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A HYBRID APPROACH OF FRACTAL AND LINGUISTIC FORECASTING OF WINTER WHEAT YIELDS IN SOUTHERN RUSSIA

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Abstract:
The article investigated and formed the imperatives of the impact of the external natural environment on the grain yield in the south of Russia, forcing to abandon the simplified classical concepts and methods of analysis. The author's research concept defines quantitative risk analysis, as a category, inverse forecast, which is possible only on the basis of economic and mathematical modeling. The modern theory of assessing measures of economic risks, forecasting and managing them is still far from adequate to the real needs of practical agricultural management. This determines the main feature of modern risk, which is its total and comprehensive nature. It is difficult to manage risks in regions with frequent droughts, which are classified as areas of risk farming. The methodology of studying risks in the field of agriculture is based on the study of the dynamics of the natural environment of growing crops, the conjuncture uncertainty of the external economic environment, the variability of land management technologies. Climatic and agrometeorological conditions are becoming an important factor affecting crop yields. The yield series accumulates information about the fluctuation of weather conditions and their influence on the yield, they contain information about certain regularities that synergy relates to the concept of "long-term memory". The paper describes the features of the spectrum of climatic conditions affecting socio-economic indicators, the growth and yield of grain (winter wheat) in southern Russia, as well as the results of the implementation of the author-hybrid approach to the fractal and linguistic forecasting of winter wheat yield in southern Russia.

Key words: *prediction, linear cellular automaton, long-term memory, forecast horizon, validation.*

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INTRODUCTION:

In the new conditions of fundamental reforming of the economy, changes in the organizational and legal forms of enterprises, the development of market relations, the introduction of private ownership of land, and so forth. Rural production is a typical risky field of activity, therefore the problem of the sustainability of agricultural production becomes one of the most debated topics. Sustainability is important for the long-term integrated development of the agrarian sector, determining the reliability and economic security of the country. Sustainability cannot be achieved without calculating prospects, without forecasting crop yields.

The first group of climatic conditions affecting grain yield is solar activity, humidity or rainfall, and the ambient temperature (with the temperature of the earth's surface). For example, the literature states that winter wheat makes better use of autumn and winter precipitation, an increase in its volume, as well as the volume of early spring precipitation in previously arid regions of Russia, dramatically increases crop yields, becoming a generator of new parametric patterns. There are four critical periods of irrigation of winter wheat, which most strongly increase its productivity: autumn watering, spring irrigation in the phase of going into the tube, in the period of earing and at the beginning of grain loading. Under these conditions, classical forecasting models are simply inadequate to the natural conditions, they are difficult to adapt to work. However, the processes of influence of precipitation on yield are successfully predicted using nonlinear methods and cellular automata. Natural and climatic conditions can be described by time series, analytically, graphically and numerically, and operate with them in the fractal construction of forecasts [1, 2].

The second group of conditions is technological. There are three macro characteristics in land use technology for arable lands: soil fertility status, environmental assessment of soil and products, and economic efficiency of various land use options. Part of the technological impact on the yield of winter wheat is not of a systemic nature; mathematically it cannot be represented in time series. From the above it follows a clear conclusion that any adequate construction of a global agro-ecological-economic-mathematical model should be based on a multidimensional approach, while having to solve essentially multicriteria problems of the whole spectrum of modeling, analysis and forecasting, quantification of risks and objectives vector optimization.

The main component of a multi-criteria approach with direct decision support methods for the safety of investments in the agro-industrial complex is a complex of socio-economic mathematical models. The variability of the expected income is adequate to the variation of crop yields, the yield of winter wheat is especially important. Although the yield itself is a random variable determined on the basis of statistical data.

In addition to statistical distributions when dealing with continuous stochastic yield indicators, we have to deal with sharp emissions (drought, for example). The study of the predictability of the socio-economic processes of grain farming under the influence of early precipitation of such cataclysms can be seen on the example of forecasting the catastrophic level of mountain river flow as a source of cumulative information about crisis precipitation, a new indicator of average moisture saturation of the soil and grain yield. cultures [1].

Forecast and risk are inversely related. The higher the quality of the forecast, the lower the risk, the higher the risk, the worse the forecast. Three types of forecasts usually differ in time or along the forecast horizon: “intra-annual” forecast of the socio-economic background, while the judgment about the future size of the crop is generated within the forecast year, according to the current characteristics of the “reporting period”. It expands as it approaches the time of harvest, the “forecast horizon”, on the contrary, narrows. The closer we are to the time of harvest, the more we should expect the data of such a forecast.

