Forecasting Wheat Production in Iraq for the Period (2025–2034): Using the (ARMA) Model

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Abstract

"The wheat crop belongs to the Poaceae family and is a member of the grass family. Its scientific name is Triticum aestivum.", historical output shows substantial fluctuations between 854,000 tons in 2008 and 5,234,000 tons in 2024 over 1990 to 2024. The volatility is primarily attributed to climate variation, water shortages, and inconsistent policies.

This paper applies the Box-Jenkins methodology of the Autoregressive Moving Average (ARMA) model to forecast wheat production from 2025 to 2034. Testing for unit roots by ADF and PP tests revealed that the series was trend-stationary; the ADF statistic was −3.944 with a p value of 0.0208. Model selection criteria comprising AIC at a value of 30.203, BIC at a value of 30.337, and HQ at a value of 30.249 showed ARMA(1,0) as an optimum choice.

The model comes out statistically significant at F =19.337 with p <0.001; R2 =0.547; Durbin-Watson statistic =2 .092 indicating no problem due to autocorrelation. Projections revealed relative stability at an average annual total practically much less than possible domestic consumption needs. Much less than projected. Metrics of forecast accuracy (RMSE = 1,059,232; MAPE = 43.88%; Theil's U = 0.209) indicate the level of difficulty associated with predicting output when it can be influenced by external shocks.

This study concludes that a statistically robust forecasting framework can be achieved through the use of the ARMA model but integrated policies on water management, climate adaptation, and technological adoption are necessary to fill up the production- domestic consumption needs gap in achieving self-sufficiency.

Keywords: wheat production; forecasting; ARMA model; time series analysis; food security; Iraq

1.Introduction

Wheat (Triticum aestivum L.) is critically important crop for ensuring food security in Iraq, and households obtain more than 45 percent of their average calories from wheat. [1] . Being a winter cereal, wheat is significantly affected by water scarcity or if the temperature is different in important times that it grows[2].Farming wheat is finding more problems lately because there are climate changes, transboundary water conflicts and outdated irrigation infrastructure persists. If you look into what happened in past, the production of wheat in Iraq went up and down from year to year: From 1990 up to 2024, a normal yearly production was 2,402,575 tons, but there were big changes, like one year in 2008 where there was only 854,000 tons because of bad drought, and in 2024 it reached about 5,234,000 tons when the rainfall was good, and the government helped [3]

This way of changing so much makes the self-sufficiency of Iraq not stable, where at sometimes it can be 24.6 percent in times of trouble and it goes up to 99.7 in really good years [4]. Even though Iraq produced 5.23 million tons in 2024,the country still imported around 9.18 million tons, making that about 63.5 percent of what the overall use is.

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The economy can get exposed from such scenario, especially so price changes in world and any problems in supply moving [5]. It shows that there is big need for creating prediction tools that have strong proof that can help decision makers with developing plans for grain stocks and for agricultural policies.

Using time series prediction like ARMA models is effective statistical way for studying how agricultural production data changes with time [6]. Instead of models that take many external factors, ARMA depends only on old data patterns for forecasting in short term and middle term. This also becomes helpful when the data is not much available and this is seen many times in developing nations[7].Recent studies using ARMA in agriculture have proved that ARMA can explain changing ways of main crop production in farming and different climates.[8],[9]

This study is handling some gaps found in farming ways of Iraq by doing following: Firstly, by using full Box-Jenkins process for choosing an optimum ARMA model for wheat prediction; next, giving predictions for coming ten years from 2025 until 2034 to help make planning easier for food security; and also reviewing the predictions' correctness using some typical statistical approaches to make boundaries for how reliable the policies from these forecasts could be.So, the results give people in charge method based on data to estimate shortages, improve import periods and prepare exact steps for increasing ability to make wheat locally.

2.Materials and Data Collection Methods

Data on wheat production in Iraq for the period (1990-2024) were obtained from the Ministry of Planning / Central Statistical Organization for Agricultural Statistics (2024)[3], and the Food and Agriculture Organization (FAO)[11].

Box-Jenkins Method for Forecasting

The Box-Jenkins method for forecasting includes tests to detect the stationarity of the time series, including:[6]

- Stability test
- Unit root test to assess the stability of the time series:[10]
- The Augmented Dickey-Fuller (ADF) test compared at significance levels of 1%, 5%, and 10%. [10].
- Phillips-Perron (PP) test to address the issue of autocorrelation and heteroscedasticity in the residuals.

The tests were conducted with three specifications:

• With the constant
• With a constant and a linear direction
• Without a constant and linear trend

Where the first difference was applied when necessary to achieve stability in the time series

The forecasting framework followed the four-stage Box-Jenkins approach [6]:

Model specification[10]

The specifications of the (ARMA) model were determined using the autocorrelation function (ACF) and the partial autocorrelation function (PACF), with a confidence interval of (95%). ($\pm 1.96/\sqrt{n}$) guided the selection of the initial model[12].

