Tikrit Journal of Administrative and Economic Sciences, Vol. 20, No. 66, Part (2): 318-333
Doi: www.doi.org/10.25130/tjaes.20.66.2.18

Tikrit Journal of Administrative and Economics Sciences
مجلة تكريت للعلوم الإدارية والاقتصادية
EISSN: 3006-9149
PISSN: 1813-1719

Forecasting Cotton Production in Iraq during the years (1960-2022) using Markov Chain Approach and Holt-Winter Method

Heshu Othman Faqe*, Ayad Otham Hamdin, Mohammad Mahmood Faqe Hussein
College of Administration and Economics/University of Sulaymaniyah

Keywords:
Markov Chain, Holt-Winters, Dickey-Fuller test,Transition probability matrix, Randomnes test.

ARTICLE INFO

Article history:
Received 25 Jan. 2024
Accepted 20 Mar. 2024
Available online 30 Jun. 2024

*Corresponding author:
Heshu Othman Faqe
College of Administration and Economics/University of Sulaymaniyah

Abstract: Cotton is a fibrous material derived from the seed pods of the cotton plant (Gossypium). It is a natural fiber extensively utilized in the textile industry for the manufacturing of items like clothing, linens, and other fabric-based products. Two models are used in this study, such as the Markov chain approach and the Holt-Winter method, to forecast cotton production in Iraq over the years 1960–2022.

A Markov chain approach model is a accurate framework describing a series of states in a system. The chance of moving from one state to another depends only on the present state, without consideration of the historical. This model adheres to the Markov property, exhibiting a memoryless characteristic. It encompasses a set of states, transition probabilities between these states, and a stochastic process evolving over discrete time intervals.

The Holt-Winters method is a robust technique for forecasting time series data, particularly when the data exhibits both trend and seasonality. This method integrates three key components into its forecasting model: level, trend and seasonality. The data for this study was obtained from the website: https://www.indexmundi.com/agriculture. The study evaluates the performance of the two forecasting models. The results show that the Holt-Winter method is more accurate than the Markov chain dependent on RMSE, MAE, and MAPE, and cotton production in Iraq will decrease over the coming years.

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التنبؤ بإنتاج القطن في العراق للأعوام (1960-2022) باستخدام أسلوب سلسلة ماركوف وطريقة هولت-وينتر

هيشو عثمان فقي
كلية الادارة والاقتصاد
جامعة السليمانية

اياد عثمان حمدين
كلية الادارة والاقتصاد
جامعة السليمانية

محمد محمود فقى حسين
كلية الادارة والاقتصاد
جامعة السليمانية

المستخلص

القطن عبارة عن مادة ليفية مشتقة من قرون بذور نبات القطن (الجوسيبيوم). إنها ألياف طبيعية تستخدم على نطاق واسع في صناعة النسيج لتصنيع سلع مثل الملابس والبياضات وغيرها من المنتجات القائمة على القماش. تم استخدام نموذجين في هذه الدراسة، طريقة سلسلة ماركوف وطريقة هولت-وينتر، للتنبؤ بإنتاج القطن في العراق للأعوام 1960-2022.

نموذج سلسلة ماركوف هو إطار رياضي يصف سلسلة من الأحداث أو الحالات في النظام. إن احتمال الانتقال من حالة إلى أخرى يعتمد فقط على الوضع الحالي، دون النظر إلى الماضي. يلتزم هذا النموذج بخاصية ماركوف، ويظهر خاصية عديمة الذاكرة. وهو يشمل مجموعة من الحالات، واحتمالات الانتقال بين هذه الحالات، وعملية عشوائية تتطور على فترات زمنية منفصلة.

تعد طريقة هولت-وينترز تقنية قوية للتنبؤ ببيانات السلاسل الزمنية، خاصة عندما تظهر البيانات كلا من الاتجاه والموسمية. تدمج هذه الطريقة ثلاثة عناصر رئيسية في نموذج التنبؤ الخاص بها: المستوى والاتجاه والموسمية. تم الحصول على بيانات هذه الدراسة من الموقع الإلكتروني: https://www.indexmundi.com/agriculture. تقوم الدراسة بتقييم أداء نموذجي التنبؤ. بينت النتائج أن طريقة هولت-وينتر أكثر دقة من طريقة سلسلة ماركوف المعتمدة على RMSE، MAE، وMAPE، وأن إنتاج القطن في العراق سينخفض خلال السنوات القادمة.

