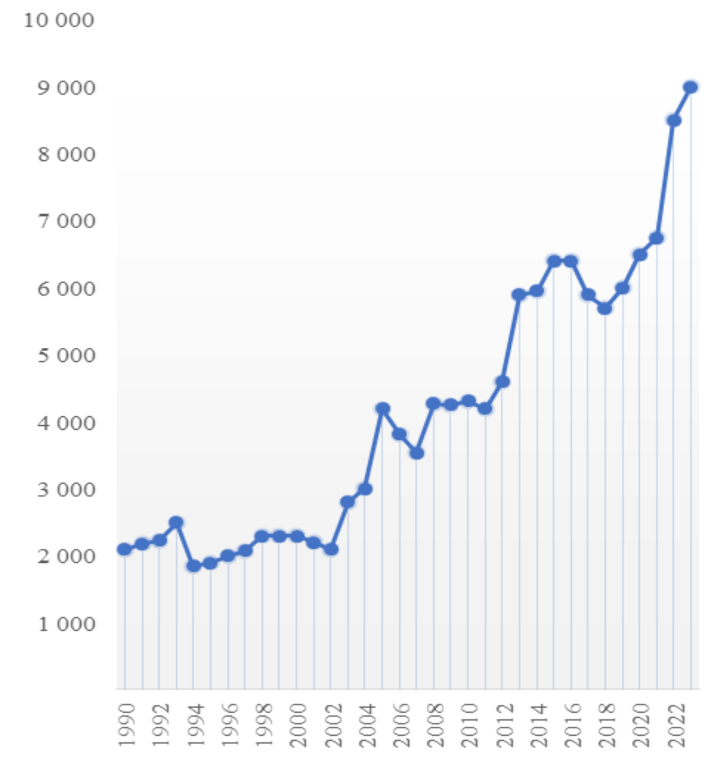
3.1. Maize Production in Türkiye

In 1990, 2.1 million tonnes of grain maize was produced in Türkiye. In this period, production increased slightly until the 2000s. In the 2001-2005 period, the annual average production amount reached 2.86 million tonnes, a significant increase compared to previous years. In 2006-2010, production amount reached 4.03 million tonnes, an increase of 92% compared to 1990. In 2011, production increased to 4.2 million tonnes, doubling compared to 1990. Between 2013 and 2016, production was in the range of 5.9-6.4 million tonnes, with a significant increase of 180-204%. Although some fluctuations in production were observed in 2017-2019, production regained an acceleration from 2020 onwards. 8.5 million tonnes in 2022 and 9 million tonnes in 2023, reaching an increased rate of more than 305%. In general, when the 1990-2023 period is analyzed, grain maize production in Türkiye has increased 4.5 times and the increase has accelerated especially since the 2000s (Table 1.).

Tablo 1. Changes in Türkiye's grain maize production (FAOSTAT, 2025; TÜİK, 2024)

Year	Production Amount (tons)	Change (base year 1990)
1990-1995	* 2 125 833	1.23%
1996-2000	* 2 195 400	4.54%
2001-2005	* 2 860 000	36.19%
2006-2010	* 4 036 000	92.19%
2011	4 200 000	100.00%
2012	4 600 000	119.05%
2013	5 900 000	180.95%
2014	5 950 000	183.33%
2015	6 400 000	204.76%
2016	6 400 000	204.76%
2017	5 900 000	180.95%
2018	5 700 000	171.43%
2019	6 000 000	185.71%
2020	6 500 000	209.52%
2021	6 750 000	221.43%
2022	8 500 000	304.76%
2023	9 000 000	328.57%

Changes in Türkiye's maize production (x1000 Ton)



Note: (*) 5-year average production amount

3.2. Forecasting the Future Outlook for Maize Production in Türkiye

In forecasting the future course of maize production in Turkey with the ARIMA model, three basic steps were followed as stated in the methods section of the study. In addition, 95% confidence interval was taken as a basis in the analysis processes and the significance level indicated in the hypotheses refers to a 5% margin of error.

3.2.1. Stationarity Test and Stationarization of the Series

The stationarity of the time series of maize production was analyzed at the basic level and both ADF and PP unit root tests revealed that the series contains a unit root. This indicates that the series is non-stationary. In order to stationarize the series, first order differencing, in other words, the reduction method was applied, and after differencing, in both ADF and PP unit root tests were determined that the series was free from unit root and became stationary (Table 2.).