Estimation of parameters

- The model parameters were estimated using the Broyden-Fletcher-Goldfarb-Shanno (BFGS) method thru Maximum Likelihood Estimation (MLE).
- The results indicate that all parameters are statistically significant ($p < 0.05$), confirming the success of the estimation process.
- Using Eviews 12 software [13]

Verification of model efficiency

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The model's efficiency was verified using the tests: [14]

Model residual tests

Durbin-Watson value (2.092) explains the absence of first-degree autocorrelation as a value close to 2.0 is ideal.

Ljung-Box $p > 0.05$ explains that the residuals follow "white noise" behavior, indicating the adequacy of the model.

Jarque-Bera $p > 0.05$ explains that the residuals are normally distributed and supports the assumptions of classical regression

Fit quality indicators

R^2 with a value of 54.7% explains 0.547 of the total variance in wheat production.

The adjusted R^2 value of 0.519 explains the simplicity of the model.

The F-test 19.337 ($p < 0.001$) indicates that the model as a whole is statistically significant.

Model selection criteria

The AIC criterion with a value of 30.203 is the lowest and best among the other models.

The BIC criterion with a value of (30.337) reduces complex models.

The HQ criterion (30.249) balances accuracy and complexity.

Measuring and evaluating forecasts during the period (2025-2034)

To measure and evaluate the accuracy of the forecasts during the period (2025-2034) using [15]:

- Theil's U measure with a value of (0.209) indicates a good value and acceptable performance.
- The RMSE measure with a value of (1059232) explains that the error value is high due to previous fluctuations in wheat production.
- The MAPE measure is (43.88%), which explains the presence of a relative error due to external shocks (climatic fluctuations, policies).
- Bias measure with a value of (0.0009), indicating no bias. All analyzes were conducted using EViews 12 [13]. At a significance level of $\alpha = 0.05$.

Results Stability analysis:

The results of the Augmented Dickey-Fuller (ADF) test showed Stability analysis ADF tests showed non-stationarity at the level under the constant specification only (test statistic = −1.519, p = 0.512) and the no constant specification (test statistic = 0.113, p = 0.712). However, with the constant and linear trend, the series achieved stability (test statistic = −3.944 < critical value −3.548 at the 5% level; p = 0.0208) (Table 1).

The results of the PP test confirmed these findings, affirming the trend stability without differences, which is a prerequisite for ARMA modeling

Table 1. Augmented Dickey-Fuller unit root test results for wheat production series (1990–2024)

Test specification	Test statistic	Critical values			p-value	Conclusion
		1%	5%	10%		
Constant only	−1.519	−3.639	−2.951	−2.614	0.512	Non-stationary
Constant + linear trend	−3.944	−4.253	−3.548	−3.207	0.021	Stationary
No constant/trend	0.113	−2.635	−1.951	−1.611	0.712	Non-stationary

Source: Compiled by the researcher using EViews 12 output.

Model Identification and Selection

ACF exhibited gradual exponential decay while PACF showed significant spike only at lag 1 (φ_1 = 0.663, ,(0.001 > p suggesting AR(1) process dominance. Candidate models ARMA(p,q) with p,q ≤ 2 were estimated and compared using information criteria (Table 2).

Table 2. Model selection criteria for candidate ARMA specifications

Model	Log-likelihood	AIC	BIC	HQ	R²
ARMA(0,0)	−532.184	30.525	30.614	30.559	0.000
ARMA(1,0)	−525.561	30.203	30.337	30.249	0.547
ARMA(0,1)	−528.917	30.395	30.529	30.441	0.412
ARMA(1,1)	−525.103	30.349	30.528	30.418	0.551
ARMA(2,0)	−523.234	30.356	30.536	30.424	0.583

Source: Compiled by the researcher using EViews 12 output.

ARMA(1,0) emerged optimal based on lowest AIC, BIC, and HQ values despite marginally lower R^2 than ARMA(2,0), reflecting superior parsimony-accuracy balance [13].

ARMA(1,0) Model Estimation

The estimated model specification:

$Yt = 2{,}519{,}614 + 0.792Yt_{-1} + \varepsilon t$

$\varepsilon t \sim N(0, 6.28\times10^6)$

Table 3. ARMA(1,0) parameter estimates and diagnostic statistics

Variable	Coefficient	Std. Error	t-statistic	p-value
Constant (C)	2,519,614	706,282	3.567	0.001
AR(1)	0.792257	0.120	6.577	<0.001
SIGMASQ	6.280×10^6	1.590×10^6	3.939	0.001

Diagnostic statistic	Value	Interpretation
R²	0.547	54.7% variance explained
Adjusted R²	0.519	Model parsimony accounted for
Durbin-Watson	2.091585	No first-order autocorrelation
F-statistic	19.33686	Model significant (p < 0.001)
Inverted AR root	0.792	Stationary (Stationary root1 >

Source: Compiled by the researcher using EViews 12 output.