الكلمات المفتاحية: سلسلة ماركوف، هولت-وينترز، اختبار ديكي-فولر، مصفوفة احتمالات الانتقال، اختبار العشوائية.

1. Introduction

Cotton cultivation holds considerable importance within Iraq's agricultural landscape, serving as a cornerstone of the nation's economy and supporting numerous livelihoods. Anticipating cotton production levels is pivotal for policymakers, farmers, and stakeholders alike, guiding informed choices on agricultural planning, resource distribution, and market tactics. Our study adopts a dual approach, utilizing both the Markov Chain method and the Holt-Winter technique, to project cotton production trends in Iraq spanning from 1960 to 2022. Liu et al. (2019) applies the Markov Chain approach to forecast agricultural commodity prices, demonstrating its effectiveness in capturing the transition dynamics between different price levels over time. Rahman et al. (2020) utilizes the Markov Chain model to forecast rice production in Bangladesh. Zhang et al. (2018) study employs

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the Markov Chain Monte Carlo (MCMC) simulation technique to forecast electricity consumption, showcasing the versatility of Markov Chain methods in various forecasting domains. Hyndman et al. (2008) provide a comprehensive overview of the Holt-Winter method, discussing its application in time series analysis and forecasting across different industries and domains. Alvisi et al. (2017) study compares the performance of Holt-Winter and ARIMA models in forecasting urban water demand, highlighting the strengths and limitations of each method. Mendis et al. (2020)"Evaluation of Holt-Winters Method for Forecasting Intraday Electricity Demand" Comparative Studies. Singh et al, (2017). conduct a comparative analysis of ARIMA and Holt-Winters methods in time series forecasting, discussing their respective advantages and limitations in different contexts. Assimakopoulos et al. (2000) "Comparison of Exponential Smoothing and ARIMA Models for Retail Sales Forecasting". Chan et al. (2012) compare Holt-Winters and ARIMA models for short-term water demand forecasting in Melbourne, highlighting the importance of model selection based on data characteristics and forecasting objectives.

2. **The Study Aim:** The aim of this study is providing accurate and reliable forecasts of cotton production in Iraq over a significant historical period employing the Markov Chain approach and the Holt-Winter method, the study aims to analyze the past trends and patterns in cotton production and use them to predict future production levels. The ultimate goal is to offer valuable insights for policymakers, farmers, and stakeholders to facilitate informed decision-making regarding agricultural planning, resource allocation, and market strategies related to cotton production in Iraq.

3. Methodology

3-1 Markov Chain Approach: A sequence of events where the result at each stage depends only on the current state and not on the previous sequence of events is represented mathematically by a Markov chain technique. The system consists of various states, with chance controlling the transition between stages. Usually, these chances are arranged into a matrix called the transition probability. The future state is said to depend solely on the current state according to the Markov property, often known as the memoryless property. Applications of Markov chains for modeling stochastic and changing systems can be found in computer science, physics, economics, and biology, among other subjects. The following are the main ideas and

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elements of a Markov chain: (Boalsbet, 2025: 3-6), (Hussein, Saeed, Husen, 2023: 2-4).

States: The system can exist in one of several possible states. These states represent different situations or conditions (Auwalu, L. B., A.S. 2013: 1-3).