Table 2. Stationarity Analysis of Time Series

ADF Unit Root Test					
At Level			**At First Difference**		
	t-Statistic	**Prob.**		**t-Statistic**	**Prob.**
With Constant	2.3532	**1.0000**	With Constant	-6.9472	**0.0000***
With Constant & Trend	0.0043	**0.9955**	With Constant & Trend	-7.5719	**0.0000***
Without Constant & Trend	3.6051	**0.9999**	Without Constant & Trend	-6.3118	**0.0000***
PP Unit Root Test					
At Level			**At First Difference**		
	t-Statistic	**Prob.**		**t-Statistic**	**Prob.**
With Constant	2.9842	**1.0000**	With Constant	-6.9476	**0.0000***
With Constant & Trend	0.1003	**0.9967**	With Constant & Trend	-7.5700	**0.0000***
Without Constant & Trend	3.8688	**0.9999**	Without Constant & Trend	-6.3864	**0.0000***

Note: (*) Significant at the 1%

3.2.2. Determination of the Forecasting Model

The results of 20 different ARIMA models were compared using the automatic model selection option of Eviews software. In this analysis, the ARIMA (0.2.1) model was found to have the highest LogL value and the lowest AIC, BIC and HQ values (Figure 1.). When the outputs of the ARIMA (0.2.1) model are analyzed, it is observed that the F-statistic and t-statistic values are lower than the significance level. This reveals that the model is statistically significant. The R^2 value of the model is 48.57% and the adjusted R^2 value is 47.70%. Moreover, the fact that the Durbin-Watson (DW) statistic is higher than the R^2 value ($DW > R^2$) increases the reliability of the model by eliminating the possibility of spurious regression. In light of these findings, ARIMA (0.2.1) is considered to be the most appropriate model to forecast the future trend of maize production in Türkiye (Table 3.).

Figure 1. The Best 20 Models According to Schwarz Criterion

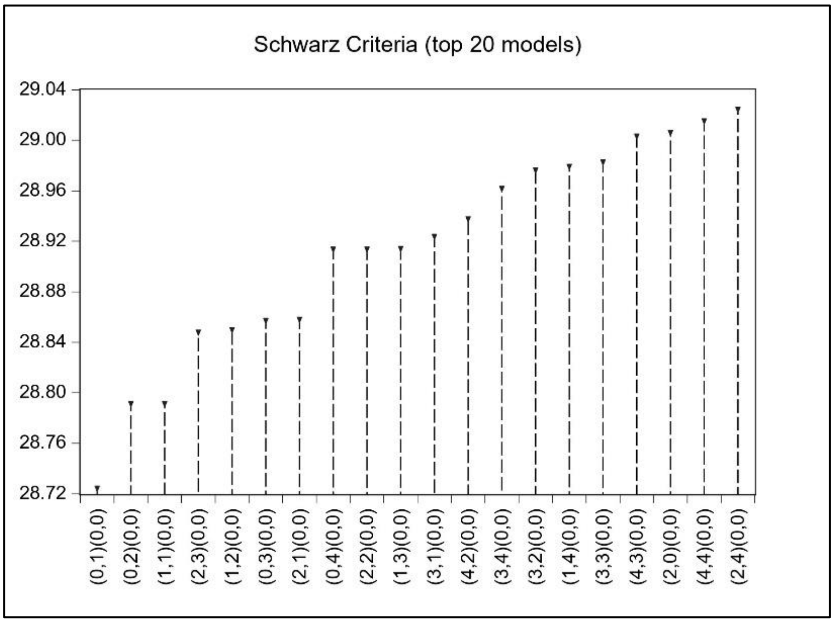


Table 3. Results for The ARIMA (0.2.1) Model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	7080.700	2851.525	2.483127	0.0159
MA(1)	-0.980443	0.020315	-48.26097	**0.0000 ***
R-squared	0**.485719**	Mean dependent var		11754.10
Adusted R-squared	0**.477003**	S.D. Dependent var		518700.9
S.E. Of regrssion	375117.0	Akaike info criterion		**28.54010**
Sum squared resid	8.30E+12	Schwarz criterion		**28.60931**
Log likelihood	**-868.4731**	Hannan-Quinn criterion		**28.56722**
F-statistic	55.72333	Durbin-Watson stat		**1.963449**
Prob(F-statistic)	**0.00000***			

Note: (*) Significant at the 1%

3.2.3. Model Performance Test and Forecasting Results

In determining the coherency of the ARIMA model selected for forecasting, the fact that the errors of the forecast results show a normal distribution indicates that the model can produce accurate and reliable results. For this reason, the error distribution of the ARIMA (0.2.1) model was analyzed by 2 different methods. The correlogram graph in Figure 2 shows that the autocorrelation (AC) and partial autocorrelation (PAC) values decrease over time and approach zero. Furthermore, the prob. value in the histogram of the distribution of errors is smaller than the significance level ($p<0.05$), indicating that the model errors are normally distributed (Figure 3.).