All parameters statistically significant (> 0.05p ,The AR(1) coefficient (1 > 0.792 confirms) series stability and mean-reverting behavior critical for reliable forecasting [14].

3.Forecast Results (2025–2034)

The model projects remarkable production stability during 2025–2034, with annual output converging toward 2,519,000 tons (Table 4).

The narrow range (2,519,232–2,519,567 tons) reflects the autoregressive process's mean-reversion property, where deviations from long-run equilibrium are gradually corrected.

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Table 4. Forecasted wheat production in Iraq (2025–2034)

Year	Forecasted production (tons)	95% Confidence interval (lower–upper)
2025	2,519,232	1,460,000 – 3,578,464
2026	2,519,311	1,038,000 – 4,000,622
2027	2,519,374	802,000 – 4,236,748
2028	2,519,424	670,000 – 4,368,848
2029	2,519,463	585,000 – 4,453,926
2030	2,519,495	525,000 – 4,513,990
2031	2,519,519	480,000 – 4,559,038
2032	2,519,539	445,000 – 4,594,078
2033	2,519,554	418,000 – 4,621,108
2034	2,519,567	397,000 – 4,642,137

Source: Compiled by the researcher using EViews 12 output.

Forecast Accuracy Assessment

Backtesting against historical data yielded:

Table 5. Forecast accuracy metrics

Metric	Value	Interpretation
RMSE	1,059,232	High absolute error due to production volatility
MAE	818,487	Substantial average deviation
MAPE	43.88358%	Moderate relative error
Theil's *U*	0.209	Acceptable forecasting performance
Bias proportion	0.0009	Negligible systematic over/under-prediction
Variance proportion	0.759	Model captures trend but not full volatility
Covariance proportion	0.240	Moderate correlation with actual values

Source: Compiled by the researcher using EViews 12 output .

Theil's U 0.21 > indicates acceptable predictive capability despite MAPE < ,%40reflecting inherent challenges in forecasting agricultural output subject to exogenous shocks (climate extremes, policy shifts)

Model Assumptions and Limitations

The ARMA(1,0) model employed in this study is based on several key assumptions that are critical for its validity and forecasting accuracy. Firstly, the model assumes that the wheat production time series is stationary with a linear trend, which was confirmed through the Augmented Dickey-Fuller test (ADF statistic = −3.944, p = 0.0208). Secondly, the model assumes that the residuals follow a white noise process, exhibiting no autocorrelation, normal distribution, and constant variance over time. Diagnostic tests confirmed these assumptions, with the Durbin-Watson statistic of 2.092 indicating no first-order autocorrelation, Ljung-Box test (p > 0.05) confirming white noise behavior, and Jarque-Bera test (p > 0.05) supporting normal distribution of residuals.

However, several limitations must be acknowledged. The univariate nature of the ARMA model restricts its ability to incorporate exogenous variables such as climate shocks, policy changes, water availability, and technological adoption, which significantly influence wheat production in Iraq. The model's forecasting accuracy, as indicated by MAPE of 43.88%, reflects these limitations, particularly when external shocks occur.

Historical evidence shows that extreme events such as the 2008 drought (reducing production to 854,000 tons) and the ISIS conflict (2014–2017) caused substantial deviations from model predictions.

Furthermore, the model assumes that future production patterns will follow historical trends without major structural breaks. This assumption may not hold under scenarios of significant climate change, major policy reforms, or technological breakthroughs. The narrow confidence intervals in long-term forecasts (2025–2034) should be interpreted with caution, as they may underestimate uncertainty associated with potential external shocks.

Despite these limitations, the ARMA model provides a statistically robust framework (R^2 = 54.7%, F-statistic = 19.337, $p < 0.001$) for short- to medium-term forecasting. For enhanced accuracy, future research should consider multivariate approaches such as ARIMAX models that incorporate external determinants identified in the FMOLS analysis, including cultivated area (β = 0.321, $p < 0.001$), yield (β = 4,774.293, $p < 0.001$), population (β = 348,803.8, $p < 0.001$), rainfall (β = 2,659.107, $p = 0.005$), and temperature (β = −962,026.7, $p < 0.001$).

4.Discussion

Interpretation of Forecast Stability

The forecasted production stability has a large contrast between historical volatility and the model ARMA(1,0) also exhibits the same characteristics of production: the autoregressive coefficient (0.792) means that the production for this year is based upon the previous year's production 79.2% of the time which creates very strong inertia that will eliminate extreme fluctuations unless large shocks occur. This represents production stability (baseline stability) for Iraq when projected to occur in the future with continuing the same agronomic practices in place today and moderate climate not factoring in potential future severe drought conditions versus policy disruptions to the agronomic or agricultural systems.

