Economic and mathematical modelling of regional market of grain crops

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Abstract. The article dwells upon the theoretical and applied issues of modeling grain yield at the regional level. In particular, traditional models of optimization of branch structure of the regional market of grain crops are considered, the block-diagonal economic and mathematical model of market production of grain crops is offered. The implementation of the proposed model will allow developing conceptual and methodological approaches to the definition of strategies for the development of the market of grain crops, to forecast the volume of production of grain crops in the regional context.

1. Introduction

Crop yield is an important generalizing indicator characterizing the level of development of agriculture in the region as a whole. In this regard, the task of improving methods of forecasting yields remains unconditionally relevant.

The yield depends on many factors, which can be divided into three groups by variability:
- stable factors (location, soil mechanical composition, biological features of plants);
- factors, which change from year to year occurs in one direction and has a positive impact on productivity (fertilization, reclamation, mechanization);
- factors which change in time affects either positively or negatively on the formation of the crop (meteorological factors and the state of crops).

According to the criterion of time, short-term, medium-term, long-term forecast. Different types of forecasts (short-term, medium-term, long-term) require different methods and approaches. For long-term yield forecasting, the method of analysis of interrelated series is used. For short-term and medium-term forecasts it is important to investigate the influence of factors of the third group on the yield, which is set by statistical methods and is written in the form of predictive equations. Factors of the second group are taken into account as an amendment to the trend of yield growth, which is expressed by the trend line or regression equation[1, 2].

It is difficult to foresee weather conditions of the planned years, therefore methods of forecasting productivity differ in the probabilistic approach, i.e. the forecast is given with a certain probability. In this paper, we consider the prediction of yield on Markov chains, which is based on the extrapolation of trends and provides an analysis of yields on groups of plots with different yields and analysis of the
probability of their transition from one group to another in the dynamics based on the transition probability matrices.

In the “Strategy of scientific and technological development of the Russian Federation”, approved by the decree of the President of the Russian Federation dated December 1, 2016 № 642, it is noted that “in the next 10-15 years the priorities of scientific and technological development of the Russian Federation should be considered those areas that will allow to obtain scientific and technical results ... and provide ... the transition to a highly productive and environmentally friendly agro- and water management”.

The cultivation of agricultural crops, including cereals, based on the optimization of their production management using economic and mathematical models in the region ensures the stability of highly productive crops, the preservation of fertility, prevents desiccation and will increase the level of resource conservation in conditions of differentiated sowing [3].

In this regard, the development and optimization of control parameters of production of grain crops on the basis of e modeling is an urgent problem for the effective use of water resources and stable high-yielding crops.

Traditional models for optimizing the sectoral structure of production in agro-economic systems of different levels allow to determine the need for seeds of agricultural crops, but do not take into account the varietal and reproductive composition of individual crops, while the yields of different varieties and reproductions differ significantly.

In this regard, the task of detailing the crops of grain crops in the context of varieties and reproductions in grain farms and determining the need for elite seeds and seeds of various reproductions is very important.

2. Materials and methods
Crop yield is an important generalizing indicator characterizing the level of development of agriculture in the region as a whole. In this regard, the task of improving methods of forecasting yields remains unconditionally relevant.

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   - Stable factors (location, soil mechanical composition, biological features of plants);
   - Factors, which change from year to year occurs in one direction and has a positive impact on productivity (fertilization, reclamation, mechanization);
   - Factors which change in time and affect either positively or negatively on the formation of the crop (meteorological factors and the state of crops) [4, 5].

   According to the criterion of time, short-term, medium-term, long term forecast. Different types of forecasts (short-term, medium-term, long-term) require different methods and approaches. For long-term yield forecasting, the method of analysis of interrelated series is used [6]. For short-term and medium-term forecasts it is important to investigate the influence of factors of the third group on the yield, which is set by statistical methods and is written in the form of predictive equations. Factors of the second group are taken into account as an amendment to the trend of yield growth, which is expressed by the trend line or regression equation.

   It is difficult to foresee weather conditions of the planned years, therefore methods of forecasting of productivity differ in the probabilistic approach and the forecast is given with a certain probability. In this paper, we consider the prediction of yield on Markov chains, which is based on the extrapolation of trends and provides an analysis of yields on groups of plots with different yields and analysis of the probability of their transition from one group to another in the dynamics based on the transition probability matrices [7].

   We propose a block-diagonal economic and mathematical model to optimize the sectoral structure of production in specialized seed farms, supplemented by the definition of the need for elite and reproductive seeds in the context of individual varieties for grain farms in the region.

   The model took into account that on the basis of science-based farming system, the share of grain in the structure of crops can vary from 50 to 60%, including winter grains - from 20 to 30 %.
For unknown for each block taken the area of grain crops seeds of the super elite in the context of varieties, acreage of forage crops, livestock of farm animals [8] the regional demand for seeds of super elite varieties of different crops produced by specialized farms from the originators of varieties and determine the volume of production of elite seeds of cultivated varieties.

In a separate block, which is an aggregated commodity economy of the region, the volumes of production of seeds of grain crops and commercial grain in the context of varieties and reproductions are modeled.

The system of restrictions, as well as the system of variables, is built on blocks. The main groups of restrictions are as follows: on the use of production resources for the production and sale of products, on the implementation of agrotechnical, zootechnical and organizational and economic requirements, etc.

