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# Apple production forecasting in Afghaninstan using ARIMA model

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**Abstract.** This article statistically examines the amount of apple production and its forecast in Afghanistan. Data from 1961 to 2019 have been used to obtain an ARIMA model that can significantly predict apple production in the coming years. In this paper, the amount of apple production in the current period is a function of the amount of apple production in the previous two periods, in which the amount of production in previous periods plays the role of an independent variable. Finally, the desired function was estimated as a first-order differential equation and based on that, the amount of apple production in ten years (2020–2029) was predicted.
**Key words:** apple production, ARIMA, forecasting.

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# Прогнозирование производства яблок в Афганистане с использованием модели ARIMA

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**Аннотация.** В данной статье статистически рассматривается объем производства яблок и его прогноз в Афганистане. Данные с 1961 по 2019 год использовались для получения модели ARIMA, которая может в значительной степени предсказать производство яблок в ближайшие годы. В этой статье объем производства яблок в текущем периоде является функцией объема производства яблок в предыдущие два периода, в которых объем производства в предыдущие периоды играет роль независимой переменной. Наконец, искомая функция была оценена как дифференциальное уравнение первого порядка, и на ее основе был предсказан объем производства яблок через десять лет (2020–2029 гг.).
**Ключевые слова:** производство яблок, ARIMA, прогнозирование.

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## Introduction

Afghanistan is a landlocked country located at the crossroads of Central and South Asia. It borders Pakistan to the east and south, Iran to the west, Turkmenistan and Uzbekistan to the north, and Tajikistan and China to the northeast. The 652,864 square kilometer country is predominantly mountainous, with plains in the north and southwest separated by the Hindu Kush mountain range[6].

Horticulture has always been fundamental to the Afghan economy; it has played a central role in the past and continues to be very important for a stable and prosperous society. Although only 12% of Afghanistan's total land area is arable and only about 6% is currently under cultivation, Afghanistan's climatic conditions are extremely favorable for many




6 Landlocked Countries In Asia. WorldAtlas.com : [website]. Available at: https://www.worldatlas.com/articles/which-are-the-landlocked-countries-in-asia.html (accessed 12/16/2021).

tree crops, vegetable species, and seed production. In the 1960s, Afghanistan was a world leader in raisin production, and in the 1960s and 1970s, exports of high-value horticultural products accounted for 48% of Afghanistan's annual export earnings [Yousufi 2016]. In the 1970s, annual exports averaged US$600 million, of which 30% was dried fruit and 70% fresh fruit. It is estimated that revenues from horticultural products were three to seven times higher than those from wheat. However, conflicts in recent decades have led to widespread destruction of agricultural infrastructure, especially orchards, and irrigation systems. Rebuilding the horticulture sector will allow Afghanistan to rise again and provide abundant employment opportunities and livelihoods for up to 80% of the population. This will lead to a better economy and greater food security. The revitalization of horticulture should focus on high-quality products with increased production. The development of modern horticulture in Afghanistan with all its components and elements will be a major challenge. Nevertheless, it has great potential to contribute to the revitalization of the economy in Afghanistan [The future of food... 2017 ]

One of the most important and basic fruits produced all over the world is the apple, Apple (Malus domestica) accounts for 50% of the world's deciduous fruit tree production. China is the leading apple-growing country which is producing about 41% of the world's apples; followed by the United States, India, and Turkey [Ntakyo 2013].

Afghanistan has favorable climatic conditions for the production of apples. Apples are still an important fruit in the country despite unfavorable conditions like lack of storage facilities, packaging, and transportation problems thus limiting the domestic market. The more accessible areas and local markets have heavy competition with imported apples from Iran and Pakistan; nevertheless, cultivation is still widespread and mainly aimed at satisfying the small rural local market [Yousufi 2016].

Apple trees are temperate zone fruits that require 400–1,100 chilling hours (temperature below 45F$^0$) during winter as a dormant period. Apple trees can grow in a wide range of soils from medium-textured clay to sandy soils. However, the best soil for the cultivation of apples is fertile and well-drained loams soil. The required range of pH is between 5.8–7 (acidic to neutral soil) [Moety Salama 2021].

