Production of sugar beet in Russian Federation: analysis and forecast

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Abstract. The article analyzes the dynamics of indicators characterizing the production of sugar beets in Russia. The Krasnodar region, the Penza region and the Russian Federation as a whole were chosen as the object of study, the sown areas, the gross harvest and the yield of sugar beet were chosen as the subject of the study, and the period from 2005 to 2022 was chosen as the time interval. At the first step of the work, a primary analysis of the studied dynamic series is carried out, which showed a stable growth of indicators with a maximum jump in 2010. Next, regressions are constructed that describe long-term trends in the development of processes, for which, in most cases, quadratic functions are chosen. The next step is modeling the cyclical component and developing multiplicative trend-seasonal models, the error of which was 7.4% - 13.8%. As a result of the study, a forecast for the development of the industry for 2023-2024 is built.

1 Introduction

The production and consumption of sugar (and, as a result, sugar beets) can be regarded as an indicator of economic and political stability in our country, since any fluctuations lead to a rush demand for this product [1-5].

In European countries, beet sugar produces up to 80% of the total collection in the world [6]. China, the world's fourth-largest sugar producer after Brazil, India, and the European Union, 20% of sugar comes from sugar beets [7]. Sugar beet requires an abundance of sun, warmth and moderate humidity, therefore, in the Russian Federation, the cultivation of this crop is concentrated in the southern regions. On the lands of the Krasnodar region, the Volga and Chernozem regions, 51% of the total sugar beet is grown [7-10].

The purpose of this work is to consider the current state and trends in the production of sugar crops in the country and, based on the analysis, give a forecast for the development of the industry.

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2 Materials and methods

The object of study in the work was shown, characterizing the process of growing sugar beets in the Krasnodar region, the Penza region and the Russian Federation as a whole. In particular, y_1 - sown area, thousand ha, y_2 - gross harvest, million tons, y_3 - yield, cwt/ha. The information base of the study was the data of the Federal State Statistics Service [11]. The time interval of the study is the period from 2005 to 2021. Regression parameters were calculated using the STATISTICA package [12-13]. The results of the research are presented in graphical forms.

3 Results and Discussion

Primary analysis of data based on indicators of time series dynamics makes it possible to conclude that over the considered period of time [11-18], the volume of acreage allocated for sugar beet increased in all the studied regions (Fig. 1).

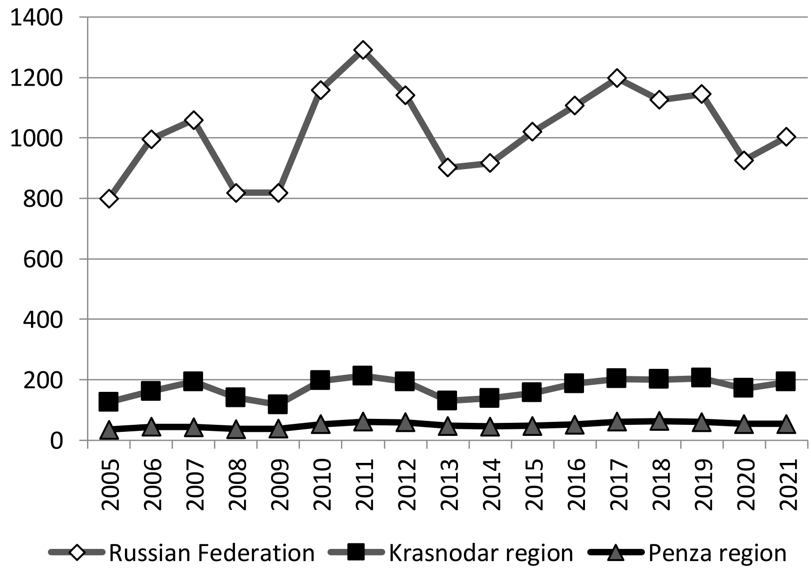

Fig. 1. Sugar beet sown areas, thousand ha [11].

