



## Regarding the prediction of fruit yield dynamics

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### Abstract

Pomology serves as a source of essential food products and raw materials for industry. Fruits possess unique medicinal properties, offering undeniable nutritional and dietary benefits due to their content of fructose, glucose, organic acids, vitamins, pectins, and mineral salts. The function of the fruit is to preserve the seeds that contribute to the spread of flowering plants, i.e. the seeds are a way of propagating plants. Fruit is a valuable food containing an irreplaceable complex of vitamins, enzymes and other biologically active substances necessary for maintaining human health. This study covers the period of fruit growing in farms of all categories of autonomy for the years 1995-2018, i.e. the last 24 years. A brief analysis of production indicators shows that from 1995 to 2018, with an increase in yield by 119.4 c/ha, the cultivated area decreased by 58.4%, while the gross grain harvest increased by more than 3.7 times. The positive dynamics in fruit production are not only due to their social significance, which allows for assessing the country's food security, but also to their reasonably acceptable efficiency in the food market.

**Keywords:** Yield, Fruit, Production potential, Land productivity potential

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### 1. Introduction

Agriculture is a vital part of the national economy for the Republic of Moldova, as well as for the Autonomous Territorial Unit of Gagauzia, serving as one of the primary sources of employment in both the country and the autonomous region.

The effectiveness of agriculture depends on socio-economic factors such as land use patterns, the extent of agricultural lands, and the level of development and implementation of scientific advancements and technology (Siptits, 2017).

Fruits will never lose their popularity. After all, they contain so many vitamins, and no modern consumer dish can do without them. Fruits have always been considered a decoration for a festive table. There has been consistently high demand for fruits throughout the year (Parmakli, 2016).

The domestic production of fruits is a crucial component of the Republic of Moldova's food security. Fruits have consistently maintained a high demand over many years. Consumers are increasingly concerned about the safety and quality of fruit and vegetable products. Therefore, during the research, an analysis was conducted and calculations were made regarding the growth (or decline) rates of harvesting areas, gross fruit harvest, and yield (Parmakli et al., 2017).

For the Republic of Moldova, whose economy is predominantly determined by agricultural development, forecasting the dynamics of fruit yields is of vital importance. Consequently, research aimed at analyzing and calculating the dynamics of fruit yields remains highly relevant.

Studies by various authors indicate that increased fruit consumption contributes to an extended lifespan. Presently, the fruit-growing industry, with products in



constant demand, faces certain challenges (Bajura et al., 2018).

**2. Material and Methods**

In this study, fruit trees grown in the Gagauz autonomous region of Moldova were used as material.

Scientific research is based on the utilization of individual methods. The following methods were utilized during the research: statistical-economic, economic-mathematical, analysis and synthesis, calculation formulas, and trend dynamics.

One of the simplest, most visual, and accessible methods is the graphical method. Forecasting results are obtained through trend analysis over the last 5 years or more.

To use the graphical analytical method for forecasting, the graph should display two types of trends: linear and polynomial, along with equations and approximation coefficients for each. It is known that the polynomial trend better reflects the growth trend of indicators due to its higher approximation coefficient. With this trend, fluctuations in the indicator are smoother, the approximation coefficients are significantly higher, thus the equations more objectively reflect the trend, resulting in more accurate predictions based on this graph (Doga and Bajura, 2016).

Since the indicators for the two trend lines (linear and polynomial) differ, we take the average values as predictive. Therefore, for forecasting indicators for the next two years (2019 and 2020), we utilize both polynomial and linear trends.

During the analysis, calculations were made for the rates of increase (decrease) in harvesting areas, gross fruit yield, and productivity. In absolute terms, the average annual increase in harvesting areas ( $\Delta S_{cp}$ ) is calculated using the equation:

$$\Delta S_{cp} = \frac{S_k - S_H}{n - 1} \tag{1}$$

Where:  $S_k$  and  $S_H$  are indicators of harvesting areas at the end and beginning of the period, respectively, and  $n$  is the number of years in the studied period.