Commercial varieties of Apples are produced in the colder areas of Afghanistan, such as Wardak, Logar, Kabul, Parwan, Ghazni, Paktya, Paktika, Badakhshan, and Bamiyan provinces. Apples flower in early spring with fruit ripening in August to October, depending on varieties and locations. Apples are mostly cross-pollinated, requiring growers to plant two or three different varieties in the same orchard. Many varieties of apples are grown in Afghanistan, with the most popular commercial varieties being Red Chief 101, Blushing Gold 102, Royal Gala 110, Double Red Delicious 109, Michgla Modal Gala 7209, Fuji 7237, Galaxy 7243, and Saturn 7235. Common rootstocks of apples available in Afghanistan are B9, M7, M9, M26, MM106, and MM111 [Islamic Republic of Afghanistan... 2014].

## Literature review

The apple belongs to the group of roses, where this fruit is produced the most worldwide. There are over 7,500 varieties of apples. Among the most recognized are Red Delicious, Golden Delicious, Fuji, Jonagold, etc. The great ability to adapt to different natural conditions and high fruits quality ensured apple's important position in fruit production [Lukač-Bulatović... 2019]

Awareness of healthy food, population growth, increasing incomes, and urbanization raise the global demand for fruit, where the second position goes to apples. However, their supply is insufficient, implying the lost revenues and exacerbating nutritional food insecurity [Vasylieva & James 2021].

A rational and nutritious diet is a prerequisite for human health support. Agriculture is a core provider of nutritional food. More and more consumers become aware that food must be safe and provide sufficient calories and supply vitally important elements like protein, vitamins, and minerals. Causes of these shifts can be linked to socio-demographic and economic drivers such as globalization, urbanization, promotion of a healthy lifestyle, increases in disposable income, improved marketing, and advanced food supply chains [Kearney 2010].

Concerning the supply of fruits, apples with a production of 86 million tons were ranked second after bananas with a production of 115 million tons in 2018. Simultaneously, the third and fourth most popular fruits were grapes and oranges, with 79 and 75 million tons of harvest (FAOStat, 2020).

Standing temperature between −30 and +30-40 degrees Celsius, apples are grown in 96 countries

for their domestic markets and export. Since 2000, apple production showed an accelerated increase by 51.1%, which is consistent with an increment of the urban world population by 50.3%, while the total population grew at a much slower rate of 25.8% (WB, 2019).

Concerning the demand for fruits, it is expected that their world average daily consumption will grow from 204 to 242 g per capita by 2025 and 2050. The respective figures for the developing countries are 172 and 213 g of daily fruit intake in contrast to 336 and 388 g of consumed fruit per capita in the industrial countries for 2025 to 2050 [Kearney 2010].

WBJAERD, Vol. 2, No. 1 (1-68), January – June, 202022source, almost 2/3 of global apple production is organized in Asia (62.1%), whereas the greatest producer could be labeled China with the production of over 39.2 million tons. Among the largest European producers could be marked Poland (almost 4 million tons), Turkey (3.6 million tons), Italy (2.4 million tons), and France (1.7 million tons).

Agriculture plays a key role in Afghans' livelihoods, provided income for 49% of all households, and is the potential source of income for approximately 40% of the total workforce. The important crops in Afghanistan, especially cash crops are apples, pomegranate, grapes, apricots, pear, peach, etc. The government of the Islamic Republic of Afghanistan (GoIRA) has recognized that agricultural development is a key priority for employment creation, improvement of livelihood, capital accumulation, and economic growth. World Bank and the government acknowledged that increases in agricultural production and market access for small-scale farmers should be a target for rural economic development and the national economy [Islamic Republic of Afghanistan... 2014].