The forecasted level of production is significantly below the projected level of domestic demand.

The population of Iraq is growing approximately 2.4% Per annum [16]- With an average of 110 kg/year of per capita wheat consumption, wheat demand will surpass 4.8 million T in 2030, almost double the amount of production that will occur during the same period. Therefore, either huge increases in import amounts (increasing fiscal risk) or radical changes to the agricultural system will be required to close this gap between food supply and demand.

Contextualizing Forecast Accuracy

The MAPE of 43.88% appears high but reflects wheat production's sensitivity to exogenous factors beyond temporal autocorrelation:

- •Climate shocks: The 2008 production collapse (854,000 tons) followed severe drought reducing Tigris-Euphrates flows by 40% .
- •Policy disruptions: ISIS conflict (2014–2017) displaced farmers and damaged irrigation infrastructure, causing 48% production drop in affected governorates
- •Input constraints: Fertilizer subsidies fluctuated by ±35% during 2010–2020, directly impacting yields [17].

These factors explain why univariate ARMA models while statistically robust cannot fully capture production dynamics. This limitation motivates our supplementary FMOLS analysis (detailed in Arabic manuscript Section 4.1), which identified significant long-run relationships between production and:

- •Cultivated area (β = 0.321, 0.001 > p)
- •Yield (β = 4,774,0.001 > p)
- •Population (β = 348,804, 0.001 > p)
- •Rainfall (β = 2,659, p = 0.005)
- •Temperature (β = −962,027, 0.001 > p)

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Integrating these determinants into multivariate frameworks (e.g., ARIMAX) could enhance forecast accuracy a recommended direction for future research.

Policy Implications

There are three major implications of this analysis:

1. Strategic reserve provisioning: The narrow production range allows for reliable estimates of minimum production over the decade and includes the evaluation of any consequent strategic reserve requirements. Iraq should hold sufficient strategic reserves to cover at least 6 months of consumption that is dependent on imports.

2. The need for prompt adaptation to climate change: The model has been developed with the assumption that there have been no significant climate-related shocks. Iraq is ranked 5th in the world in terms of vulnerability to climate change. [18]. Supplying adequate funding toward drought-resistant crops and using additional irrigation to close forecast gaps is key.

3. Gap closure for yield It is 40% less than the available maximum yield of 4.7 tons per hectare, for an average agricultural wheat yield in Iraq of only 2.8 tons per hectare. By closing this large gap with both the use of extension and input subsidies, the total production is expected to increase by 1.7 million tons annually toward achieving 70% self-sufficiency in Iraq.

Comparative Analysis

Our projection for total production is 2.52 million tons, which is almost the same as the Food and Agriculture Organization’s 2025 projection of 2.48 million tons and higher than Iraq’s Ministry of Agriculture estimation of 2.2 million tons. The difference in these estimates stems from different assumptions made regarding water availability in Iraq during the period being analyzed. Compared to its neighbours, Syria (3.1 tons/ha) and Turkey (3.8 tons/ha), Iraq has the lowest projected yield (2.9 tons/ha). This is evidence of an opportunity for technology transfer between countries. [5].

5.Conclusions:

1. Analysis of wheat crop production data in Iraq during the period (2025-2034) proved the efficiency of using the ARMA model, as the results showed high significance of the estimated transactions at a significant level (95%)
2. Predictions indicate that local production will stabilize until (2034) at the amount of (2519415.5) million tons per year , but the amount needs to increase due to the increase in the population and the achievement of self-sufficiency.
3. The success of the ARMA model in this study by providing a timeline that can be planned in advance to confront external influences and environmental shocks.
4. The path of the actual and estimated values in one direction above the zero line, but it suffers from high fluctuations during the periods (2015, 2019) due to the political events in that period and the Corona pandemic at the beginning of the year (2019)
5. Statistical results of the Dickie-Fuller test with a constant and a time trend for the t-statistic test (-3.943773) with a probability of (0.0208) less than (0.05), meaning that the time series is stable .

Recommendations:

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1- The need to reduce the state of risk and uncertainty by using agricultural policies predicted for long-term future periods (5 years and above) , which contributes to reducing the variability of production
2- Developing scientific research using modern technology that combines past and current data improves the level of production
3- Population planning by linking the expected population growth rates to the volume of agricultural production to meet their future needs and achieve self-sufficiency.
4- The use of advanced sensors that contribute to reducing the risks of climate fluctuations during the coming periods
5- Expanding modern irrigation projects to reduce water waste contributes to bringing actual production close to future value projections

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