In relative terms, the increase is estimated according to the expression:

$$\Delta S_{cp}^{or} = \sqrt[n-1]{\frac{S_k}{S_H}} \tag{2}$$

The increase in areas according to Equation 1 amounted to:

$$\Delta S_{cp} = \frac{2138 - 5141}{24 - 1} = -130.5 \text{ hectares.}$$

The growth in areas according to Equation 2 will be:

$$\Delta S_{cp}^{or} = \sqrt[n-1]{\frac{2138}{5141}} = 0.96$$

Therefore, on average per year, the fruit harvesting area decreased by 130.5 hectares or 4.0%.

The average annual increase in produced grain was:

$$\Delta Q_{cp} = \frac{Q_k - Q_H}{n - 1} = \frac{36265 - 9808}{24 - 1} = 1150,3 \text{ ton}$$

In accordance with Equation 2:

$$\Delta Q_{cp}^{or} = \sqrt[n-1]{\frac{Q_k}{Q_H}} = \sqrt[n-1]{\frac{36265}{9808}} = 1.06$$

Thus, fruit production increased annually by 1150.3 tons or 6.0%.

The yield of fruits per hectare in 1995 was 19.1 quintals, and by the end of the period in 2018, it was 138.5. According to formula 3, the average annual increase amounted to 5.19 quintals/hectare. In relative terms, the increase was 1.09 or 9% per year.

The established indicators of the average annual yield and their annual increases for all crops in the studied regions over the 24 years are presented in Table 1. It is worth noting the rapid pace of yield growth for most cultivated crops by Moldovan farmers, trailing only in vegetables in this aspect. The data from Table 1 is visually represented in the graph (Figure 1).

Table 1. Changes in fruit production indicators on an average annual basis in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for the years 1995 to 2018

Indicators	Average Annual Indicator	Growth per Year	
		Total	%
Harvesting Area, ha	3245.5	-130.5	-4.0
Gross Yield, tons	9762.4	1150.3	6.0
Yield, quintals per ha	37	5.19	9.0

Source: Conducted according to the methodology presented above (Anonymous, 2023a)

The described methods in this scientific study (economic, sociological, physical, etc.) operate in synergy. Analysis elements are an integral part of this research, transitioning from describing fruit yield to identifying its structure, characteristics, and attributes.

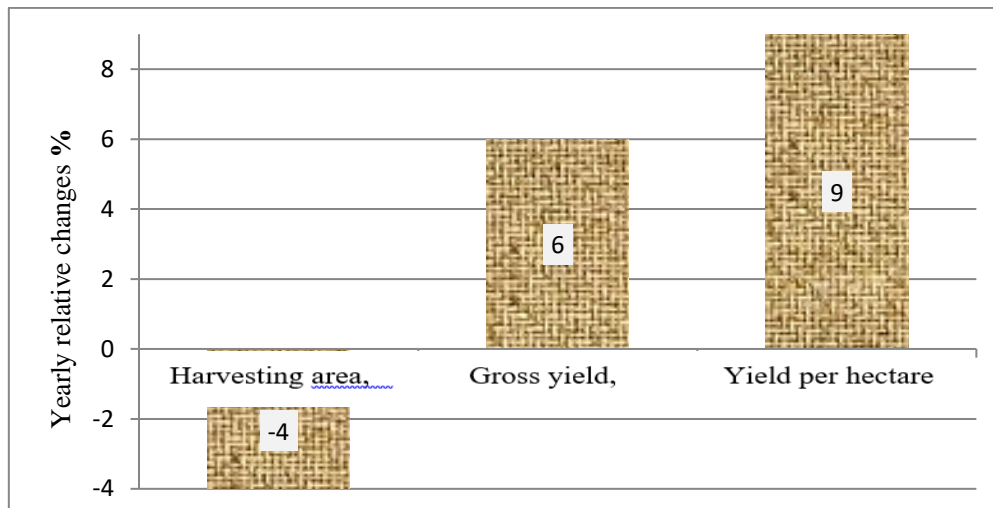


Figure 1. Average annual growth of fruit production indicators in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for 1995-2018 (Source: compiled from Anonymous (2023b))

### 3. Results and Discussion

The research has indicated that with roughly equal yield values, the economic evaluation can significantly differ. Hence, giving an economic assessment based solely on the absolute magnitude of yield values is inappropriate. The above explanation will enable agricultural specialists, as well as educators and students in educational institutions, to justify the economic evaluation of the obtained yield indicators for each cultivated crop on the farm (Anonymous, 1994).

