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Article

Forecasting Gross Yield in Agriculture Using The Arima Model: The Case of Cereal Crops

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Abstract: Forecasting gross yield in agriculture, particularly for cereal crops, using the ARIMA (Autoregressive Integrated Moving Average) model has become a vital tool for agricultural planning and risk management. The ARIMA model is adept at analyzing time series data, allowing for the identification of trends and seasonal patterns in crop yields. In recent studies, ARIMA has been successfully applied to predict cereal crop yields over various time frames. For instance, forecasts indicate that cereal crops are expected to show increasing trends from 2020 to 2030, highlighting the model's capability to capture underlying growth patterns in agricultural production. The model's strength lies in its ability to incorporate historical yield data, which helps in making informed predictions about future outputs. This is particularly important in regions where agricultural productivity is influenced by climatic variations and market dynamics. By utilizing ARIMA, farmers and policymakers can better anticipate yield fluctuations, enabling them to implement strategies that enhance food security and optimize resource allocation. Overall, the application of the ARIMA model in forecasting cereal crop yields not only aids in understanding potential agricultural outputs but also supports the development of effective agricultural policies and practices.

Keywords: Agriculture, grain crops, regression equation, dynamic series, factors, model, perspective, forecast, elite seeds, efficiency.

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1. Introduction

It is known that the standard of living of the population of each country depends more on the level of supply of the basic types of food products necessary for living of the population. In this, flour, rice, bakery products, pasta, cereals and other products obtained from grain crops have a special place. Our republic the population of the world is among the countries that consume cereal products more than the average. In our opinion, this is mainly due to the high consumption of products obtained from cereal crops, which have become a tradition in our national traditions. Therefore, taking into account the growth of the population, the development of forecast indicators of the cultivation of cereal crops is the most relevant today. is one of the issues.

Correlation-regression analysis of statistical forecasting, which allows to determine the form and density of the connection between the resulting indicator and the factors, can be effectively used to determine the future parameters of grain crops cultivation. In the scientific literature on forecasting, it is possible to observe that various options, methods and methods of forecasting the volume of production and its market conjuncture are used.

R.F. According to Djumanova, there are 130 different methods of making forecasts in practice, and social-economic processes can be conditionally divided into z different important groups. They consist of extrapolation method, expert assessment method of forecasting and modeling methods.[1]

LITERATURE REVIEW

Economists and experts on the importance of ensuring the stability of grain production and its beneficial aspects in their research and international conferences. have passed By them, the practices of increasing the production of grain products in a natural and intensive way, the role of grain products in the country's economy and their positive aspects according to the existing conditions of their time. have shown. According to Atabaeva Kh.N., Wheat is one of the most common cereal crops. More than half of the world's people use wheat bread as food. [2] According to A. Kh. Burkhanov, wheat bread has a lot of protein and starch in it, and high-quality bread is made from its flour because the protein molecules are mainly in gluten [3].

Z.M. Ilina suggests using the following approaches for the analysis of the stability of the food market in agriculture: static (determining the limits of market development); dynamic (study of the vibration of a series of speakers); adaptive (factorial assessment of the degree of adaptation of the food system to changes in external conditions) [4]:

In our article on the topic "Analysis of the trade situation of agricultural products of the Commodity Exchange of the Republic of Uzbekistan", we analyzed a number of economic indicators and analyzed the sustainable development of the food system, especially in agriculture. we found that the activity of the exchange mechanism in the trade of grain products is directly related to grain stability [5].

Organizational and economic mechanisms of ensuring food sustainability in agriculture, according to their object and scale (food market, agricultural production, investment activity, state regulation, growth stability, strategy implementation, etc.) structural elements are proposed in the works of foreign scientists in the field of agriculture: E.F. Zavorotin, V.Z. Mazloev [6][7].

It can be observed that various options, methods, methods of forecasting the volume of production and its market conjuncture are used in the scientific literature about grain crop forecasting. R.F. According to Djumanova, there are 130 different methods of making forecasts in practice, and social-economic processes can be conditionally divided into z different important groups. They consist of an extrapolation method, an expert assessment method of forecasting, and modeling methods [8].

