Vestnik MIRBIS. 2024; 3(39)': 6–13.
Вестник МИРБИС. 2024. № 3(39)'. С. 6–13.

Original article
DOI: 10.25634/MIRBIS.2024.3.1

An empirical study of pistachio production and its forecast in Afghanistan

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Abstract. This article discusses the statistical analysis of pistachio production in the last 46 years and its forecast for the next 10 years in Afghanistan. The premier focus of this paper is to find the effect of pistachio production in the next years by using the data of the previous years from 1976-2022, and by analyzing time-series data using the ARIMA model. For better and more precise results we used Eviews 10 for data analysis for the ARIMA model. The coefficients of the obtained model are statistically significant and show that the previous period of pistachio production and its errors can significantly affect the future period of pistachio production. Even though the forecast shows that pistachio production has not increased significantly between 2023 and 2032, the corresponding line shows decreasing pistachio production in coming years. Therefore, according to this estimation, Afghanistan will experience a significant decrease in pistachio production in the coming ten years..

Key words: Afghanistan, pistachio production, ARIMA, forecasting.

For citation: Mowahed S. M. An empirical study of pistachio production and its forecast in Afghanistan. By S. M. Mowahed, M. W. Sharif Zada. DOI: 110.25634/MIRBIS.2024.3.1. *Vestnik MIRBIS*. 2024; 3: 3–13.

JEL: B41, L23, L25

Научная статья
УДК 005+330.101

Эмпирическое исследование производства фисташек и его прогноз в Афганистане

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Аннотация. В этой статье обсуждается статистический анализ производства фисташек за последние 46 лет и его прогноз на следующие 10 лет в Афганистане. Основное внимание в этой статье уделяется поиску эффекта производства фисташек в последующие годы с использованием данных за предыдущие годы с 1976 по 2022 год и путем анализа данных временных рядов с использованием модели ARIMA. Для получения лучших и более точных результатов мы использовали Eviews 10 для анализа данных для модели ARIMA. Коэффициенты полученной модели статистически значимы и показывают, что предыдущий период производства фисташек и его ошибки могут существенно повлиять на будущий период производства фисташек. Несмотря на то, что прогноз показывает, что производство фисташек существенно не увеличится между 2023 и 2032 годами, соответствующая линия показывает снижение производства фисташек в ближайшие годы. Таким образом, согласно этой оценке, в Афганистане в ближайшие десять лет произойдет значительное снижение производства фисташек.

Ключевые слова: Афганистан, производство фисташек, ARIMA, прогнозирование.

Для цитирования: Mowahed S. M. An empirical study of pistachio production and its forecast in Afghanistan / S. M. Mowahed, M. W. Sharif Zada. DOI: 10.25634/MIRBIS.2024.3.1 // Вестник МИРБИС. 2024; 3: 6–13.

JEL: B41, L23, L25

1. Introduction

The Agriculture and natural resource sectors are the major production sectors in Afghanistan, upon which more than 80% of the population depends for livelihood. Agricultural land is estimated to be 7.8 million ha of which 3.3 million ha is irrigated and 4.5 million ha is rain-fed cropping. Afghanistan's economy is largely supported by sales of fresh and dry fruits. In 1970 dried fruits, Raisins, and Nuts contributed to more than 40% of the country's foreign exchange earnings. According to a natural forest inventory in 1971, the only surviving natural forests were some 1,313,000 ha of mixed forests in the southeast and some 450,000 ha of pistachio forests in the north. Rangeland covered 70% of the total land area. Due to the past long period of war and drought, the agriculture sector in Afghanistan has been greatly influenced and its products have decreased by 50%. Parallel to that due to a lack of rule enforcement the rural people have started to utilize the free natural resources [Whitehouse 1957].

Pistachio is a deciduous tree that can grow well in dry and unfavorable climatic conditions with little rain. Pistachio plants are well adapted to desert and semi-desert areas of temperate and subtropical regions. Although the pistachio tree is compatible with a wide range of different soil types, this tree grows better with relatively deep, light, or dry sandy loam soils with high lime content. The response of pistachio plant growth to irrigation with hard water is excellent and the plants tolerate water and soil salinity. A recent study on the efficiency of water used for cultivation shows that pistachio trees survive drought conditions and yield is not significantly affected by the limitations of moderate irrigation and proper timing during the growing season [Pistachio nuts 2022]. This is noteworthy, as an aspect of sustainability that frequently arises in connection with agriculture is water usage, especially in semi-arid regions.