Afghanistan has a strong advantage in the production of specific fruits and has strong potential for exporting and income generation, contributing $1.4 billion to the national GDP, equivalent to 34% of agricultural GDP and 6.7% of national GDP. Currently, it is extending to 360 thousand ha, covering almost 14% of the total irrigated area and involving more than two million people. The country's different topographical and climatic conditions allow for a wide range of cash crops to be grown in all growing seasons of the year. Although there has been a positive trend in exports of Afghan fruit commodities including fresh, dried, and semi perishables products. The major markets are domestic, neighboring markets, and high-end markets in Europe, the Middle East, or more distant Asian countries. Major fruits that have been exported are grapes, apple, apricot, and pomegranate [ibid].

In the case of apple, the conventional farming system is a major problem and has been affected the quantity and quality of production and reduced efficiency of input resources for apple. This directly impacts rising unemployment, food insecurity, poverty level, and migration. Addressing poverty, apple farmers' livelihood is an important issue in the current situation of Afghanistan, particularly 9 provinces of the country in the area of 27 thousand ha is a zone of growing apple. Most farmers working in the area have 0.4ha on average, produced fruits for making income through distribution to domestic markets and exporting abroad [Verma 2014].

## Model specification and methodology

Since the data used in this article are annual time series data, ARIMA model can be used to measure and predict apple production in Afghanistan. For more clarity of work methodology and estimation of model coefficients, different types of models are examined and one of them is selected as the optimal and practical model.

If it is assumed that the amount of apple production is not a function of the error components in the previous periods and is stationary, the following model is used to predict the amount of production.

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

In Model 1.1, parameters such as

$$(\phi_1, \phi_2, \phi_p \ \& \ \phi_0)$$

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 cycles and the expression ($\varepsilon_1$) is the model error. The above equation is used when the model is defined as ARIMA(*P*, 0, 0 ).

If the amount of production in the future is not a function of production in previous periods and is a function of the amount of errors of previous periods and the data is stationary, then the following model

is used to predict the amount of apple production in the future.

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

In model 1.2, parameters such as

$$(\omega_1, \omega_2, \omega_q \ \& \ \mu)$$

are coefficients and constants of the equation constant that must be calculated, and variables

$$(\varepsilon_t, \varepsilon_{t-1}, \varepsilon_{t-1}, \ \& \ \varepsilon_{t-q})$$

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 amount of production in the future is a function of the error components and the amount of production in previous periods, then Equations 1.1 and 1.2 are used simultaneously.

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

If the data used in the model is not stable, then the data difference needs to be taken as first-order or second-order. Therefore, if the first-order difference of the data is taken, the obtained model will be a first-order differential equation, and if the second-order difference of the data is taken, the obtained model will be a quadratic differential equation. A kind of differential equation arises when the model is given as ARIMA (*p, d, q*).

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

(1.4)

Equation 1.4 shows the first-order differential model in which case ARIMA(*p*,1,*q*) is considered.

## Data sources and variables

The data used in this article is taken from the website (https://www.tilasto.com/en). In this paper, to predict the amount of apple production in the years 2020 to 2029, the ARIMA model is used and the results are extracted and interpreted through Python analytical software.

To obtain the ARIMA model, annual data on apple production in Afghanistan from 1961 to 2019 are considered and shown in the simple graph below.

## Empirical results

In the previous paragraphs, the structure, types of models and methodology of the research were discussed. Now we are going to review and estimate the model of Arima used in this article and make the necessary forecast in terms of apple production in the years 2020 to 2019. To achieve this goal, Python software was used and the results were calculated in the table below.

Table 1.1. **ARIMA model results**

| SARIMAX Results | | | | | | |
|---|---|---|---|---|---|---|
| Dep. Variable: | | APP No. Observations: | | | 59 | |
| Model: | | ARIMA(1, 1, 0) Log Likelihood | | | -217.728 | |
| Date: | | Sun, 06 Feb 2022 AIC | | | 439.456 | |
| Time: | | 16:50:57 BIC | | | 443.577 | |
| Sample: | | 0 HQIC | | | 441.061 | |
| Covariance Type: | | org | | | | |
| | coef | Std err | z | P>\|z\| | [0.025 | 0.975] |
| ar. L1 | 0.5939 | 0.101 | 5.889 | 0.000 | 0.396 | 0.729 |
| Sigma2 | 105.8981 | 8.116 | 13.048 | 0.000 | 89.991 | 121.80 |
| Ljung-Box (L1) (Q): | | | 2.08 | Jarque-Bera (JB): | | 235.38 |
| Prob (Q): | | | 0.15 | Prob (JB): | | 0.00 |
| Heteroscedasticity (H): | | | 12.62 | Skew: | | 2.19 |
| Prob (H) (two-sided): | | | 0.00 | Kurtosis: | | 11.84 |
| ADF – Statistic | | | 2.0938 | P-Value | | 0.9987 |

