Cognitive map of the model for managing the sustainability of reproductive processes in industrial viticulture

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Abstract. The necessity of developing models for managing the sustainability of reproductive processes in long-term agrocenoses with the participation of grapes is substantiated. The main trends in the grape-growing industry development in the Russian Federation and the Krasnodar Territory are revealed. The factors affecting the level of stability and efficiency of reproduction processes in long-term agrocenoses with the participation of grapes are determined. Methodological bases for the formation of cognitive models for managing the stability of reproductive processes in ampelocenoses are proposed. A cognitive map of the model for managing the sustainability of reproductive processes in long-term agrocenoses with the participation of grapes has been constructed, which allows to give a statistical assessment of the functional relationships between factorial and resultant indicators characterizing various types of functional and system-wide sustainability of agroecosystems with the participation of grapes. The tools for managing the sustainability of reproductive processes in complex natural and man-made systems are defined.

1 Introduction

Industrial viticulture is currently characterized by high rates of development. The area of grape plantations in agricultural organizations of the Russian Federation increased to 78.2 thousand hectares by 2023 (an increase of 7.2% by 2017), and the gross harvest – up to 672.1 thousand tons or 1.7 times. At the same time, the yield increased by 45% – from 7.5 tons/ha in 2017 to 10.8 tons/ha in 2023, which indicates the actively carried out renovation of plantings, the entry into fruiting of new areas cultivated using modern technologies.

In the Krasnodar Territory, the largest grape-producing region of Russia (the share of the Krasnodar Territory in the Southern Federal District is 49.9%), the yield of grapes for 2017-2022 increased from 9.6 t/ha to 13.0 t/ha, and the gross harvest - from 187.4 thousand tons in 2017 to 271 thousand tons in 2022.

Despite the positive dynamics in the grape-growing industry development, risks remain due to the negative impact of man-made, climatic, and macroeconomic factors on the stability of reproduction processes in ampelocenoses and a decrease in the efficiency of manufacturing

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industrial products.

2 Materials and Methods

The veracity and reliability of the results obtained is determined by the use of modern methods and world-class instrumentation and analytical equipment, the complexity and multiplicity of interrelated studies, modern mathematical methods of statistical analysis. The statistical software package Statistica 10 was used in the cognitive map construction.

3 Results and Discussions

Management of reproduction processes sustainability in long-term agrocenoses with the participation of grapes is a tool for developing management decisions, the purpose of which is to achieve a balanced state and compliance with regulatory parametric characteristics of structural elements of complex natural and man-made systems, as well as ensuring the efficiency of industrial production.

The basis of the sustainability management tools under the effect of many different factors on the organization of reproductive processes is cognitive modeling, which provides for the construction of cause-effect diagrams (cognitive maps) using the ACS analysis method [1].

Methodological foundations for the formation of cognitive models for managing the sustainability of reproductive processes in industrial viticulture include the following: development of principles for the structural organization of complex natural and man-made systems; identification of the causes of bioresource deformations and functional imbalances; determination of the fundamental relationships of agrotechnological and economic factors; economic and statistical characteristics of the identified relationships; justification of tools for managing sustainability and improving the effectiveness of reproductive processes.

The cognitive map of the management of reproductive processes sustainability by sustainability types and functional areas of impact will allow to determine the correlation and regression relationships between indicators characterizing the effectiveness of the implementation of agrotechnological regulations and effectiveness indicators of the manufacturing industrial products (Figure 1).

Cognitive maps of the reproductive processes sustainability in ampelocenoses are the basis for the development of a mechanism for ensuring the sustainability of complex natural and man-made systems and the construction of digital technologies for managing production and technological processes in industrial viticulture, including platform solutions based on digital technologies [2].