For example, in the Penza region, the average growth was 3.8% per year, or 1.9 thousand hectares per year; in the Krasnodar region 5.15% or 8.84 thousand hectares; as a whole in the Russian Federation 2.7% or 27.7 thousand hectares per year. The strongest growth in sown areas in all regions was in 2010 (41% in the whole of the Russian Federation).

Conducting a component analysis of time series in order to model further changes in the dynamics of sown areas, a two-sample F-test for variance was carried out [12, 19-25], which showed the presence of a trend in all-time series, since, for example, the value of variances at the beginning and at the end of the time series for sown areas area in the Russian Federation differs by 2.8 times. Similarly for the time series of the Krasnodar region and the Penza region.

Carrying out a comparative analysis of several regression equations, the following were chosen as the trend equation in time series describing the dynamics of changes in sugar beet sown areas [26-27]:

- according to the Russian Federation: quadratic function $y_{11}=796.07+46.8t+1.89t^2+\varepsilon$, coefficient of determination $R^2=0.521$, hypotheses about the significance of parameters are accepted;
- for the Krasnodar region: exponential function $y_{12}=148.5e^{0.01t}$, $R^2=0.514$, parameters are significant;
- for the Penza region: a linear function $y_{13}=38.35+1.24t+\varepsilon$, $R^2=0.725$, the parameters are significant.

Based on the analysis of the autocorrelation function, which for the RF series took the values $f(\tau=1)=0.36$, $f(\tau=2)=0.32$, $f(\tau=3)=0.31$, $f(\tau=4)=0.02$, $f(\tau=5)=0.28$, we can conclude that there is a cyclical component in the dynamics of changes in sugar beet acreage in the whole of the Russian Federation with a period of $\tau=5$. In addition, the analysis of Fig. 1 makes it possible to assume a multiplicative relationship between the main trend and the cyclical component in the dynamics of time series [28-32].

Indicators of periodic fluctuations are seasonality indices, which show the differences between the corresponding levels of the series from the main trend. To determine them, it is necessary to find the average values of the same-name levels of the series composed of the ratios of the original series and the corresponding smoothed values using the trend equation [2].

As a result of modeling, the following seasonality indices were obtained: $I_1=0.975$, $I_2=1.086$, $I_3=1.111$, $I_4=0.913$ and $I_5=0.914$.

The indicated values indicate that in each five-year period, in the second and third years, there is an increase in the acreage of sugar beet by 8.6% - 11.1% relative to the average level set by the trend; in the remaining three years, there is a decrease of 2.5%, 7% and 6%, respectively. The coefficient of approximation of the obtained trend-seasonal model was A=7.8%.

Similarly for other regions:

- for the Krasnodar Region: seasonality indices: $I_1=0.954$, $I_2=1.094$, $I_3=1.167$, $I_4=0.911$ and $I_5=0.872$; approximation error A=10.6%;
- for the Penza region: seasonality indices: $I_1=0.953$, $I_2=1.053$, $I_3=1.104$, $I_4=0.964$ and $I_5=0.923$; approximation error A=9.2%.

The resulting models can be used to predict the dynamics of sown areas devoted to sugar beet in the regions of Russia [33-39]. So, for example, in 2023 the sown area of the Penza region should be 68.3 thousand ha, in 2024 - 60.9 thousand ha; in the Krasnodar region in 2013, the area will amount to 231.1 thousand ha, in 2024 - 182.9 thousand ha; in general, in the Russian Federation 1112.5 thousand ha and 889.9 thousand ha, respectively.