In the last row of Table 1.1, the test ADF is performed. This test shows that the data used in this paper are not likely to be stationary. Because, the P-Value obtained in this test is equal to 0.9987 which can provide a sufficient reason for non stationarity of data. Therefore, Arima model was estimated by the first-order differential equation in which the coefficient of variation of apple production in previous periods was calculated equal to 0.5939, which is significant at the alpha level of 5% (P>|z|=0.000).

The confidence interval obtained in the model shows that the coefficient of difference of apple production in previous periods, which has a significant effect on the production of apples in the future, can not be more than 0.792 and less than 0.396 at the level of 95%. According to the calculations, ARIMA(1, 1, 0) can be arranged as follows.

$$Y_t' = \phi_0 + \phi_1 Y_{t-1}' + \phi_2 Y_{t-2}' + \ldots + \phi_p Y_{t-p}' + \varepsilon_t \quad (1.5)$$

$$Y_t' = 0 + 0.5939 Y_{t-1}' + \varepsilon_t, \quad Y_t' = Y_t - Y_{t-1}, \ Y_{t-1}' = Y_{t-1} - Y_{t-2}$$

$$\hat{Y}_t = 1.5939 Y_{t-1} - 0.5939 Y_{t-2} \quad (1.6)$$

Equation 1.6 is a model that will be used to predict the amount of apple production in the coming years. This model is derived from a first-order differential equation. In this model, it is clear that apple production this year ($Y_t$) is a direct function of the amount of apple production last year ($Y_{t-1}$). This means that the amount of apple production in 2020 is directly related to the amount of apple production in 2019, and the coefficient of impact of the amount of apple production in 2019 on the amount of apple production in 2020 is equal to 1.5939 per unit.

Similarly, since the data used in this paper were not stationary and were converted to stationary data by taking the first-order difference, the model was obtained as a first-order differential equation (eq 1.5). In such a model, the forecast of apple production in the desired year is a function of the amount of apple production in the previous two periods. So it can be said more clearly that the amount of apple production in 2020, in addition to being affected by the amount of apple production in 2019, will also be negatively affected by the amount of apple production in 2018. Finally, the impact factor of apple production in 2018 on apple production in 2020 is equal to 0.5939 (eq 1.6).

Considering Equation 1.6, we calculate the amount of apple production in the years 2020 to 2029 (table 1.2).

Table 1.2. **Predicts the amount of apple production in the years 2020 to 2029**

| Years | Model [$\hat{Y}_t = 1.5939Y_{t-1} - 0.5939Y_{t-2}$] | Forecasting APP (Tones) |
|---|---|---|
| 2020 | $\hat{Y}_t = 1.5939(2019 = 250.32) - 0.5939(2018 = 217.19)$ | 270.00 |
| 2021 | $\hat{Y}_t = 1.5939(2020 = 270.00) - 0.5939(2019 = 250.32)$ | 281.68 |
| 2022 | $\hat{Y}_t = 1.5939(2021 = 281.68) - 0.5939(2020 = 270.00)$ | 288.62 |
| 2023 | $\hat{Y}_t = 1.5939(2022 = 288.62) - 0.5939(2021 = 281.68)$ | 292.74 |
| 2024 | $\hat{Y}_t = 1.5939(2023 = 292.74) - 0.5939(2022 = 288.62)$ | 295.19 |
| 2025 | $\hat{Y}_t = 1.5939(2024 = 295.19) - 0.5939(2023 = 292.74)$ | 296.64 |
| 2026 | $\hat{Y}_t = 1.5939(2025 = 296.64) - 0.5939(2024 = 295.19)$ | 297.51 |
| 2027 | $\hat{Y}_t = 1.5939(2026 = 297.51) - 0.5939(2025 = 296.64)$ | 298.02 |
| 2028 | $\hat{Y}_t = 1.5939(2027 = 298.02) - 0.5939(2026 = 297.51)$ | 298.33 |
| 2029 | $\hat{Y}_t = 1.5939(2028 = 298.33) - 0.5939(2027 = 298.02)$ | 298.51 |