Transition Probabilities Matrix (TPM): A TPM is a mathematical representation used in the Markov chain approach to describe the probabilities of moving from one state to another within a finite set of states. In a Markov chain, the upcoming state of a system depends only on its current state and not on its historical states. The TPM captures the probability of transition from one state to another in one step(Boalsbet,2025:3-6), (Hamdin & Hussein, 2023: 3-5)

$$\mathrm{P_{ij}} = [\text{ Transition probability from state i to state j}]$$

The TPM is typically denoted by $\mathrm{P_{ij}}$ and has the form:

$$\mathrm{P}_{ij} = \begin{bmatrix} p_{11} & p_{12} & . & . & p_{1n} \\ p_{21} & p_{22} & . & . & p_{2n} \\ . & . & . & . & . \\ . & . & . & . & . \\ p_{n1} & p_{n2} & . & . & p_{nm} \end{bmatrix} \quad (1)$$

Here, n is the number of states, and $\mathrm{P_{ij}}$ represents the TPM. The state moves from i to j in one step. The properties of a valid transition probability matrix are:

i) All entries in the matrix must be non-negative, ($\mathrm{P}_{ij} \geq 0$).

ii) $\sum_{\mathrm{j=1}}^{\mathrm{n}} \mathrm{P_{ij}} = 1$, i=1,2, .., n

Memoryless Property: According to the property of Markov chain, the likelihood of a transition occurring in the future is only dependent on the present state and not on the previous state (Hussein & Saeed & Husen, 2023: 2-4).

$$\mathrm{P(X_{n+1} = j \mid X_0 = 1, X_1 = 2, \dots, X_n = i) = P(X_{n+1} = j \mid X_n = i)} \quad (2)$$

Chapman-Kolmogorov Equation: This equation defines the probability of transition from one state to another over multiple steps (Sultan, K. F., J.A, 2019:103-109)

$$\mathrm{P_{ij}^{(n+m)} = \sum_k P_{ik}^{(n)} P_{kj}^{(m)}} \quad (3)$$

3-2 Holt-Winters Technique: The method, also called as a triple exponential smoothing, is a prediction approach designed to analyze and forecast data by considering both trend and seasonality. This method extends

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simple exponential smoothing and double exponential smoothing. It employs three smoothing equations for level (l_t), trend (b_t), and seasonality (s_t). The equations update these components iteratively based on observed values and specified parameters (α, β, γ). The method is valuable for forecasting in time series with clear trends and seasonality, and it requires initial values for level, trend, and seasonality components. The extrapolation of these components into the future enables future value predictions. The method can adapt to both additive and multiplicative seasonality, depending on the characteristics of the data. The method includes three equations as follows: (Goodwin, 2010: 30-33), (Kuzmin and et al., 2017: 80).

1. Level equation (l_t):

$$l_t = \alpha \times (Y_t - s_{t-L}) + (1-\alpha) \times (l_{t-1} + b_{t-1}) \quad (4)$$

2. Trend equation (b_t):

$$b_t = \beta \times (l_t - l_{t-1}) + (1-\beta) \times b_{t-1} \quad (5)$$

3. Seasonality (s_t):

$$s_t = \gamma \times (Y_t - l_t) + (1-\gamma) \times s_{t-L} \quad (6)$$

4. Forecast equation($\hat{y}_{t+h/h}$):

$$\hat{y}_{t+h/h} = I_t + hb_t \quad (7)$$

Where:

y_t is the observed value at time t.

l_t, b_t and s_t are the level, trend and seasonal component respectively at time t.

L is seasonal cycle length.

α, β, and γ are smoothing parameters for the level, trend, and seasonality, respectively. The range between 0 and 1.

The initial values for $l_0, b_0, s_{0,} s_1, \dots, s_{L-1}$ need to be specified or estimated. Once the initial values are set, the equations are used to update the level, trend, and seasonality components iteratively for each new observation.

3-3 Dickey-Fuller (ADF) test: The test is employed to ascertain the stationary nature of a given data collection.The unit root test, which determines whether a time series variable has a unit root, indicating that it is non-stationary, is the foundation for the test. The following augmented of the Dickey-Fuller test: (Ritu Santra, 2023: 13)

$$\Delta y_t = \alpha + \beta_t + \gamma y_{t-1} + \gamma_1 \Delta\gamma y_{t-1} + \gamma_2 \Delta\gamma y_{t-2} + \cdots + \gamma_p \Delta\gamma y_{t-p} + \varepsilon_t \quad (8)$$

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Δy_t: Represents the 1-difference of the time series . The 1-difference is calculated as

$$\Delta y_t = y_t - y_{t-1} \qquad (9)$$

t is a time tendency.

y_{t-1} is the lagged value of time series variable.