Pistachio belongs to the Anacardiaceous family, which includes plants such as cashew nut, mango, sumach, and poison ivy. Pistacia vera L. (2n = 32) is the only species in this genus that produces edible nuts large enough to be commercially acceptable. In addition, the global market demand in the United States and European countries and growing consumer awareness about the health benefits of this incredible dry fruit, is leading to an extensive expansion of the pistachio industry in the coming years. Pistachio nuts are relatively low in sugar (approx. 10%) and high in protein (2000) and oil (50%) contents. The oil is 90% unsaturated fatty acids, 70% of which is oleic acid and 20% the more desirable linoleic acid [Kamangar 1977]. Areas with low rainfall can be suitable for pistachios even if other plants are incompatible. Pistachio plants are compatible with desert and semi-desert areas of temperate and subtropical regions [Hürkul 2021], making Afghanistan the best destination for growing its plants. They are also adapted to a wide range of different soil types, they prefer relatively deep, light, or dry sandy loams with a high lime content. The growth response of pistachio plants to irrigation with hard water is excellent and plants are tolerant to salinity in water and soil [Country Report on...; 2016 Whitehouse 1957].

Literature review

The origin of the pistachio tree is said to be in Central Asia, including present-day Iran and Afghanistan [Duckett 2011]. Archeology shows that pistachios were a common food as early as 6750 BC. The modern P. vera pistachio was first cultivated in Bronze Age Central Asia, where the earliest example is from Djarkutan, modern Uzbekistan. The Romans brought the pistachio tree to Europe from Asia in the first century AD. They are cultivated throughout southern Europe and northern Africa [Calaresu 2010].

In the paper, Bailey and Stein mentioned Pistachios have an essential amino acid ratio higher than most other commonly consumed nuts, with a high percentage of branched-chain amino acids [Bailey 2020]. Pistachios are also a good source of fiber, having 10% by weight of insoluble fiber and 0.3% of soluble fiber. Pistachios are a source of at least 15 different micronutrients in significant amounts, based on the U.S. Food and Drug Administration (FDA) (providing over 10 % of the Daily Recommended Value (DRV) per ounce (28.5 g) serving) or the European Union (EU) (providing at least15% Nutrient Reference Value per 100 g) Nutrition and Health Claims Regulation (NHCR) thresholds [Food Labeling 2020; Guidance on the Provision... 2013]. As such, pistachios are a significant source of protein, fiber, copper, manganese, vitamin B6, thiamin, potassium, phosphorous, chromium, vitamins E and K (phyllo Quinone), riboflavin, folate,

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magnesium, iron, zinc, and selenium with smaller quantities of other micronutrients also present.

Recent studies reveal that pistachios Contain a wide variety of important phytochemicals such as carotenoids, phenolics, and flavonoids. New studies also show that pistachio is high in antioxidants. "Scientific research continues to prove that pistachios are at the top of the list of high-antioxidant foods," said Jim Graham, owner with his wife, Ruth, of Cochise Groves farming pistachios and wine grapes in southern Arizona. Pistachio phytochemical extracts also showed patent antiproliferative activities against human cancer specifically breast, liver, and colon cancer. and researchers emphasized that this area should be more of a focus in future studies to find out how pistachio extracts are blocking the growth of cancer cells (breast, liver, and colon). "The health benefits of pistachios have been studied over the past 20 years and we are excited to dig further into the specific makeup of pistachios that may be contributing to overall health," notes Amber Wilson, MS, RD, Director of Nutrition Research and Communication for American Pistachio Growers[1]. With all these health benefits it is obvious that in the future pistachio will play a significant role in the dry fruit industry, and will produce a significant amount of revenue for the countries who owns this plant.

The U.S. and Iran are the global leaders in the production and cultivation of pistachios. Turkey and Syria follow the U.S. and Iran in pistachio production. Meanwhile, Global Pistachio Market was valued at USD 3,907.07 million in 2021 and is expected to reach USD 5,282.52 million by 2029, registering a CAGR of 3.7% during the forecast period of 2022–2029[2]. However, because of the conflict in Syria, it is difficult to determine its pistachio production. While Afghanistan, Argentina, Australia, Egypt, Greece, Lebanon, Israel, Italy, Morocco, Spain, and Tunisia also produce pistachios, most are locally consumed, with few exports. The Foreign Agriculture Service, USDA GAIN publication reports that the People's Republic of China also has planted some 4,000 acres of pistachios in the Xinjiang Region [American Pistachio Growers 2020].