We calculated harvesting area, gross yield, and fruit yield indicators using the moving average method. We have chosen a 4-year moving average.

The data in Table 2 show that using a 4-year moving average reduces the coefficient of variation for harvested areas from 45.3% to 44%, or by a factor of 1, for gross yield from 81.8% to 50.7%, or by 1.6 times, and for yield from 95% to 76.8%, or more than 1.2 times. Naturally, the range of variation values decreases by a factor of 1 for harvested areas, by more than 1.8 times for gross yield, and by more than 1 time for yield.

To partially neutralize the influence of natural factors on the instability of production, we will calculate forecast indicators using the method of finding the moving average. For this purpose, we will utilize the average values of the four-year moving averages, as presented in Table 2. Figure 2 illustrates the dynamics of gross fruit yield over the investigated period, indicating two trend options: linear and polynomial.

Calculate the forecasted gross fruit yield using the linear trend equation ( $y = 139.29x + 7008.8$ ):

Gross fruit yield in 2019:  
 $y = 139.29 * 22 + 7008.8 = 10074$  tons

Gross fruit yield in 2020:  
 $y = 139.29 * 23 + 7008.8 = 10213$  tons

Calculations based on the polynomial trend line equation ( $y = 98.252x^2 - 2022.3x + 15295$ ):

Gross fruit yield in 2019:  
 $y = 98.252 * 22^2 - 2022.3 * 22 + 15295 = 18358$  tons

Gross fruit yield in 2020:  
 $y = 98.252 * 23^2 - 2022.3 * 23 + 15295 = 20757$  tons

Therefore, the forecasted gross fruit yield in 2019 will be 14216 tons ( $= (18358 + 10074) / 2$ ), and in 2020 will be 15485 tons ( $= (20757 + 10213) / 2$ ) (Figure 3).

### 4. Conclusion

In Moldova, two decades ago, cooperatives of small farmers were purposefully created, with the organizational and financial support of international donors, as socio-economic clusters to combat poverty in rural areas of Moldova. But large volumes of products of uniformly high quality (from the point of view of the strictest standards of international supermarket chains) can be obtained by agricultural producers only if their plantations are under a single agronomic management. If their products are sorted and packed in a uniform container, and it will be sold by a highly qualified sales department. Even wealthy farmers will be able to afford all this only by joining together in a cooperative, making joint investments in production/export infrastructures and a staff of specialists. It is obvious that such associations will have a synthesis character, combining the features of both entrepreneurial and production cooperatives, industry associations, and marketing groups (Curaxina, 2015).

Table 2. Annual and average annual fruit production indicators in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for the years 1995-2018

Year	Harvested area, ha		Gross yield, t		Yield, c/ha	
	per year	for the last 4 years	per year	for the last 4 years	per year	for the last 4 years
1995	5141		9808		19.1	
1996	5127		5398		10.5	
1997	5609		21208		37.8	
1998	5046	5231	13020	12359	25.8	23.3
1999	4970	5188	1246	10218	2.5	19.2
2000	4539	5041	4985	10115	11.0	19.3
2001	4265	4705	8725	6994	20.5	15.0
2002	4059	4458	4842	4950	11.9	11.5
2003	3808	4168	15403	8489	40.4	21.0
2004	4098	4058	6007	8744	14.7	21.9
2005	3935	3975	10202	9114	25.9	23.2
2006	3956	3949	6937	9637	17.5	24.6
2007	3249	3810	3724	6718	11.5	17.4
2008	2442	3396	7141	7001	29.2	21.0
2009	2733	3095	1581	4846	5.8	16.0
2010	2080	2626	3625	4018	16.6	15.8
2011	958	2053	2735	3771	24.5	19.0
2012	1042	1703	4309	3063	41.4	22.1
2013	1333	1353	7753	4606	58.2	35.2
2014	1533	1217	10596	6348	69.1	48.3
2015	1716	1406	12481	8785	72.7	60.4
2016	1847	1607	23084	13479	124.9	81.2
2017	2269	1841	13222	14846	58.3	81.3
2018	2138	1993	36265	21263	138.5	98.6
On average	3245.5	3184	9762.4	8541	37	33
Range of variations	4651	4014.3	35019	18200.5	136	87.1
Annual average deviation	1470.8	1393.8	7984.8	4333.8	35.2	25.4
Coefficient of variation, %	45.3	44	81.8	50.7	95	76.8