$\Delta y_{t-1}, \Delta y_{t-2}, .., \Delta y_{t-p}$ are the 1-differences of the lagged values up to order p.

ε_t is the error term.

The test statistic formula is:

$$DF_t = \frac{\hat{\delta}}{SE(\hat{\delta})} \qquad (10)$$

Hypothesis test:

H_0: The unit root is present and is non-stationary. vs H_1: The unit root is not exist and is stationary.

3-4 Model Comparison

In the realm of model evaluation, comparing the performance of different models is crucial for determining their effectiveness in making predictions or forecasts. Several metrics are commonly employed for this purpose, including (Nicolas Vandeput, 2019: 324):

3-4-1. Root Mean Squared Error (RMSE):

RMSE is a measure of the average scale of the differences between foretold and observed values, emphasizing larger discrepancies.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - \hat{Y}_i)^2}{n}} \qquad (11)$$

3-4-2. Mean Absolute Error (MAE):

MAE is a measured that evaluates the average absolute differences between predicted and observed values. It provides a robust assessment of model accuracy without considering the direction of errors(Nicolas Vandeput,2019:65).

$$MAE = \frac{\sum_{i=1}^{n}|Y_i - \hat{Y}_i|}{n} \qquad (12)$$

3-4-3. Mean Absolute Percentage Error (MAPE):

MAPE is a metric expressed as a percentage, measuring the average relative difference between predicted and observed values. It gauges the accuracy of predictions in a percentage format. (Nicolas Vandeput,2019:123)

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{Y_i - \hat{Y}_i}{Y_i}\right| \times \%100 \qquad (13)$$

4. Analysis and Discussion: The Cotton is versatile material has been a staple in the textile industry, contributing to the production of clothing, household items, and various industrial products. The data for this study was obtained from the website: https://www.indexmundi.com/agriculture.To analyze the data of this study, the program (E-View) and (Excel) were used.

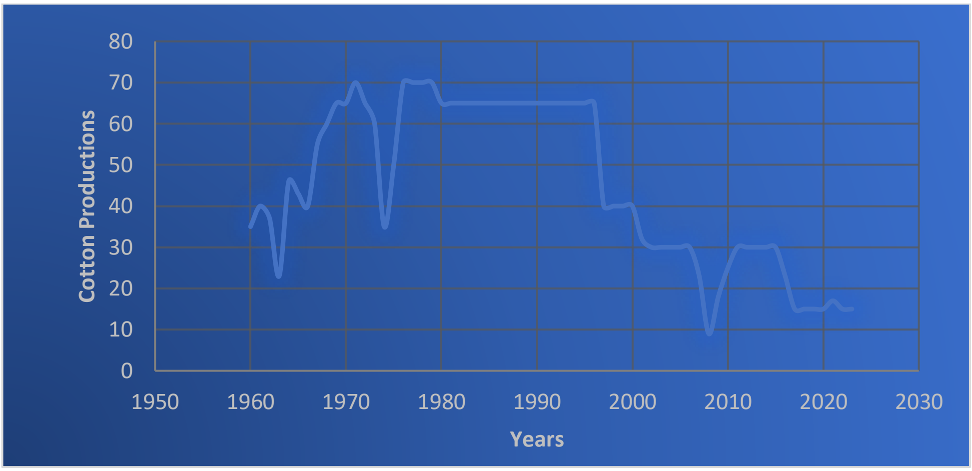

Figure (1): Iraq cotton production by year

Source: Prepared by researchers based on (Excel)

First, Use a Markov chain approach to forecast cotton production in Iraq.

A: We divide the cotton production levels in the chosen time period into seven levels; after subtracting the smallest level from the largest, we divide the result by seven, that is:

$$Z_{min} = 9 \;\; , \;\; Z_{max} = 70$$

$$\text{Class length or width} = \frac{\text{Range}}{\text{Number of class}} = \frac{70 - 9}{1 + 3.3\log(64)} \simeq 9$$

We now configure the levels referred to above, as follows in the table (1):

Table (1): Level of states

Class	Frequency	State
9-17	8	1
18-26	5	2
27-35	13	3
36-44	8	4
45_53	2	5
54-62	3	6
63-71	25	7

Source: Prepared by researchers based on (Excel).