Note the so-called “annual” forecasting, the forecast is determined with a constant length of the forecast horizon of one year, while the length of the “reporting period” of the time series of yield must exceed the length of the forecast horizon several dozen times. This is the most well-known classical methodology, when according to the characteristics of the yields of previous years, the forecast for the desired year following the last year of the “reporting period” is determined.

MATERIAL AND METHODS:

Perennial “fractal”, “long”, “long”, “block” or “cyclical” forecasting determines future yields for several years ahead in the “forecast horizon” through certain generalized characteristics of yield trajectories for previous years. Such generalized characteristics in the study are the yield cycles, so that the forecast can be calculated ahead, at least for the length of the next cycle, and this is 2-9 years. It seems that this

forecasting is a more difficult and fundamentally inaccurate prediction of the economic future due to the complex architectonics of the world grain economy; speed, non-stationarity, turbulence, stochastics of the modern increasingly complex and accelerating dynamics of natural-climatic processes and their volatility increasing every year; due to changes in the technology of grain management in the global economy, network economy, services economy. However, if it is recognized that cyclicality is a certain universal property of Matter and Nature, then it makes sense to continue predicting precisely along cyclical trajectories, their stability in grain production is much higher than the repeatability of individual points of the process. "Block" forecasting, coupled with nonlinear fractal approaches, finds and refines the long-term forecast [2]. The authors propose to use the hybrid approach of fractal and linguistic prediction based on cellular automata as such a predictive method [7]. Below is the final result of the implementation of the linguistic forecasting model.

RESULTS AND DISCUSSION:

Based on the validation of the results of linguistic forecasting of the time series of wheat yield in the Stavropol Territory, an estimate of the average forecast error was obtained $\overline{\varepsilon_i} = 16{,}6\%$ on the basis of a linear cellular automaton [1]. In the process of validation, the forecast model produced an almost accurate forecast in linguistic terms for each year from 1943 to 2015.

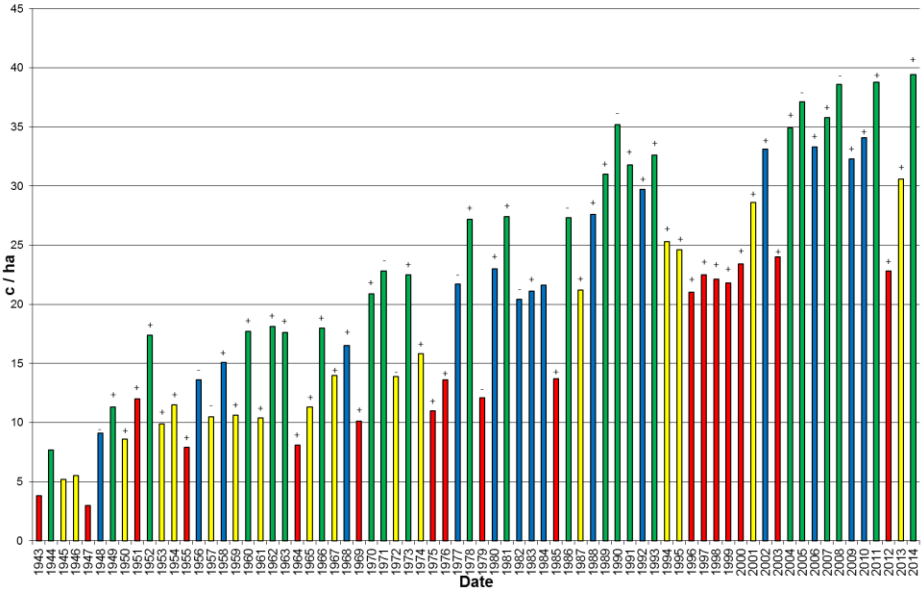

Figure 1: Application of the procedure for coloring the time series of the yield of winter wheat in the Stavropol Territory for the period from 1949 to 2015: red - low yield, yellow - medium, blue intermediate, green - high.

Once again, we emphasize that the scope of synergetic forecasting is evolutionary processes, whose time series have a "long-term memory". The latter means that such series accumulate information about fluctuations of weather conditions and their effect on crop yields [5]. In other words, these ranks contain information about certain time patterns characteristic of natural time series of yields in areas of high-risk farming.

Figure 1 shows the validation of a 4-color predictive model of a linear cellular automaton. The "-" sign indicates the time series levels in which the predictive model did not guess the linguistic variable. In this case, the prediction algorithms are based on "quasi-genetic algorithms", which are implemented in a study based on cellular automata.