The world production of pistachios in 2019 is estimated to be approximately 0.9 million tons, and the countries of Iran and the United States were the first producers with 74% of the world's total pistachios. Secondary producers were China, Turkey, and Syria. A 2020 report indicated that nearly half of the global production of pistachios in 2019 came from the United States, with production in Iran falling to as low as 7% due to US trade sanctions against Iran, climate change, and weak economic and water management in Iran [Razavi 2006].

Besides all of the health benefits that pistachio has it also has commercial benefits for all small and big businesses, that can hugely contribute to the economy of a nation. The study by Cardassilaris Food broker (2023, May 28)[3], which is in regards to Global Pistachio Production and Consumption and the estimated results for 2023/2024 from the analysis of the data from 2022/2023 shows that, the world supply of pistachio will be witnessing a significant increase from 1.058.056 metric tons to an estimated 1.237.650 metric tons in 2023/2024, which shows a growth of 17% between these years. These numerical figures indicate a positive trend in the global market of the pistachio industry, by increasing the level of production and favorable market conditions. Also, the pistachio will have a positive shift of more than 4%, from 843.006 metric tons to 877.650 metric tons between the mentioned years, which again shows an increasing demand of consumers for this product worldwide. This study also represents that besides the USA the leading producer of pistachio, other countries such as Iran, Syria, and Greece had a significant positive increase in the estimated production for 2023/2024. These studies and research smoothen the way for us to further discover the changes in pistachio production in Afghanistan.

Afghanistan once had more than 450,000 hectares of pistachio trees, of which 40 percent have been destroyed, according to the Ministry of Agriculture. Officials there attribute this destruction to the effects of the last 40 years of war — when the jurisdiction of

1 New Study Reveals Pistachios Are an Antioxidant... (Jan 30, 2023).AZBF. org : [website]. Available at https://www.azfb.org/Article/New-Study-Reveals-Pistachios-Are-an-Antioxidant-Powerhouse (accessd 05/12/2023).

2 Pistachio Market Size, Share, Growth, Research Report, Share, & Forecast. (2023, May). Data Bridge Market Research : [website]. Available at https://www.databridgemarketresearch.com; Ibid: All Rights Reserved 2024. Available at: https://www.databridgemarketresearch.com/reports/global-pistachio-market(accessd 05/12/2023).

3 Pistachios Market (Update March 2022 Week 11). Cardassilaris Food Broker. Cardassilaris Family : [website]. Available at https://www.cardassilaris.com/news/global-pistachio-production-and-consumption-analysis-for-2022/2023-and-estimated-figures-for-2023/2024 (accessd 05/12/2023).

the central government in the provinces was weak or non-existent. The problem is particularly acute in the northwest province of Badghis and Herat Province in the Western part of Afghanistan, which has Afghanistan's highest concentration of pistachio forests. Residents say that poverty and the lack of any other source of fuel are forcing them to cut down the trees for firewood.

A 2018 report by IWPR[4] mentioned that local authorities in the southern province of Afghanistan Helmand were encouraging farmers to replace growing fruits and nuts with poppy (Opium), where according to the provincial Department of Agriculture, irrigation, and livestock, under UN alternative project about 150 pistachio orchards were planted and extra 400 orchards were planned to be planted as an alternative for poppy in Helmand province.

It is worth mentioning that Afghanistan pistachio production in 2021 was 2.79Mkg with an increase of 0.35% from the previous year, and by 0.30% share of production, it ranked 8th worldwide[5].

Model specification and methodology

The data used by this research is taken from the website (https://www.tilasto.com). The data is set in yearly starting from 1976 and ending to 2022. The study attempts to use the ARIMA model to predict the amount of pistachio production in Afghanistan from 2023 to 2026 annually. For greater clarity of the method and working materials, different types of ARIMA models are examined.