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B: Constructing the basics of the transition probability matrix: The frequency distribution matrix and the transition probability matrix from one level to another, which represent the elements of the transition matrix, can be determined as follows:

Table (2): Frequency matrix

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	6	1	0	0	0	0	0
2	2	1	1	0	1	0	0
3	0	2	9	1	1	0	0
4	0	1	1	5	0	1	0
5	0	0	0	1	0	0	1
6	0	0	1	0	0	1	1
7	0	0	0	1	0	1	23

Source: Prepared by researchers based on (Excel)

Table (3): Transition Probability Matrix (TPM)

	1	**2**	**3**	**4**	**5**	**6**	**7**
1	0.857143	0.142857	0	0	0	0	0
2	0.4	0.2	0.2	0	0.2	0	0
3	0	0.153846	0.692308	0.076923	0.076923	0	0
4	0	0.125	0.125	0.625	0	0.125	0
5	0	0	0	0.5	0	0	0.5
6	0	0	0.333333	0	0	0.333333	0.333333
7	0	0	0	0.04	0	0.04	0.92

Source: Prepared by researchers based on (Excel)

C: Calculate the average of production cotton for each of the seven levels:

Table(4): Present the average of each levels

M1	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
9	23	35	40	46	55	65
15	23	35	37	50	60	65
15	18	32	43	**48**	60	70
15	25	30	40		**58.33333**	65
15	23	30	40			70
17	**22.4**	30	40			70
15		30	40			70
15		30	40			70
14.5		30	**40**			65

M1	M2	M3	M4	M5	M6	M7
		30				65
		30				65
		30				65
		30				65
		30.92308				65
						65
						65
						65
						65
						65
						65
						65
						65
						65
						65
						65
						66

Source: Prepared by researchers based on (Excel)

D: Make the vector row: This is as follows: The level of cotton production that follows the last number we stopped at when we determined the seven levels, meaning that production of cotton in the year 2023 falls into the first level, and accordingly, the vector

$$p_0 = (1\ 0\ 0\ 0\ 0\ 0\ 0)$$

And so:

$$p_1 = (1\ 0\ 0\ 0\ 0\ 0\ 0)\begin{pmatrix} 0.857 & 0.143 & 0 & 0 & 0 & 0 & 0 \\ 0.4 & 0.2 & 0.2 & 0 & 0.2 & 0 & 0 \\ 0 & 0.154 & 0.692 & 0.077 & 0.077 & 0 & 0 \\ 0 & 0.125 & 0.125 & 0.625 & 0 & 0.125 & 0 \\ 0 & 0 & 0 & 0.5 & 0 & 0 & 0.5 \\ 0 & 0 & 0.333 & 0 & 0 & 0.333 & 0.333 \\ 0 & 0 & 0 & 0.04 & 0 & 0.04 & 0.92 \end{pmatrix} = (0.857\ 0.143\ 0\ 0\ 0\ 0\ 0)$$

$$p_2 = (0.857\ 0.143\ 0\ 0\ 0\ 0\ 0)\begin{pmatrix} 0.857 & 0.143 & 0 & 0 & 0 & 0 & 0 \\ 0.4 & 0.2 & 0.2 & 0 & 0.2 & 0 & 0 \\ 0 & 0.154 & 0.692 & 0.077 & 0.077 & 0 & 0 \\ 0 & 0.125 & 0.125 & 0.625 & 0 & 0.125 & 0 \\ 0 & 0 & 0 & 0.5 & 0 & 0 & 0.5 \\ 0 & 0 & 0.333 & 0 & 0 & 0.333 & 0.333 \\ 0 & 0 & 0 & 0.04 & 0 & 0.04 & 0.92 \end{pmatrix} = (0.792\ 0.151\ 0.029\ 0\ 0.029\ 0\ 0)$$