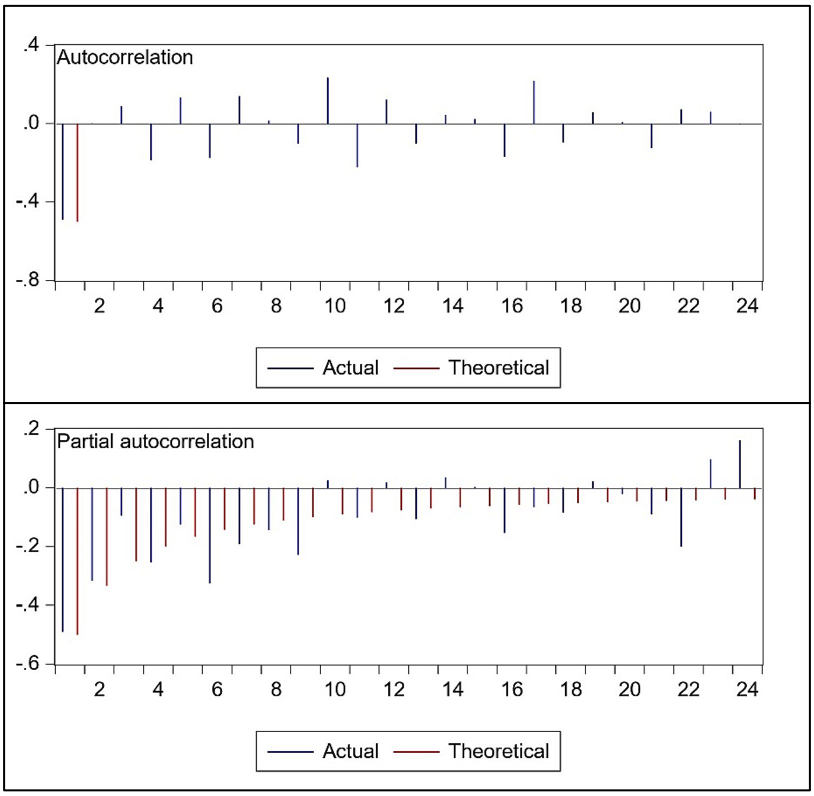


Figure 2. Correlogram Graph of Errors Related to Forecasting Results

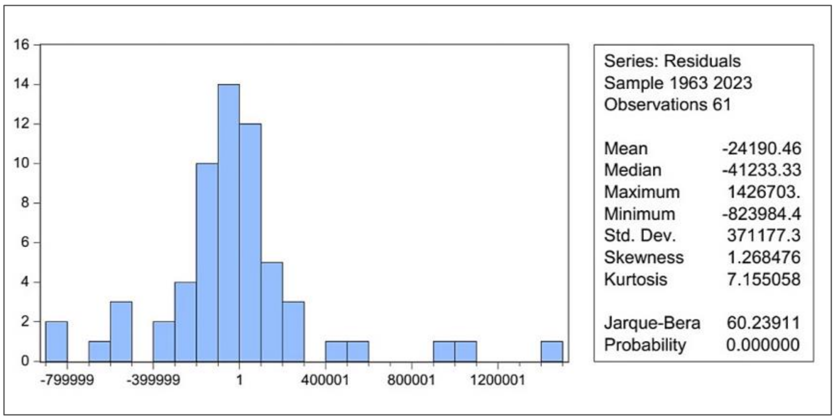


Figure 3. Normal Distribution Graph of Errors for Forecasting Results

Another method used to evaluate the forecast performance is to examine the MAPE (Mean Absolute Percentage Error) value. In the analysis, the MAPE value of the model was calculated as 43%. This result indicates that the model's predictions are at a certain level of accuracy and that it performs acceptably (Figure 4).