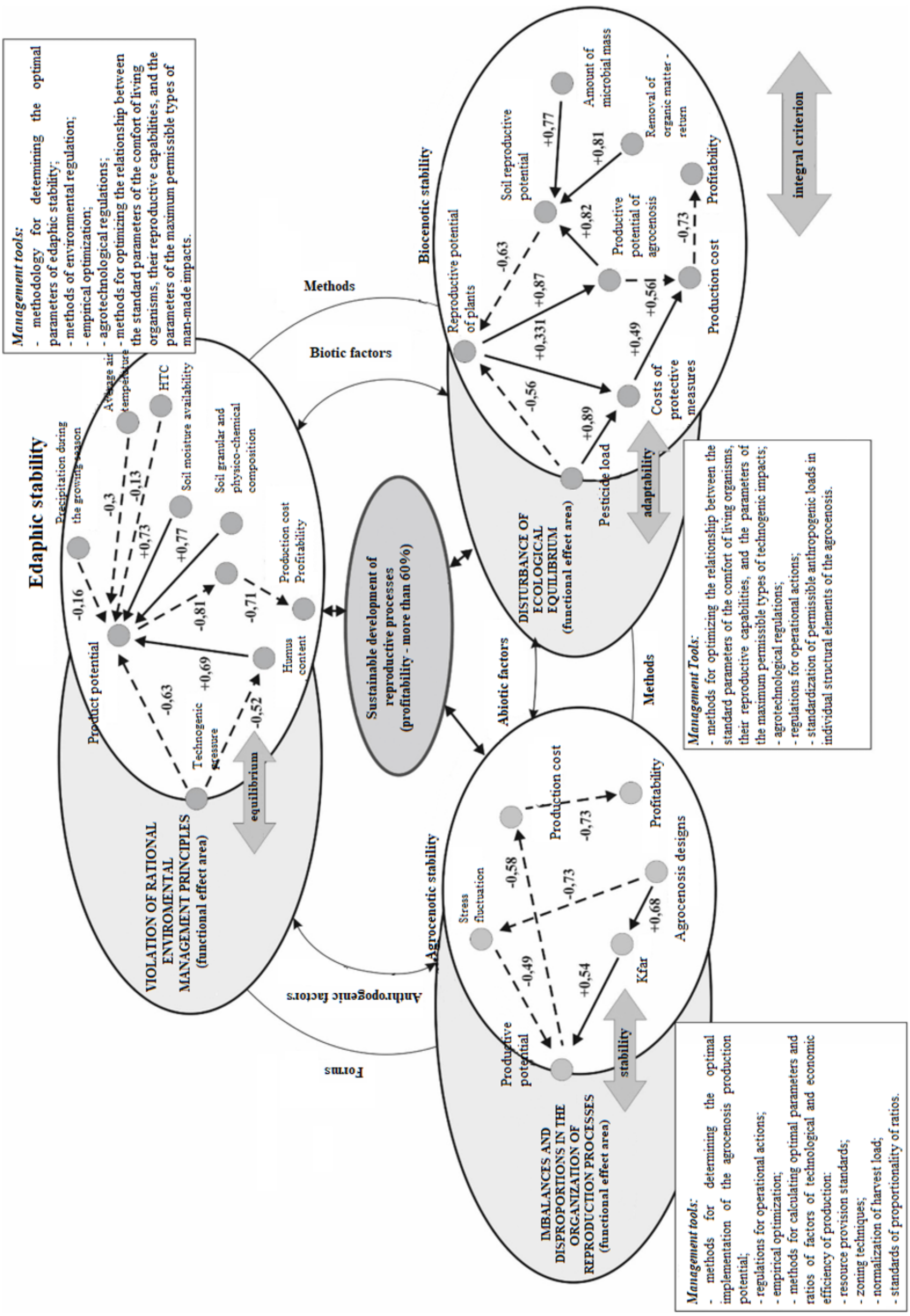

Fig. 1. Cognitive map of the model for managing the sustainability of reproductive processes in industrial viticulture.

The main types of stability of perennial agrocenoses involving grapes are edaphic, biocenotic, and agrocenotic ones. Achieving the normative level of functional and system-wide stability is carried out by various ways and methods.

The fundamental methods of achieving edaphic stability are optimization and optimization-normative methods, which make it possible to ensure a balanced state of complex natural and man-made systems as a result of achieving optimal proportions in their structural components. To manage biocenotic stability, the most rational are optimization, regulatory and regulatory-operational methods that allow achieving the values of parametric characteristics of structural elements of reproductive processes in a dynamic optimum. Optimization-regulatory and regulatory-operational methods are used to ensure agrocenotic stability, their application allows to ensure competitiveness and high efficiency of manufacturing industrial products [3-5].

Ensuring the sustainability of reproduction processes in industrial viticulture is achieved by modern, high-precision technologies that consider zonal soil-climatic and breed-varietal characteristics, based on the biologization of intensification processes using the digitalization of biotechnological processes.