2. Materials and Methods

The linear regression method of modeling and formulas of ARIMA models from the stata program were used in forecasting the production of grain crops in agriculture. This method makes it possible to determine the factors affecting the development of grain crops and to assess their impact level, and determines the prospects for the development of grain crops in agriculture.

3. Results

Analyzing the volume of grain crops grown in our republic in 2000-2022, in 2000, 3929.4 thousand tons of grain crops were grown in our republic, and by 2022, 7913.1 thousand tons were grown. We can see an increase of 201.3 percent in 2022 compared to 2000. Also, many models for assessing food safety and ensuring its sustainability have been developed in the world, and we can give examples of these models as simulation and forecasting models. These models are successfully used in countries with a high level of food security, forecasting models such as EPACIS, ARMA, Aglink, ARFA are used to assess food security at the macro level.

y = Gross yield, thousand tons 1/ha

x1 = Cultivated area in thousand /ha

x2 = Soil fertility (point credit)

x3 = Mineral fertilizer, 1 ha.kg

x4 = The share of the area planted with elite seeds in the total area of crops, in %;

x5 = Provision of required techniques and equipment in the implementation of agrotechnical activities, in %

x6 = Provision of machinery for agrotechnical activities, 100 ha, (thousand) horse power

Based on the values of the above factors, the following correlation matrix of pairwise correlation coefficients representing the relationship between the factors influencing the change in the size of grain crops was generated by the STATA program. We have sufficient and average statistics of the gross yield indicators of the factors in the period 2000-2023. The model consists of one component. These include the autoregressive (AR) and moving average (MA) components. Based on the data of the components of the ARMA model, the value of the autoregressive component variable in the current year depends on its values in previous years, and all the values of the autoregressive component must be within the unity range for the model to be stable.

To perform forecasting, we first perform a multivariate regression analysis [9]

$$y = \alpha_0 + \sum_{i=1}^{n} a_i x_i$$

here - the resulting indicator; - factors influencing the final indicator, - unknown parameters.

In order to determine the connection in the given linear model y=f(x1, x2, ..., xn), it is necessary to determine the parameters of the unknowns, for which it is appropriate to use the method of least squares. Using this method, it is possible to determine the unknown parameters by constructing the following system of normal equations and solving this system of equations:

$$\begin{cases} na_0 + a_1 \sum x_1 + a_2 \sum x_2 + \ldots + a_n \sum x_n = \sum y \\ a_0 \sum x_1 + a_1 \sum x_1^2 + a_2 \sum x_1 x_2 + \ldots + a_n \sum x_n x_1 = \sum y x_1 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ a_0 \sum x_n + a_1 \sum x_1 x_n + a_2 \sum x_2 x_n + \ldots + a_n \sum x_n^2 = \sum y x_n \end{cases}$$

After the number of unknown parameters exceeds 2, it is advisable to implement it using existing computer programs.

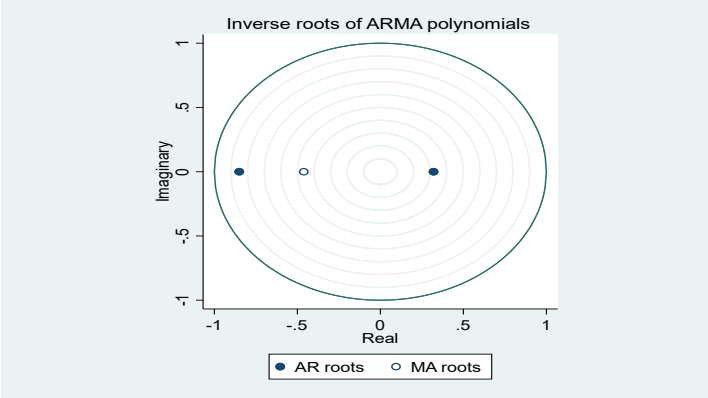

Figure 1. Stability analysis of the ARMA model.