The ARIMA model consists of three different parts. If the pistachio production value is only a function of its production value in previous periods, we use the following equation which is called AR(p) model:

$$Y_t = \phi_0 + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \ldots + \phi_p Y_{t-p} + \varepsilon_t \quad (1.1)$$

In Model (1.1), parameters such as (φ_1, φ_2, φ_p & φ_0) are the model coefficients that must be calculated. The variable (Y_t, Y_{t-1}, Y_{t-2} & Y_{t-p}) indicates the amount of production in different periods and the expression (ε_t) is the model error. The above equation is used when the model is defined as ARIMA (P, 0, 0).

If the pistachio production value is only a function of the component of its errors in previous periods, we use the following model which is called MA(q). In this model, the production of pistachios is not subject to the amount of production it has produced in previous periods:

$$Y_t = \mu + \varepsilon_t - \omega_1 \varepsilon_{t-1} - \omega_2 \varepsilon_{t-2} - \ldots - \omega_q \varepsilon_{t-p} \quad (1.2)$$

In model (1.2), parameters such as (ω_1, ω_2, ω_q & μ) are coefficients and constants of the equation that must be calculated, and variables (ε_t, ε_{t-1}, ε_{t-2}, ε & ε_{t-q}) are components of error at different periods that affect the amount of output at time t. This equation is used when the mode model adopts ARIMA (0, 0, q).

If the pistachio production value is simultaneously a function of the errors and its production value in previous periods, we use the following equation which is called ARMA(p, 0, q) model:

$$Y_t = \phi_0 + \mu + \sum_{i=1}^{p} \phi_i Y_{t-i} - \sum_{i=1}^{q} \omega_i \varepsilon_{t-i} + \varepsilon_t \quad (1.3)$$

Equation (1.3) is used when the model is calculated as ARMA (p, 0, q).

Models AR(p) and MA(q) are used to predict and estimate variables as long as the data has stationarity properties at level, but if the data does not have stationarity properties at level, the first (1st), second (2nd), differences should be taken ..., till the data become stationary. When on the time series data, the differences are (1st, 2nd, ...), apply, the following model is suitable for estimating coefficients and predicting variables. A kind of differential equation arises when the model is given as ARIMA (p, d, q):

$$\dot{Y}_t = \varphi_0 + \mu + \sum_{i=1}^{p} \varphi_i (Y_{t-i} - Y_{t-(i+1)}) - \sum_{i=1}^{q} \omega_i (\varepsilon_{t-i} - \varepsilon_{t-(i+1)}) + \varepsilon_t$$

(1.4)

Equation (1.4) shows the first-order differential model in which case ARIMA ( ) is considered [Mowahed 2022].

Stationarity test

To know that our data has stationarity conditions, we use the Dickey-Fuller test. This test is applied once at level and once again at 1st difference. The data is seen to assume stationarity conditions after taking the 1st difference. Because, P-Value (=0.1781) in the first case (at level), does not confirm the assumption of data stationarity, and the P-Value (0.0001),

4 Institute for War and Peace Reporting, Afghanistan: Pistachio, not poppy, 10 July 2018, available at: https://www.refworld.org/docid/5b8660f3a.html (accessed Jan 29, 2024).

5 Afghanistan Pistachio Kernel Market Overview 2023. Tridge : [website]. Available at https://www.tridge.com/intelligences/pistachio/A (accessed Jan 29, 2024).

confirms the assumption of data stationarity at 1st difference. Table 1 contains the results of the Dickey-Fuller test to recognize the stationarity of the data:

Table 1. **Augmented Dickey-Fuller test statistic**

Tests	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic at level	−2.29355	**0.1784**

Tests		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic at 1st difference		−19.4536	**0.0001**
Test critical values	1% level	−3.58474	
	5% level	−2.92814	
	10% level	−2.60222	

Source: author's estimation

Stationarity and non-stationarity graphs

Figure 1, consists of two parts. The left side of Figure 1 shows the data in a state that is not stationary, and the right side shows the graph of the data after taking the 1st difference, which oscillates around the zero mean and is in a state of stationarity.