$$p_{10} = (0.528\ 0.131\ 0.114\ 0.069\ 0.035\ 0.017\ 0.106)\begin{pmatrix} 0.857 & 0.143 & 0 & 0 & 0 & 0 & 0 \\ 0.4 & 0.2 & 0.2 & 0 & 0.2 & 0 & 0 \\ 0 & 0.154 & 0.692 & 0.077 & 0.077 & 0 & 0 \\ 0 & 0.125 & 0.125 & 0.625 & 0 & 0.125 & 0 \\ 0 & 0 & 0 & 0.5 & 0 & 0 & 0.5 \\ 0 & 0 & 0.333 & 0 & 0 & 0.333 & 0.333 \\ 0 & 0 & 0 & 0.04 & 0 & 0.04 & 0.92 \end{pmatrix} = (0.505\ 0.128\ 0.119\ 0.074\ 0.035\ 0.018\ 0.121)$$

E: Forecasting the value of production cotton form (2023 to

$$\text{Forecasting}_{\ 2024} = (0.792\ 0.151\ 0.0286\ 0\ 0.0286\ 0\ 0)\begin{pmatrix} 14.5 \\ 22.4 \\ 30.92 \\ 40 \\ 48 \\ 58.33 \\ 66 \end{pmatrix}$$

$$= 17.12316$$

Table (5): Present the forecasting value using Markov Approcah

Year	Freacsting Value
2024	17.12316
2025	18.73344
2026	20.26969
2027	21.70667
2028	23.0455
2029	24.29172
2030	25.4517
2031	26.53156
2032	27.53685

Source: Prepared by researchers based on (Excel)

We notice, through the approximate Markov model, that the predictive values for cotton crop production in Iraq are increasing, and this is due to the fact that the government is interested in raising cotton productivity by supporting farmers in cotton cultivation.

Table (6): Present the measures of Markov Chain

RMSE	MAE	MAPE
9.247377406	8.7766667	0.519041963

Source: Prepared by researchers based on (Excel)

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Second: Using Holt's exponential smoothing method to predict cotton productivity in Iraq.

The exponential smoothing method is also considered one of the important methods used in forecasting, which is characterized by ease of application as the original time series is dealt with without the need to smooth it. To apply this method, we need, as we have seen, a method to estimate its parameters, which are (α, β). In this study, the parameters were estimated using the time series using the statistical program E-view 10 shown in the table below [3],[7]:

A. **Testing for stationary using the Dickey-Fuller Test:**

The following presumptions guide the test's execution:

H_0: The unit root is present and is non-stationary. vs H_1: The unit root is not existed and is stationary.

Table (7): Present Dickey-Fuller test for stationary

Time series variable	**T-Statistics**	**P-Value**
Y=Cotton Production	-1.197339	0.6706

Source: Prepared by researchers based on (Eview)

From the table, we notice that the p-value of the test is (0.6706) and is greater than the level of significance (∝=0.05), meaning we accept the null hypothesis. We say there exists a unit root in the time series, and it is non-stationary. We take the first difference for the purpose of obtaining stationary, then we test again to obtain stationary.

Table (8): Present Dickey-Fuller test for stationary after taking the first difference

Time series variable	T-Statistics	P-Value
Y=Cotton Production	-8.040036	0.0000

Source: Prepared by researchers based on (Eview)

From the table, we notice that the p-value of the test is (0.000) and is less than the level of significance (∝=0.05), meaning we accept alternative hypotheses, which means the time series is stationary.

B. **Select the optimal value of (α, β):**

Table (9): Present to select optimal model

Models	**Parameters**	**RMSE**	**MAE**	**MAPE**
I	α=0.9086 β=0.0004	7.63534	4.05325	13.4249
II	α=0.6837	7.68543	4.52906	14.9073

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Models	Parameters	RMSE	MAE	MAPE
	β=0.0001			
III	α=0.4373 β=0.0001	8.31763	5.36699	17.6593

Source: Prepared by researchers based on (Eview)

Through comparing models to select the best value for (α) and (β), we notice that the value of the RMSE, MAE, and MAPE for the first model is lower compared to the other models.