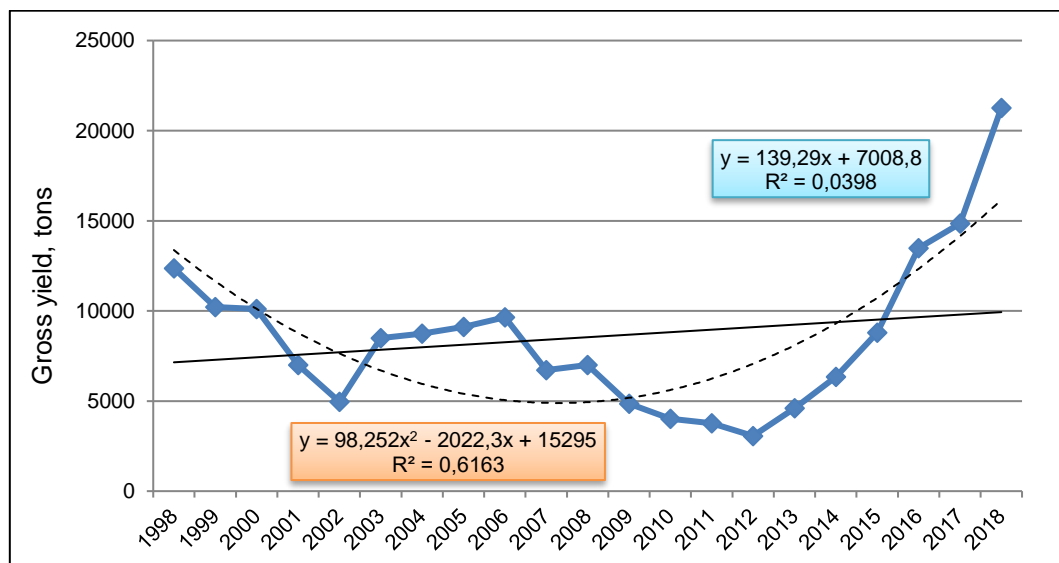


Figure 2. Dynamics of the four-year moving average of gross fruit yield in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for 1998-2018

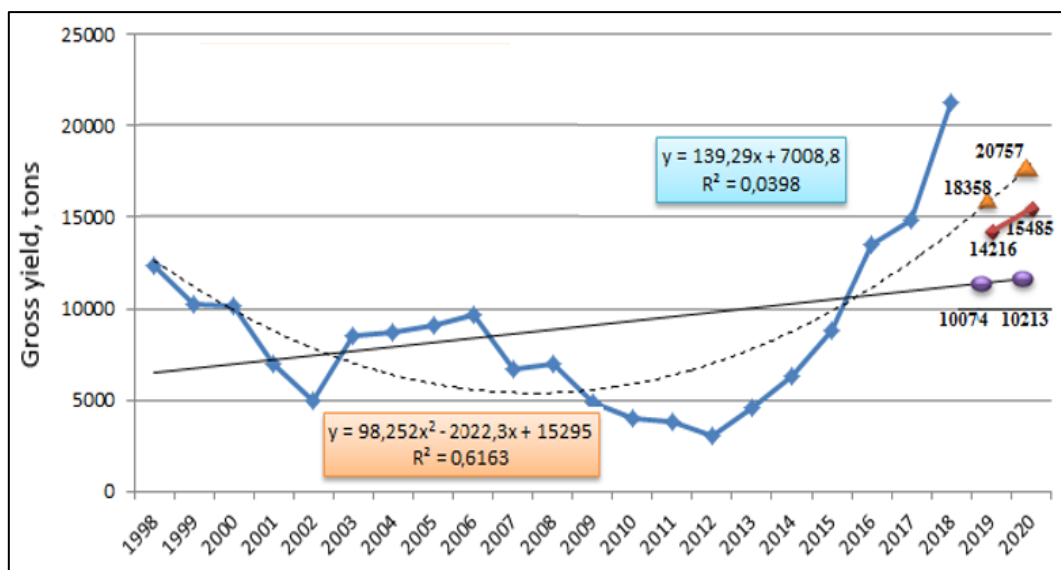


Figure 3. Forecast indicators of gross fruit yield in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for 2019-2020