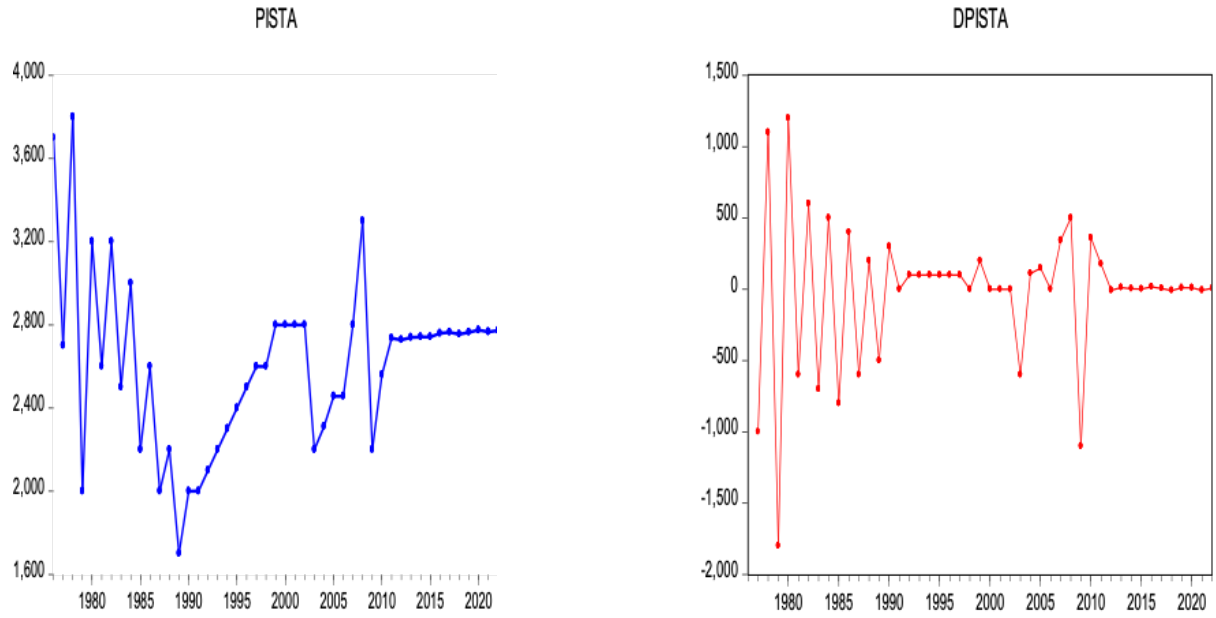

Figure 1. Stationarity and Non-Stationarity Graph
Source: author's estimation.

Choosing and estimating the best model

According to the ACF and the PACF functions, five models have been proposed to estimate the pistachio production function, which their properties are listed in Table 3. From examining and comparing the specifications of the models, we conclude that the first model has a slightly higher priority than all other models. Because, in this model, the values of volatility, Adj. R2 and AIC is less.

Table 2. **Finding optimal model of ARIMA**

Properties of ARIMA	(1)	(2)	(3)	(4)	(5)
	(1,1,1)	(2,1,1)	(3,1,1)	(4,1,1)	(6,1,1)
Significant coeff. at 10%	2	2	2	2	2
Sigma^2 (volatility)	98481.87	99925.90	125493.2	125752.0	117830.5
Adj. R^2	0.5989	0.5931	0.4890	0.4879	0.5202
AIC	14.5357	14.5471	14.7784	14.7822	14.7391

Source: author's estimation.

Table 3. **Best ARIMA (1, 1, 1) model estimation**

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	−9.7976	37.01004	−0.264729	0.7925
AR (1)	−0.9039***	0.062471	−14.47041	0.0000
MA (1)	0.2734*	0.160581	1.702883	0.0960
SIGMASQ	98481.87***	18440.77	5.340443	0.0000
R-squared	0.6257	Mean dependent var		−20.1652
Adjusted R-squared	0.5989	S.D. dependent var		518.6258
F-statistic	23.4054	Durbin-Watson stat		2.0027
Prob (F-statistic)	0.0000			

Source: author's estimation.

Stationarity of AR (1) and MA (1)

In order to ensure the selection of the optimal model and avoid measurement errors in the estimation of the model and its parameters, we

test the inverse roots of the selected ARIMA model, which are placed inside the unit circle or not. In Figure 2, it is clear that the orders of AR (1) and MA (1) are placed on the left side of the unit circle in the shaded area.