As a result, as in the case of the autoregressive component, all values are within the range of unity for the model to be stable, and the criteria of the forecasting process "Stable" or "Unstable" are determined based on the values. In our analysis, both eigenvalues are within the unity range, (0.530 and -0.468) have a module (absolute value) less than 1, in this condition, the factors influencing the size of cereal crops grown in our republic are correctly selected, and the degree of interrelationship of the factors meets the "Stable" criterion (Figure 1). Therefore, AR parameters satisfy the stability condition. The condition states that all the eigenvalues of the MA process must be outside the unit range for the model to be invertible. The figure shows only one eigenvalue (0.272) for the MA process and its modulus is less than 1. However, to be consistent, all the eigenvalues are outside the unit range should be. It can be seen that based on the criterion of stability, based on the ARMA model forecast and the curve of actual values, it is the basis for developing the forecast of grain production stability and change dynamics for the coming years.

In this case, the gross yield indicators in the cultivation of cereal crops are considered as a result factor, and the factors affecting its change are: crop area per thousand /ha, soil fertility (point bonity), mineral fertilizer, 1 kg ha, elite in the total area of crops the share of the area planted with seeds, in %, the provision of the equipment and machinery required by the standard for the implementation of agrotechnical activities, in %, the equipment implementing agrotechnical activities factors such as reliability, 100 ha, (thousand) horse power were taken as a basis.

Using the following data of these factors, we will perform a multifactorial regression analysis.

Based on the values of the above factors, the following correlation matrix of pairwise correlation coefficients representing the relationship between the factors influencing the change in cereal production was generated by STATA software (Table 1).

Table 2

The matrix of pairwise correlation coefficients with the factors affecting the result indicator (indicators of the size of cultivated grain crops) and the degree of correlation between the factors

Accordingly, the following model was generated when performing the ARIMA model of multivariate linear regression model type in STATA software based on the above data (Table 2). The ARIMA model is one of the most popular models for short-term forecasting where:

A correlation coefficient of 1 indicates a perfect positive linear relationship, while a correlation coefficient of -1 indicates a perfectly negative linear relationship. A correlation coefficient of 0 indicates that there is no linear relationship between the two variables [10]. A positive correlation means that as the value of one variable increases, the value of the other variable tends to increase. Negative correlation means that as the value of one variable increases, the value of the other variable tends to decrease. As can be seen from the table, there is a strong positive relationship between Y and X. These represent the estimated effect of each independent variable (x1, x2, ..., x6) on the dependent variable (Y) in the linear model. For example, holding all other variables constant, the coefficient for x3 is 0.883, meaning that for each unit increase in x3, we expect Y to increase by an average of 0.883 units.

Pairwise correlation refers to the statistical evaluation of the relationship between two variables. The values in the table represent the correlation coefficients between each pair of variables. For example, the correlation coefficient between y and x1 is -0.321, which

has a weak negative correlation between the two variables, while it has a strong positive correlation with the variables x3, x5, and x6 (correlation coefficients above 0.7). Variable x1 has a strong negative correlation with variables x3 and x4 (correlation coefficients below -0.7) [11]. The presented table shows the results of the ARIMA regression model. This type of model is used to analyze time series data (Table 3).

Accordingly, the function of the change in the volume of grain crops cultivation is as follows, in which we can see the regression formula based on the coefficients in the model as follows;

$$У = 55406.446 + 2.602\ X_1 + 892.946\ X_2 + 8.649\ X_3 - 6.671X_4 - 52.256\ X_5 + 13.2X_6$$

We can observe this situation through the coefficient of determination.

$$D = R^2 = 0{,}899$$

In accordance with the results of the calculations made on the basis of the calculations of the developed ARIMA model, replacing the unknown numbers with the real numbers obtained using the models and formulas used above, a forecast of the change in the volume of grain crops in agriculture in our republic for the years 2024-2030 was developed based on the dynamics of the volume of grain cultivation in 2000-2023 [12].

It is known that the coefficient of determination (R2) in determining the overall quality indicator of a multifactor linear regression econometric model is calculated using the following formula:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{n}(y_i - \bar{y})^2}$$

Correlation coefficient in multifactorial model: R=0.89. Therefore, the degree of connection between the resulting factor and influencing factors is very high. The determination coefficient is also high: 〖D=R〗^2=0.89. It follows that the influence of the above factors on the change in the productivity of grain crops is 95%. The remaining 0.05% is due to other natural factors along with factors not considered here.