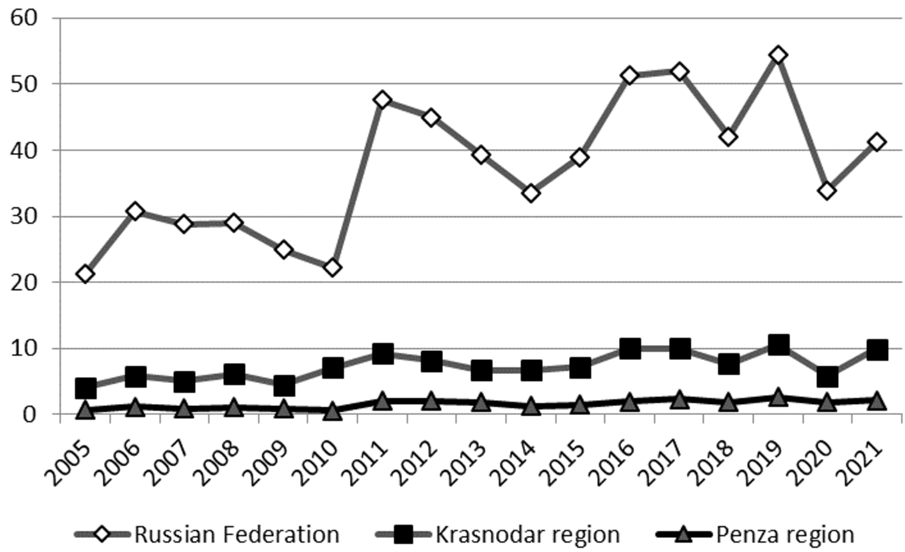

Fig. 2. Gross harvest of sugar beet, million tons [11].

Analyzing the gross harvest of sugar beet by regions of the Russian Federation (Fig. 2), it can be noted that there are general positive development trends [40-45]. The highest growth in the harvest of sugar beet was shown by the Penza region: an average of 18.8% or 0.3 million tons over the period, the average growth of the Krasnodar region was 10.5% or 0.77 million tons, the average growth in the whole of the Russian Federation amounted to 8.6% or 3.2 million tons. The largest growth in all regions occurred in 2011 (114% in the whole of the Russian Federation), which was the result of an increase in sown areas in 2010.

The regression equations describing long-term processes in the considered time series took the form [46-52]:

- according to the Russian Federation: quadratic function $y_{21}=12.8+4.18t+0.13t^2+\varepsilon$, coefficient of determination $R^2=0.894$, hypotheses about the significance of parameters are accepted;
- for the Krasnodar region: quadratic function $y_{22}=3.2+0.68t+0.02t^2+\varepsilon$, $R^2=0.9$, parameters are significant;
- for the Penza region: linear function $y_{23}=0.64+0.1t+\varepsilon$, $R^2=0.920$, the parameters are significant.

Similarly, to the above, in the time series of the gross harvest of sugar beet there is a multiplicative effect of the periodic component (period $\tau=5$):

- for the Russian Federation: seasonality indices: $I_1=0.856$, $I_2=1.169$, $I_3=1.127$, $I_4=0.947$ and $I_5=0.899$; approximation error A=12.8%;
- for the Krasnodar region: seasonality indices: $I_1=0.895$, $I_2=1.204$, $I_3=1.065$, $I_4=0.928$ and $I_5=0.906$; approximation error A=11.4%;
- for the Penza region: seasonality indices: $I_1=0.742$, $I_2=1.184$, $I_3=1.153$, $I_4=1.006$ and $I_5=0.913$; approximation error A=7.47%.

Forecast of the gross harvest of sugar beet:

- in the Russian Federation: in 2023 41.2 million tons, in 2024 38.12 million tons;
- in the Krasnodar region: 8.02 million tons in 2023, 7.7 million tons in 2024;
- in the Penza region: in 2023 2.56 million tons, in 2024 2.42 million tons.