C.Holt-Winters with α = 0.9086 and β = 0.0004

Table (10): Calculate the new value of alpha and beta use Holt-Winters

Parameters	α	0.9086
	β	0.0004
SSR		3614.5
RMSE		7.63534
End of Period Levels:	Mean	14.99335
	Trend	-0.215687

Source: Prepared by researchers based on (Eview)

D.Forecasting with optimal Parameters:

Table (11): Holt's linear exp. smoothing model with α = 0.9086 and β = 0.0004

Period	Prediction	Lower Limit 95%	Upper Limit 95%
2024	14.9977	0.268313	29.727
2025	14.9817	-4.92315	34.8866
2026	14.9658	-9.02582	38.9574
2027	14.9498	-12.5299	42.4295
2028	14.9339	-15.6408	45.5086
2029	14.918	-18.4682	48.3042
2030	14.902	-21.0786	50.8827
2031	14.8861	-23.5159	53.2881
2032	14.8702	-25.8112	55.5515

Source: Prepared by researchers based on (Eview)

It displays 95% forecast limitations for the forecasts for time periods that extend past the series' conclusion. Assuming that the fitted model is appropriate for the data, these bounds indicate the 95% confidence interval around which the true data value is expected to occur at a given future time.

E. Tests for randomness of residual

Model: Holt's linear exp. smoothing with α = 0.9086 and β = 0.0004

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(1) Excute above ↑ and below ↓ Median

# of excute ↑ and ↓ median = 17

Expected number of excute= 33

The statistical test z = 3.90612: p-value = 0.0000938256

(2) Excute counts the number of times the sequence above or below

# of execute up and down = 21

Expected number of execute== 42.3333

The statistical test z = 6.26568: p-value = 3.72777E-10

(3) Test of Ljung-Box

Test based on first 21 autocorrelations

The statistical test = 15.7216 : p-value = 0.675768

To ascertain whether or not the residuals constitute a random sequence of numbers, three tests have been conducted. Since a series of random numbers has equal contributions at various frequencies, it is frequently referred to as "white noise." The number of times the sequence was above or below the median is counted in the first test. Compared to an expected value of 33 if the series were random, the number of such runs is equal to 17. We can rule out the possibility that the residuals are random because the p-value for this test is less than (∝=0.05). The number of times the sequence climbed or fell is counted in the second test. Compared to an expected value of 42.3333 if the series were random, the number of such runs is equal to 21. We are able to rule out the hypothesis that the series is random because the p-value for this test is less than (∝=0.05). The sum of squares of the first 24 autocorrelation coefficients serves as the basis for the third test. We are unable to rule out the possibility that the series is random because the p-value for this test is larger than or equal to (∝=0.05).

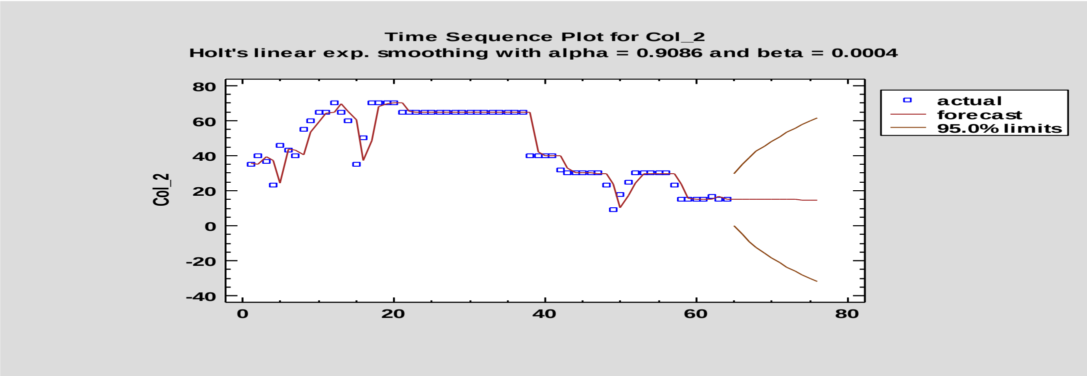

Figure (2):Present Holts linear exponential smoothing with $\alpha = 0.9086$ and $\beta = 0.0004$