The manifestation of the sharp climate continentality in the last decade, along with the chemical and technogenic pressure of ampelocenoses, led to an imbalance in the biological cycles of plant development, their weakening, increased meteorological stress damage, and a decrease in the realization level of productive potential of grape plantations. According to the analysis of climatic changes in the Krasnodar Territory and the North Caucasus region, the following trends were identified: for 2000-2022, there was a steady increase in the average annual air temperature by 10.3% (or 1.2°C), an increase in annual precipitation by 10.9% (or 78 mm), which indicates an increase in the frequency of abnormal manifestations in the form of temperature and water stress.

According to the revealed correlation and regression dependencies, climatic factors such as absolute minimum temperature (effect share 45.8%), absolute maximum temperature (effect share 29.8%) and the number of days in summer with a relative humidity of less than 30% (effect share 16.1%) have the greatest impact on the production potential of grape plantations. The correlation coefficient of the revealed dependence is 0.99, which indicates a high degree of relationship closeness between the studied factors.

Statistical analysis of the absolute minimum temperature effect on the productivity of Riesling reynsky grape variety growing in the Black Sea viticulture zone of the Krasnodar Territory established the maximum effect share among the studied factors – 45.8%.

With an increase in the minimum air temperature to minus 18-19°C, the central and replacement buds of grapes of weakly frost-resistant European varieties increases up to 50%, at minus 21-22°C - 80% of the buds are damaged. In addition, with critical decreases in air temperature (up to minus 25-30°C), with a continuous management system, annual and perennial wood, roots are damaged, individual parts of the bush die off and plants of frost-resistant varieties could completely die [6].

The absolute maximum air temperature has the effect share on the productivity of grapes of 29.8%. When the air temperature rises to 35-40°C during the growth and development of berries, growth processes are inhibited – the number of tendrils, leaves, shoots, and internodes decreases, respiration and assimilation processes are inhibited. Also, at high air temperature, which has a stressful effect on grape plants, generative processes are suppressed – the number and mass of the bunch decrease, which leads to a decrease in the productivity of grape plantations.

At high temperatures, during the growth of berries and the beginning of grape ripening, the formation of the crop, its color, and quality of the fruits are better. During this period, the most favorable temperatures are around 30 degrees. With a combination of high temperature and low relative humidity, a stressful effect is exerted on grape plants, which leads to a weakening of growth and a decrease in productivity. It was found that the number of days with a relative humidity of less than 30% has a 16.1% impact on grape productivity.

The factor "number of days with an air temperature above 35°C" has the share of effect on the productivity index of 6.8%. It is known from the literature data that when the air temperature rises above 35°C during the flowering period, there is a decrease in productivity due to deterioration of pollination and shedding of the ovaries.

The hydrothermal coefficient of the growing season, showing the conditional moisture balance, has the share of effect on grape productivity of 1.6%. The range of this indicator fluctuations over the years does not go beyond the critical boundaries for the crop and the availability of precipitation is acceptable for grapes. Some insufficiency of soil moisture at high temperatures during the growing season, observed in some years, generally does not have a critical effect on grape productivity.

The effect share of agrotechnological factors (rootstock-graft combinations, varieties, feeding area, bush formation, etc.) on production potential realization is more than 58%. Conducted agrotechnical methods (pruning, rationing the load of bushes, use of fertilizers and growth stimulants, etc., are operational methods of managing the productivity and quality of grapes in the annual ontogenesis cycle) [7-10].

To assess the agrocenotic stability of ampelocenoses, the following system of indicators was used: the coefficient of exceeding the break-even threshold, the turnover ratio of working capital, the level of production potential realization, the margin income rate, the integral assessment of resource efficiency, the profitability of products. According to the calculated delta coefficients, the greatest effect on the agrocenotic stability of ampelocenoses is influenced by such factors as (the coefficient of break-even threshold exceeding (the effect share of the factor is 66%), the efficiency of working capital management (the effect share is 20%), and the level of production profitability (the effect share of the factor is 12%).

According to the conducted cognitive modeling of the processes of reproductive processes sustainability, it was found that in industrial viticulture, the greatest influence on the sustainability of agrocenosis is exerted by technological-economic and economic factors, the effect share of which is more than 78%.

4 Conclusions

The established economic and statistical dependencies and patterns are the basis for constructing a model of digital technologies for managing reproduction processes in industrial viticulture using neural network models as tools for forming and solving problems on cognitive structures.

The creation of complex digital technologies based on cognitive modeling creates new opportunities for the use of qualitatively new technological solutions and approaches in the management of production and technological processes, which will increase the efficiency of production processes, ensure the sustainable development of the grape-growing industry under the negative influence of man-made, climatic, and macroeconomic factors.

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