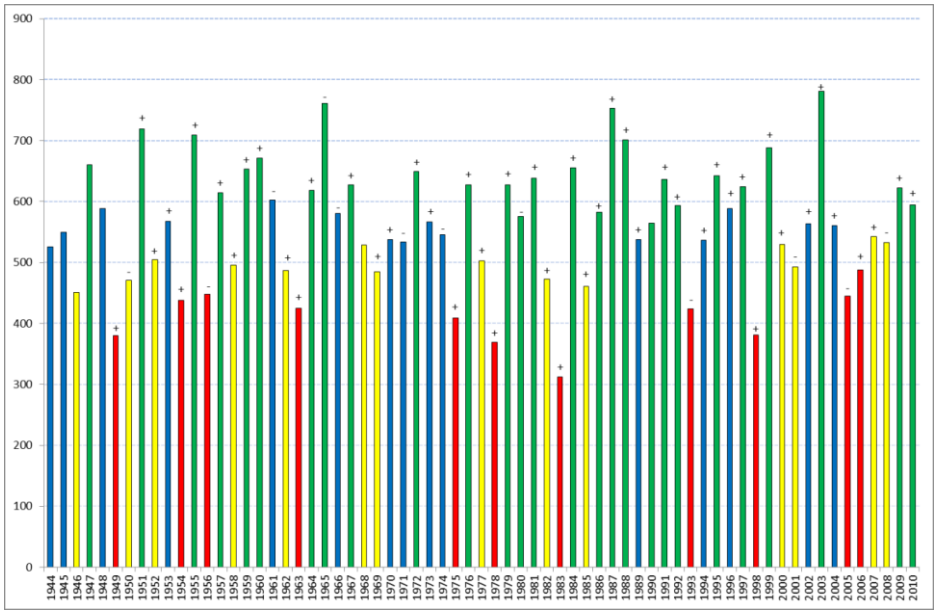

Figure 2: The operation of a linear cellular automaton for a time series of precipitation over the territory of the Stavropol Territory (forecast error was 21%)

One of the climatic factors controlling the yield is moisture or precipitation. The predicted histogram of a linear cellular automaton for a time series of precipitation over the territory of the Stavropol Territory is shown in Figure 2.

Imagine the main stages of the prediction algorithm based on cellular automata. The first is the use of statistical methods and visualization for a preliminary analysis of the time series of yield for the presence or absence of trend tolerance and “long-term memory”, “heavy tails”, seasonal and cyclic components. The identification of the degree of “predictability” of model series of natural and economic time series is carried out on the basis of fractal analysis methods. The second is a fractal analysis of the time series in order to establish a “long-term memory” in it, assess its depth and tendencies (persistence, randomness). The computational part of the fractal analysis is based on the algorithms of R / S analysis. The results obtained are of numerical nature, most adequately represented by fuzzy sets. The third is the choice of a set of carriers and the transformation of a numerical time series into a linguistic time series in order to form the memory basis of a linear cellular automaton for applying a quasi-genetic algorithm working with combinatorial configurations from elements of carriers. Conversion means replacing the numerical elements of yield with linguistic variables called terms. Both those and others accumulate information about fluctuations of weather and climatic conditions and their influence on the productivity of winter wheat. The fourth is the construction of a cellular automaton for obtaining a linguistic time series, the formation of a set of all configurations, as well as the calculation of the frequencies and frequency of transitions of configurations to term states, which means the construction of a cellular automaton memory. The fifth is the formation of a prediction for a numerical and linguistic time series when implementing a quasi-genetic algorithm based on the built-in memory of a cellular automaton. At first it will be a forecast in the form of a fuzzy linguistic set, then it will be converted into a numerical fuzzy set, which can be converted into a clear numerical forecast using the defuphication procedure. The sixth one is validation with obtaining estimates of the error of the obtained forecast for the time series of the yield of winter wheat. Note that in relation to the concept of "model", the term "verification" means checking the structure and logic of the model, and the term "validation" means checking the compliance of the data obtained on the basis of the model with the actual process. Separately, we note that the synergistic algorithm and the resulting prediction are internally consistent in the construction of their parts.

CONCLUSION:

Thus, the proposed hybrid approach of fractal and linguistic forecasting based on a cellular automaton dynamically decomposes the time series of winter wheat yields into trend components, seasonality, cyclicity, residual random “noise” and the event component of dynamics without loss of information during this decomposition. This model operates not with the numerical values of the measured

observations, but with qualitative linguistic estimates. It removes or weakens the well-known problem of using various tools or methods for measuring levels (observations). In this model, non-numeric (qualitative, linguistic, verbal) information characterizing the dynamics of the process under consideration is involved in the process of cellular automaton prediction.

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