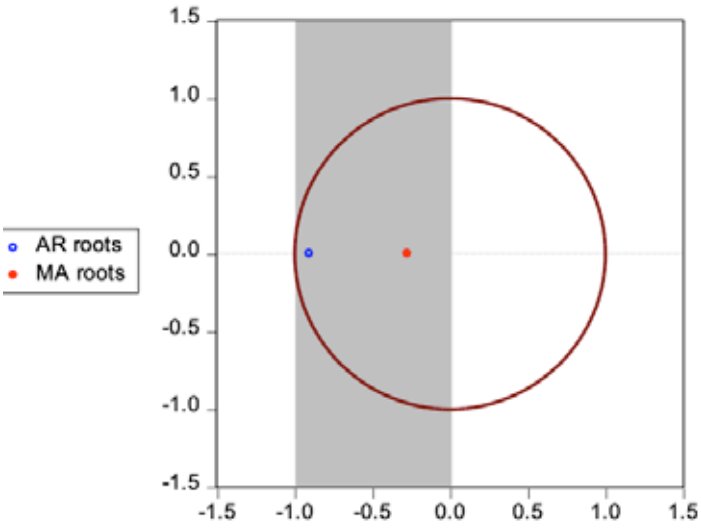

Figure 2. Inverse Roots of AR/MA Polynomial(s)

Source: author's estimation.

This means that the model chosen by order (1, 1, 1) is optimal and is more suitable than other models proposed to predict pistachio production in the coming years. According to the estimated model in Table 3, if we draw the figure of the main amount of pistachio production alongside its projected value from 2022 to 2032, we see that the amount of pistachio production in Afghanistan is declining in the coming years.

The decline in pistachio production in the coming years could have various reasons in Afghanistan, including the lack of proper mechanism of forest management by the government, the cutting of pistachio trees as a fuel and heat agent by the people, the lack of pistachio processing companies and its conversion into efficient goods, the lack of a fixed and managed market to ensure farmers and foresters by the government, the lack of new agricultural facilities and its promotion, the lack of expertise and awareness about pistachio crop cultivation and harvesting, the lack of scientific and practical attention in order to improve the quality of planting and harvesting pistachio crops, the lack of support for landowners to the production of pistachios and its promotion by the government can be noted.

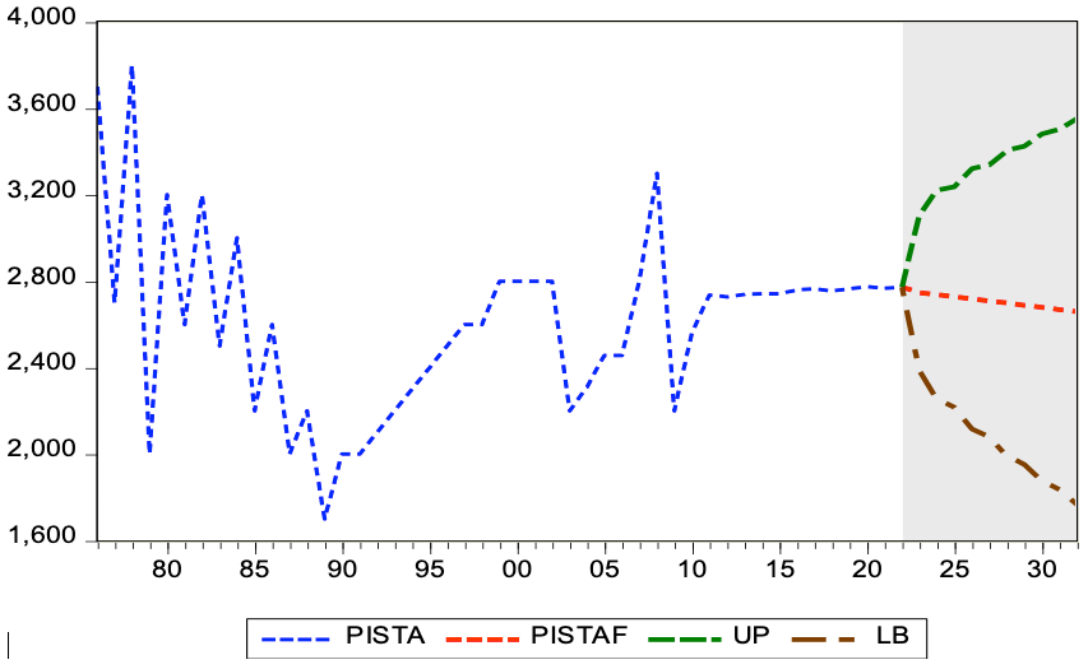

Figure 2. Pistachio production forecasted graph

Source: author's estimation.