General requirements for all blocks and the relationship between them are implemented in the connecting block. All elite seeds produced in seed farms of the region are sold to farms that are engaged in the cultivation of reproductive seeds and commercial grain. At the same time, the restrictions of the binding unit establish a relationship between the gross collection of seeds of a particular reproduction and the possible acreage for the harvest of subsequent reproductions at the appropriate seeding rates.

These restrictions do not impose strict obligations on enterprises in terms of the full use of seed for its intended purpose, it is also assumed that part of the seeds can be sold as commercial grain.

The gross harvest of the last grown reproduction and the unused part of the sowing material of the previous reproduction is commercial grain.

Thus, as a result of solving the optimization problem for each variety and culture, the duration of their cultivation will be determined by the number of reproductions used.

As a criterion of optimality, the maximization of the amount of net income is accepted. In the structural form of economic and mathematical model can be expressed as follows.

Find the maximum value of the linear function:

\[
Z_{\text{max}} = \sum_{j=1}^{n} c_j x_j - x_j
\]

where \( x_j \) - acreage of \( j \)-th agricultural crop of \( j \)-th type; \( c_j \) - commercial products obtained from 1 hectare of sowing of \( j \)-th crop; \( x \) - the amount of production costs of the agricultural enterprise.

Provided:
1. Restriction on availability of production resources:

\[
\sum_{j=1}^{n} a_{ij} x_j \leq b_i
\]

where \( i \) - ordinal restrictions; \( a_{ij} \) - inputs of production resources of the \( i \)-th type per hectare of sowing of the \( j \)-th crop; \( b_i \) - the amount of processing capacity of the \( i \)-th species available.

2. Auxiliary restriction for determination of production costs, labor costs and commodity production:

\[
\sum a_{ij} x_j = x_j
\]

where \( x_j \) - required values.

3. Performance of agrotechnical conditions of cultivation of crops and separate organizational & economic requirements:

\[
\sum_{j=1}^{n} x_j = G_i
\]

where \( G_i \) - upper or lower limits of crop rotation saturation by individual crops or groups of crops.

4. Ratio between different groups of crops:
\[
\sum_{j=1}^{n} w_{ij} x_j - \sum_{j=1}^{n} w'_{ij} x_j \leq 0
\]

where \(w_{ij}\), \(w'_{ij}\) - coefficient of proportionality.

5. Implementation of restrictions on the production and use of feed:

\[
\sum_{j=1}^{n} d_{ij} x_j - \sum_{j=1}^{n} v_{ij} x_j \leq 0
\]

where \(d_{ij}\) - the rate of feeding the \(i\)-th type of feed \(j\)-th species of animal; \(v_{ij}\) - the output of the \(i\)-th type of feed from 1 hectare of sowing of the \(j\)-th agricultural crop.

6. Determination of sales volumes of agricultural products:

\[
\sum_{j=1}^{n} q_{ij} \geq Q_i
\]

where \(Q_i\) - sales volume of the \(i\)-th type of agricultural products; \(q_{ij}\) - output of commercial products of the \(i\)-th type from 1 hectare of sowing of the \(j\)-th agricultural crop.

7. Condition of availability of livestock of farm animals:

\[
x_j \geq b_i
\]

where \(b_i\) - size of the \(i\)-th livestock industry.

8. The area of sowing for the harvest of the next reproduction should be provided with seeds from the current crop reproduction. This restriction is contained in the binding block, which simulates the commodity economy of the region:

\[
\frac{Q_t}{a_{r+1}} \geq x_{jr+1}
\]

where \(x_{jr+1}\) - the area of sowing for the harvest of the following reproduction; \(Q_t\) - the gross grain harvest in the current reproduction; \(a_{r+1}\) - seeding rate of grain seeds for the harvest of future reproduction.

9. The required values:

\[x_j \geq 0.\]

Thus, all conditions were recorded in mathematical form tasks to determine the optimal specialization and combination of industries in the studied elite-seed farms of the region.

One of the most important points in modelling is the preparation of reliable scientifically-based input information, from which the validity of the outcome of the decision will depend. During the preparation economic standards were used materials prepared research institutions, as well as obtained on the basis of practical activities directly in the enterprises themselves.

An important point in the development of the model is forecasting crop yields and simulation of agro-technical conditions of cultivation taking into account scientifically grounded crop rotations, resulting in the imposition of a particular culture or group of cultures limits the "bottom" and "top" depending on the agronomic requirements.

3. Conclusion

As a result of solving the economic and mathematical problem were determined:
- Optimal parameters of functioning of specialized seed farms with determination of production volumes of elite-seeds in them;
- Volumes of production of seeds of grain crops in the region in the context of varieties and reproductions;
- Optimal structure of acreage in the farms of the region, producing food and feed grain, in the context of varieties and reproductions;
- Volume of production of commodity grain.

Thus, the implementation of the above-mentioned model allows to develop conceptual and methodological approaches to determining the strategy of development of the market of grain crops, to
forecast the volume of production of grain crops in the region in the medium term in the context of crops, varieties and reproductions, to determine the optimal parameters of production in specialized farms, to forecast the gross grain production in the region in the short term and to determine the approximate volumes of sales of elite seeds outside the region without prejudice to the domestic market.

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