Based on the values of the above factors, it represents the relationship between the factors affecting the change in the productivity of grain crops and is related to the stability analysis. We can express this relationship through the ARMA model [13]. ARMA stands for autoregressive integrated moving average. It is a general statistical model used to forecast time interval data.

We have sufficient and average statistical data on the volume of grain grown under the influence of existing factor indicators for the years 2000-2023. Based on the above information, the following forecast values were obtained using the ARMA model [14]:

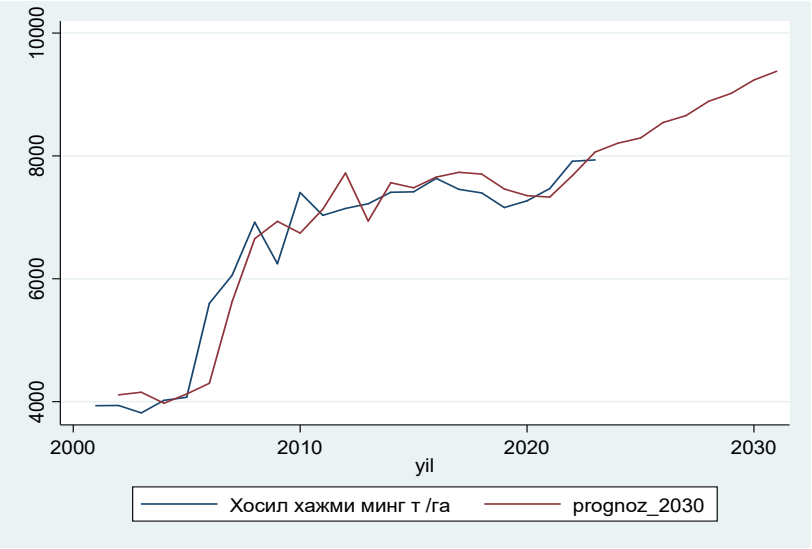

Figure 2. Dynamics of changes in the volume of grain crops based on the ARMA model forecast and the curve of actual values, thousand tons/ha.

(explanation*** ¬The blue line is the real situation, the red line is the future trend forecast based on the real situation data.)

From the figure, we can see that between 2000 and 2023, the forecast and the actual value are in high agreement (Figure 2). According to forecasts, the volume of grain crops is expected to grow steadily until 2030. Thus, it is expected that the indicators of the volume of grain crops in agriculture in our republic will exceed 9,000 thousand tons by 2030 compared to 2023 [15].

4. Conclusion

According to researches, forecasting of prospects is divided into macro-economic and micro-economic types based on the characteristics of the studied object. Correlation-regression analysis of statistical forecasting can be effectively used to determine the shape and density. As it is known, seed consumption is determined by taking into account the soil quality of the land and taking into account the moisture content of the soil. According to our conducted research, it is appropriate to use the multifactorial regression method in determining and analyzing the productivity indicators of grain crops depending on several factors. By finding a solution to this problem in the course of the research, it was determined the interrelationship of several factors affecting the productivity of grain production. However, while the cultivation of grain crops is expected to increase by 2030, taking into account the fact that the population will also increase, it is necessary to implement the following measures for the cultivation of grain crops in our republic. according to:

- Providing financial and material support by the state to scientific developments, selection works and measures aimed at the introduction of seed breeding and advanced technologies for the development of grain crops;
- Development of legal and regulatory documents aimed at protecting the interests of variety originators and research institutes in the seed breeding system and their implementation.
- Development of training manuals coordinated with foreign experiences in the development of grain crops.

- Focusing on the factors affecting economic efficiency in the sustainable development of grain crops, measures aimed at the introduction of seed production and advanced technologies, financial and material support from the state show;
- Development of legal-regulatory documents on the cancellation of state mandatory orders in the cultivation and sale of grain, organization of digitization of the grain market and their implementation.

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