As the experience of such a developed country as Germany shows, cooperation in agriculture is more relevant than ever, and this phenomenon is much broader than the unification of peasant farms. Intensive farming and the need for the use of new technologies require deep knowledge in a variety of fields. However, despite the fact that the introduction of a scientific approach from management to biotechnology is an impossible task even for the largest farms, cooperatives and their associations manage to solve issues on the application of advanced scientific methods for all members, as well as on training and retraining of personnel. They provide their members with all available scientific and technical potential on equal terms, regardless of the size of the farm and the share of the contributor (Parmakli and Todorich, 2013). To conduct forecast calculations of land productivity, let's construct graphs illustrating the dynamics of yield based on the moving averages for the years 1998-2018 (Figure 4), indicating two trend options: linear and polynomial (Timofti and Popa, 2009).

Moldova has accumulated a certain experience of cooperation among producers of table grapes. The total area under the vineyards is 1.5 thousand hectares, the members of the cooperative have plots under grapes of different sizes—from 0.2 to 30 hectares. Previously, they exported grapes “from the wheels”, that is, they sent their products directly from the field to the consumer without any storage. Over time, agricultural producers realized that by uniting in cooperatives, it is possible to increase the area of vineyards and create storage facilities and on this basis ensure higher efficiency of agribusiness. In such

cooperatives, grapes are harvested and immediately placed on rapid cooling to preserve the quality of the products. Modern cooling rooms are an important link in the process of storing the crop, here the products are cooled from +40 to + 4-6 degrees in 4 hours. Introducing modern technologies, specializing in the production of table grapes, today, on average, cooperatives collect up to 20 kg of grapes from one bush. Its own packaging in the form of boxes is designed for 9 kg of product. Let's calculate the forecasted yield values using the linear trend equation ( $y = 3.0993x - 0.9961$ ):

Yield in 2019:  
 $y = 3.0993 * 22 - 0.9961 = 67 \text{ c/ha}$

Yield in 2020:  
 $y = 3.0993 * 23 - 0.9961 = 71 \text{ c/ha}$

Calculations based on the polynomial trend equation ( $y = 0.4366x^2 - 6.5051x + 35.821$ ):

Yield in 2019:  
 $y = 0.4366 * 22^2 - 6.5051 * 22 + 35.821 = 105 \text{ c/ha}$

Yield in 2020:  
 $y = 0.4366 * 23^2 - 6.5051 * 23 + 35.821 = 117 \text{ c/ha}$

Thus, on average, the forecasted yield for 2019:  
 $(67 + 105) / 2 = 86 \text{ c/ha}$ ,

and for 2020:  
 $(71 + 117) / 2 = 94 \text{ c/ha}$ .

To visualize the forecasted yield indicators, we will depict them on the graph for clarity (Figure 5).