Source: Prepared by researchers based on (Eview)

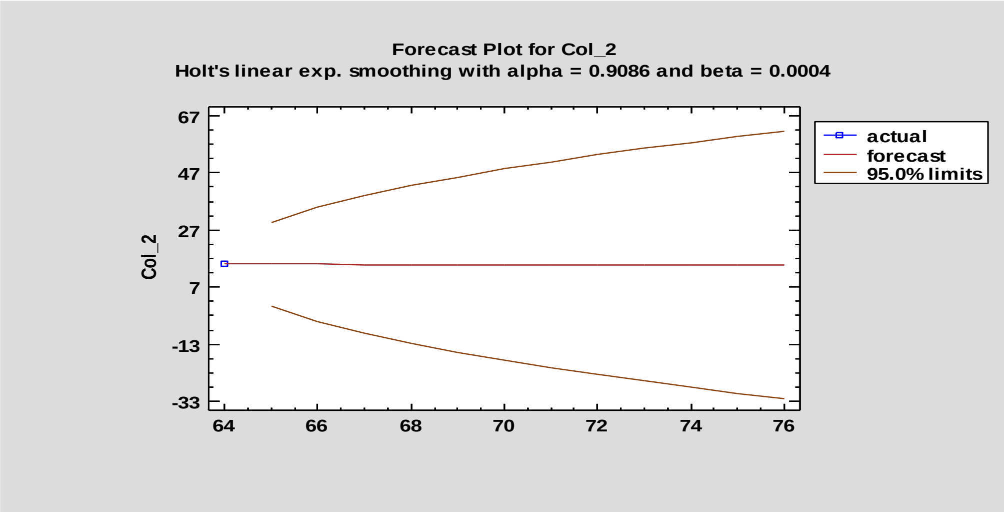

Figure (3): Forecast-Holts linear exp.smoothing with $\alpha = 0.9086$ and $\beta = 0.0004$

Source: Prepared by researchers based on (Eview)

F. **Model Comparison:** Table 12 shows the comparison results of fitting different models to the data. The model with the lowest value of the Mean Absolute Percentage Error (MAPE) is the best. The model with Holt's linear exp. smoothing is selected because the value of the measure is lower when compared with the other model. Holt's linear exp. smoothing was used to generate the forecasts.

Table (12): Present a comparison between the models.

Models	Parameters	RMSE	MAE	MAPE
Holt's linear exp. smoothing	$\alpha = 0.9086$ $\beta = 0.0004$	7.63534	4.05325	13.4249
Markov Chain Approch	-	9.247377406	8.7766667	51.904

Source: Prepared by researchers based on (Eview)

5. Conclusions and Recommandation:

5-1 Conclusions: Depending on the analysis of the results, the conclusions are the following:

1. By comparing the Holt exponential smoothing models to determine the optimal value of (alpha and beta) for the three models, we see that the optimal value of ($\alpha = 0.9086$ *and* $\beta = 0.0004$) for the first model and that the value of (RMSE = 7.63534, MAE = 4.05325, and MAPE = 13.4249) for the first model is lower compared to the value of (RMSE, MAE, and MAPE) for the other models.

2. To choose the best model between the Markov Chains Approach and the Holt exponential smoothing model to predict cotton production in Iraq based on the RMSE, MAE, and MAPE metrics. We see that the best model for predicting cotton production is the Holt exponential smoothing model because the values of (RMSE=63534, MAE=4.05325, and MAPE=13.4249) are lower compared to the value of the Markov Chain Approach.
3. Cotton is one of the agricultural crops that occupies great economic importance, due to its multiple human uses.
4. We notice through the analysis that the forecasting of the value of cotton production in Iraq using the exponential smoothing model will decrease over the coming years.

5.2 Recommendation: Based on the results of the conclusions, it is recommended the followings:

1. Emphasizing the importance of agricultural research centers and their effective role in intensifying agricultural research (especially applied research) for various cotton varieties in the Iraqi governorates and linking this research with the state's development plans.
2. Cultivation of the best varieties with high productivity, the most suitable for natural conditions, and which have proven effective in their response to climate potential and resistance to diseases.

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