In table 3, ARIMA model was estimated by the first-order (1, 1, 1) in which the coefficient of variation of Pistachio production and tis error in previous periods are calculated equal to –0.9039 and 0.2734 respectively, which is significant at the alpha level of 10%. From the coefficient obtained in the model, it is concluded that the amount of changes in pistachio production in the future is significantly dependent on

the changes in pistachio production and its error in the past two periods. According to the calculations, ARIMA (1, 1, 1) can be arranged as follows:

$$\dot{Y}_t = -9.9776 - 0.9039\dot{Y}_{t-1} + 0.2734\dot{\varepsilon}_{t-1} \quad (1.5)$$

$$Y_t' = Y_t - Y_{t-1}, Y_{t-1}' = Y_{t-1} - Y_{t-2}, \varepsilon_{t-1} = \varepsilon_{t-1} - \varepsilon_{t-2}$$

$$Y_t - Y_{t-1} = -9.9776 - 0.9039(Y_{t-1} - Y_{t-2}) + 0.2734(\varepsilon_{t-1} - \varepsilon_{t-2})$$

$$Y_t = -9.9776 + 0.0961Y_{t-1} + 0.9039Y_{t-2} + 0.2734(\varepsilon_{t-1} - \varepsilon_{t-2}) \quad (1.6)$$

Equation (1.6) is the estimated function of the ARIMA model used to predict the amount of pistachio production in 2023 to 2032. The amount of pistachio production in Afghanistan for the next ten years is summarized in Table 4, where Column (1) years, Column (2) is the predicted value, column (3) is the upper limit of estimation, and Column (4) is the lower limit of estimation.

Table 4. **Forecasted amount of pistachio production in coming ten years**

Years	Forecast	UB	LB
2023	2746.536	3104.759	2388.314
2024	2737.863	3221.725	2254.000
2025	2727.049	3236.999	2217.099
2026	2718.170	3320.541	2115.798
2027	2707.542	3338.088	2076.996
2028	2698.495	3404.900	1992.089
2029	2688.019	3424.607	1951.430
2030	2678.834	3481.236	1876.432
2031	2668.482	3502.788	1834.176
2032	2659.186	3552.606	1765.766

Source: author's estimation.

Pistachio production in 2023, 2024, 2025 and 2032 are predicted to be 2746.536, 2737.863, 2727.049 and 2659.186 tons, respectively, using the ARIMA (1, 1, 1) model obtained. The estimation of pistachio production in the forecasted years does not seem to be increased. Because, as seen in the figure related to the forecast, pistachio production in the coming years will follow downward slope trend. For example, if we consider the growth rate of pistachio production between 2031 and 2032, it is equal to –0.34%, which is declining.

Conclusion

In this article, pistachios production forecasts for this product over the next ten years have been analyzed. The data was considered annually from 1976 to 2022, and the optimal ARIMA model was identified at the first difference level and the function of pistachio production in Afghanistan was estimated on its basis.

Time series econometric models have been used to estimate the pistachio production function. ARIMA model (1,1,1) which is the basis of analysis and prediction in the article, the amount of pistachio production in the coming years is known to be significantly dependent on the amount of pistachio production and its errors in the previous two periods. The results of calculations according to pistachio production data between 1976 and 2022 show that the influence factor of one previous period is equal to 0.0961 and the influence factor of two previous periods is equal to 0.9039 on pistachio production in the coming years.

The general results show that pistachio production will not experience positive fluctuations during the years 2023 to 2032. The results of this model provide useful information for the government, citizens, farmers, specialists in the agricultural and forestry sectors. Based on the findings of this study, the government should pay serious attention to the conservation of pistachio forests, strengthening agricultural technological facilities, establishing pistachio processing companies, supporting peasants and raising awareness of the people. The results of the study also warn that if the responsible institutions and the government do not implement effective policies in the field of forest preservation and development, the pistachio crop will have a significant decrease in the coming years.

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The article was submitted 03/25/2024; approved after reviewing 04/15/2024; accepted for publication 09/27/2024.

Статья поступила в редакцию 25.03.2024; одобрена после рецензирования 15.04.2024; принята к публикации 27.09.2024.