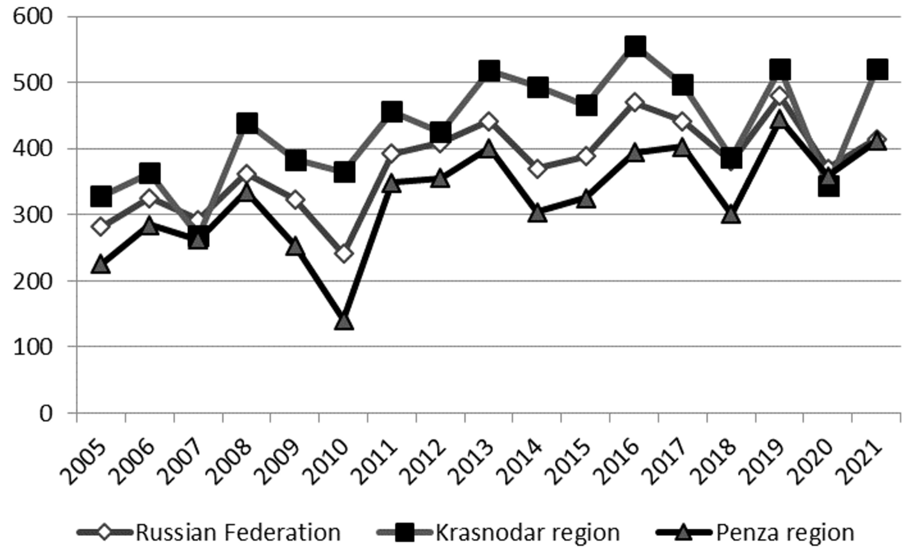

Fig. 3. Sugar beet yield, cwt/ha [11].

When analyzing sugar beet yields by regions of the Russian Federation (Fig. 3), one can note a general increase in time series trends, which indicates an increase in yield, as well as a lower volatility of processes, which indicates stability in yield dynamics. The average increase in the yield of sugar beet in the whole of the Russian Federation was 4.5% or 17.2 cwt/ha, in the Krasnodar region - 6.2% or 26.7 cwt/ha; in the Penza region - 10.2% or 33.5 cwt/ha.

In other words, the general combination of soil composition, seeds, fertilizers and plant care in the agricultural enterprises of the Penza region makes it possible to obtain large yields of sugar beet on smaller areas [53].

The regression equations describing long-term processes in the series of yield dynamics took the form:

- according to the Russian Federation: quadratic function y_{31}=224.1+25.3t+0.79t^2+ε, coefficient of determination R^2=0.893, hypotheses about the significance of parameters are accepted;
- for the Krasnodar region: quadratic function y_{32}=213.2+43.8t+1.78t^2+ε, R^2=0.866, parameters are significant;
- for the Penza region: linear function y_{33}=227.8+10.4t+ε, R^2=0.871, the parameters are significant.

The periodic component in all series has a multiplicative direction and period τ=5:

- for the Russian Federation: seasonality indices: I_1=0.888, I_2=1.069, I_3=1.018, I_4=1.038 and I5=0.985; approximation error A=8.9%;
- for the Krasnodar region: seasonality indices: I_1=0.944, I_2=1.119, I_3=0.902, I_4=1.018 and I_5=1.016; approximation error A=10.4%;
- for the Penza region: seasonality indices: I_1=0.804, I_2=1.085, I_3=1.063, I_4=1.074 and I_5=0.972; approximation error A=13.8%.

Sugar beet yield forecast:

- in the Russian Federation: in 2023 443.5 cwt/ha, in 2024 405.7 cwt/ha;
- in the Krasnodar region: in 2023 410.5 cwt/ha, in 2024 383.7 cwt/ha;
- in the Penza region: in 2023 457 cwt/ha, in 2024 423 cwt/ha.

4 Conclusion

In conclusion, it should be noted that the production of sugar and sugar beet in the Russian Federation fully covers the needs of consumers. This sector of agricultural production has a steady upward trend. As the results of the study showed, the forecast for the gross harvest of sugar beets: in the Russian Federation: in 2023 - 41.2 million tons, in 2024 - 38.12 million tons; in the Krasnodar region: in 2023 8.02 million tons, in 2024 7.7 million tons; in the Penza region: in 2023 2.56 million tons, in 2024 2.42 million tons.

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