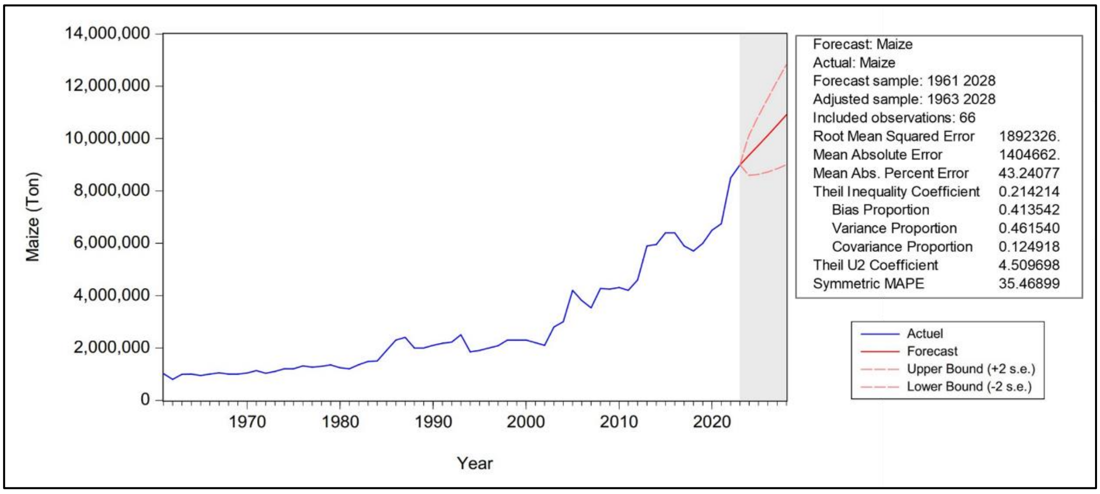


Figure 4. ARIMA (0.2.1) Model Performance Results

According to forecasts based on the ARIMA (0.2.1) model, grain maize production is expected to reach 9.36 million tonnes in 2024, up 4.09% from the previous year. In addition, a gradual increase in production is predicted between 2024 and 2028. Grain maize production is expected to increase by 12.6% on average over the next 5 years. In 2028, it is estimated to reach 10.91 million tonnes with an increase of 21.24% compared to the production amount in 2023 (Table 4).

Table 4. Forecast Results of Grain Maize Production in Türkiye

Year	Upper Bound (+2 s.e.)	Forecast (Tonnes)	Lower Bound (-2 s.e.)
2024	10 132 722	9 368 133	8 603 543
2025	10 856 037	9 743 346	8 630 655
2026	11 527 701	10 125 640	8 723 580
2027	12 180 305	10 515 015	8 849 726
2028	12 826 161	10 911 471	8 996 780

Overall, grain maize production in Türkiye has grown significantly in the past years and is expected to continue to increase in the future Celik (2016), in his study analyzing the future trends of cereal production in Türkiye, predicted that maize production will continue to increase. Similarly Nalici et al. (2024), estimated an increase in the production of barley, wheat, maize, and oats, and a decrease in the production of paddy, millet, rye, and kavılca wheat between 2023 and 2030. These increases in cereal production are considered as the effect of support policies. It was also reported that this increase in production strengthened agricultural sustainability and national food security, and facilitated consumers' access to affordable and quality products.

The findings of these studies support the consistency of the conducted study. However, independent studies on forecasting the future outlook of grain maize production were seen to be limited. In general, it has been considered under the cereals product group. In this context, this study is unique in that it focuses specifically on grain maize.

4. CONCLUSIONS AND RECOMMENDATIONS

Grain maize production in Türkiye, which was 2.1 million tonnes in 1990, increased slowly until the 2000s. In 2006-2010, the average production increased by 92% to 4.03 million tonnes. This increase reached 6.4 million tonnes in 2013-2016. By 2023, production reached 9 million tonnes. In the last 30 years, Türkiye's grain maize production has grown approximately 4.5 times in the last 30 years and production has gained acceleration, especially in the post-2000 period.

The forecasts indicate that grain maize production in Türkiye will continue to increase in the coming years. An average increase of 12.6% is expected between 2024 and 2028. By the end of 2028, production is estimated to reach 10.91 million tonnes. These projections indicate that Türkiye's strategic importance in maize production will continue in the future.

The forecasts made in this study provide valuable information for farmers' production planning and agricultural policies. However, in order to increase the accuracy of the study, it is important to develop new models and consider other factors such as infrastructure, marketing opportunities, education, climate change, incentives and subsidies.

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