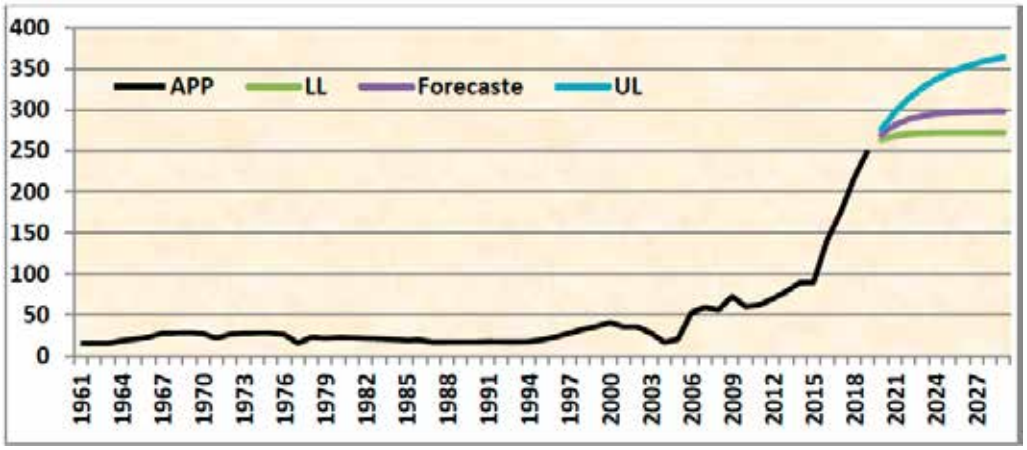


**Figure 1.1.** Dynamics of apple production (1961-2019) and its forecast (2020–2029)

Apple production in 2020, 2021, 2022 and 2029 are predicted to be 33, 44, 44 and 77 tons, respectively, using the ARIMA (1, 1, 0) model obtained. Estimates of the amount of apple production during the years 2020 to 2029 show that the trend of apple production in Afghanistan is increasing and each year compared to the previous year, the amount is more and more. If 2019 is considered as the base year, in 2028 and 2029, the growth rate of apple production will be 19.17% and 19.25%, respectively (table 1.2).

Apple production in Afghanistan before 2005 does not look very impressive. Because, before the year 2000, the people of this country were suffering from foreign and domestic civil wars, which not only destroyed the agricultural sector, but also destroyed major parts of the real economy. But since 2005, apple production in Afghanistan has increased dramatically and dramatically. The reason for the increase in apple production in this period could be the reduction of the war in the country, investment in the agricultural sector, familiarity with new horticultural models, use of agricultural technology, taming of barren lands, etc. Similarly, the forecast shows that apple production is increasing, but in recent years the growth rate of apple production seems to be slower (fig 1.1).

## Conclusion

This article is written to study the amount of apple production and its forecast in Afghanistan. At first, the weather conditions and fruit gardening facilities in general and apples in particular in Afghanistan were discussed, and then the research literature on the production and estimation of apple production was studied.

The model used in this study was ARIMA (1, 1, 0), and the results show that the amount of apple production in the previous two periods significantly affects the amount of apple production in the next period. Apple production in 10 years (2020–2029) was estimated using the first-order differential equation, and calculations show that the growth rate of apple production in Afghanistan has been increasing in recent years, but growing slowly. The results show that the amount of apple production in the current period is positively affected by the amount of apple production in a previous period ($Y_t$). But the amount of apple production in the current period has a negative reaction according to the amount of apple production in the previous two periods ($Y_{t-1}$).

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