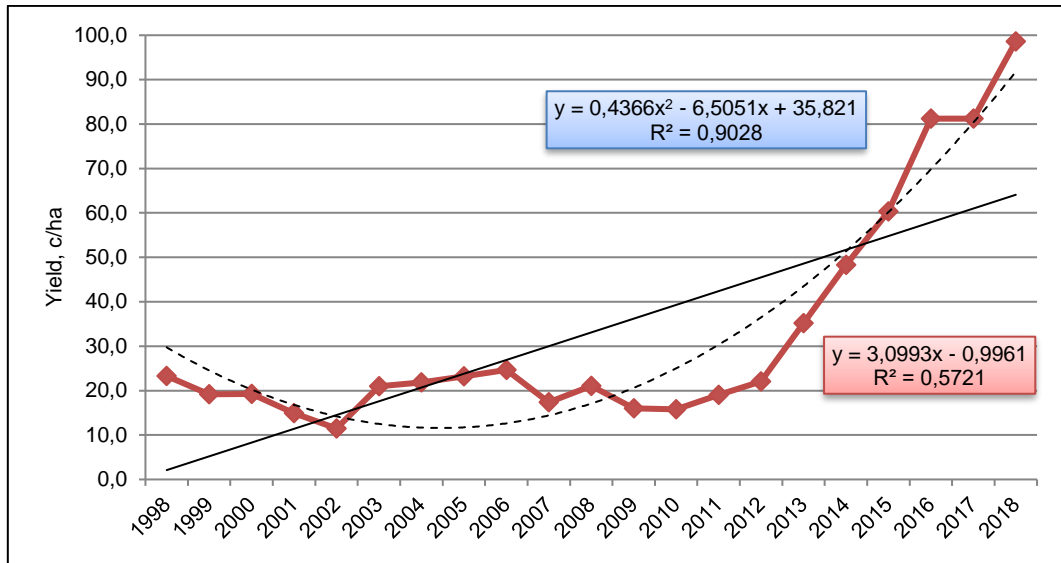


Figure 4. Dynamics of the four-year moving average of fruit yield in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for 1998-2018

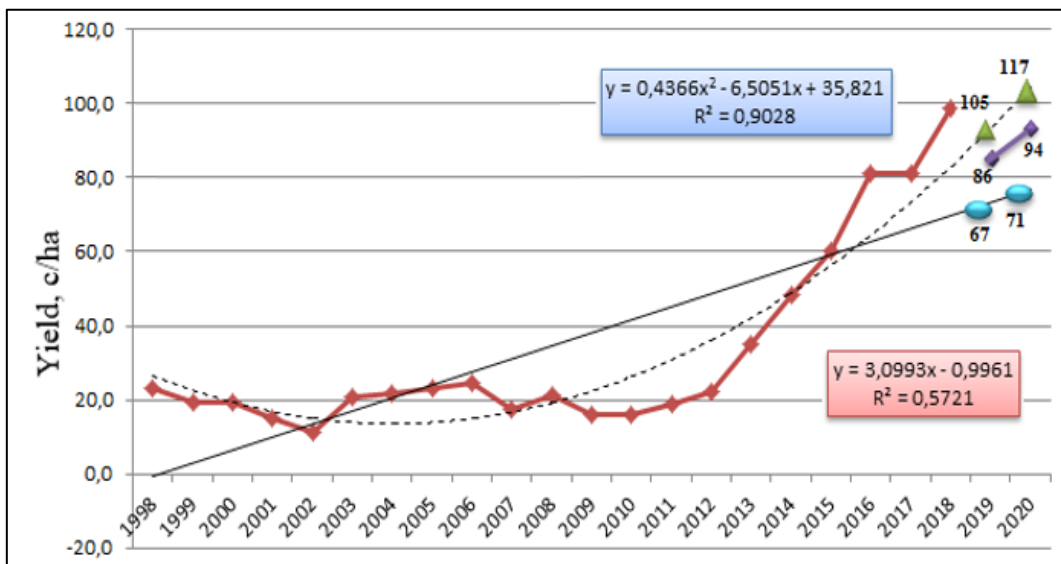


Figure 5. Forecast indicators of fruit yield in agricultural enterprises of the Autonomous Territorial Unit of Gagauzia for 2019-2020

To employ the graph-analytical method of forecasting, the graph should display two types of trends: linear and polynomial, along with the equations and coefficients of approximation for each. It's known that the polynomial trend better reflects the upward trend of indicators due to its higher coefficient of approximation. In this trend, fluctuations in the indicator are smoother, the approximation coefficients are significantly higher, thus the equations more objectively reflect the trend, resulting in a more accurate forecast based on this graph (Altukhov, 2016).

As the indicators from the two trend lines (linear and polynomial) differ, the average values are taken as predictive. Therefore, for forecasting indicators for the

next two years (2019 and 2020), we utilize both polynomial and linear trends.

**Conflict of interest**

The authors declare that there is no conflict of interest.

**Ethical Approval**

For this type of study, formal consent is not required.

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