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Online Climate-Irrigation System

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Abstract

Information technologies are more and more introduced into our life. They are also applied in agriculture under the growing conditions of this industry. It is especially important to manage agricultural processes influenced by rapid changes of climate, limitation of various resources. To overcome diverse uncertainty, it is efficient to use information technologies providing forecast information for high-quality management. The developed online system allows optimizing the economic activity on irrigated lands under the changing climate. Its distinctive feature is the scope of coverage of a considerable territory of the European part of Russia and duration of meteorological observations.

Keywords: information technologies, climate, management decisions, online system

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1. Introduction

The present stage of development of humanity is characterized by the increasing use of information technologies necessary to adopt the management decisions. There is a variety of information technologies for the adoption of optimal management decisions in the sphere of natural and engineering systems. They include the search for management decisions for various processes in agriculture, which is booming in recent years, especially it is important for hi-tech irrigation [1, 2].

Information technologies have another important feature, which is becoming ever more relevant. In modern economic conditions of fierce competition, the adoption of qualitative, innovative management decisions ensuring effective development is very important. It is highly intellectual activity combining rationality and creativity of a decision maker.

The paper presents the results of the project ``*The study and development of information system with software for the calculation of long-term impact of climate change on the need for irrigation of lands in various agroclimatic conditions of the European part of the Russian Federation''* performed within a grant of the Ministry of Agriculture of the Russian Federation (2017). The project addressed the following tasks:

1. To analyze the existing information technologies for use in management activity for irrigated lands in the conditions of the changing climate.
2. To specify the structure of management objects and the possibility to change its every component. To focus on long-term climate changes in various agroclimatic conditions of the Russian Federation.
3. To develop an algorithm of climate change influence on the need for irrigation of lands in the European part of the Russian Federation and to define key estimates.
4. To develop the structure of the information system and to design its software.

2. Methods and Materials

Information on long-term temperature and humidity conditions from 1936 to 2015 was collected for databases from 13 meteorological stations of the European part of the Russian Federation; on key hydrophysical soil criteria; various data on biology of grown crops.

First of all, the study was based on the author's meteorological observations, as well as daily climatic data of Roshydromet International Data Center in Obninsk, reference books on climate and agroclimatic resources and meteorological data from public websites [2, 3].

The following data are given to identify the chosen meteorological stations: index of the World Meteorological Organization, coordinates, terms of observations, number of years of observations and data source.

The following approaches and methods are used in the study:

Approaches: system, synergetic, physicogeographical. They were used to define the structures of agrarian irrigated systems, to identify the relations between system components, features of their nature, parameters, relations taking into account territorial and temporal changes.

Methods: statistical, forecasting (method of perspective trends, scenario method (options)). They were used to create, process and analyze databases; to calculate, define the trends in time series, to develop scenarios and recommendations for them.

3. Study and Development of the Informaiton System

Many organizations and scientists were studying the information support in irrigated agriculture, designing programs and developing online support systems: Ostapchik V.P., Kostromin V.A., Venkel K.O., Maye H.V., Ross S.S., Gelman T.Ya., Izrael Yu.A., Sirotenko O.D., Bryl S.V., Kapustina T.A., Bochkaryov A.I., Olgarenko I.V. [1--5].

It is possible to increase water resources management in irrigation due to information support systems ensuring reliability and accuracy of information.

Information technologies allow considering space-temporal differentiation of various conditions: meteorological, soil, biological and organizational-economic. This reflects geographical spatial features, repeatability hydrometeorological factors, probabilistic nature of processes occurring in the atmosphere.

If 50 years ago the traditional set of climatic forecasting variables was quite suitable for agricultural managers, then now, in the conditions of the changing climate, they seem insufficient. Former climatic models were based on cyclic climatic consistency. Proceeding from this conditions, variables and time interval for their assessment were chosen [6]. Now in many respects such approach is obsolete, a standard 30-year interval does not always meet the current requirements for calculation of climatic norms. The changing climate requires new approaches.

Let us specify the nature of the studied object. In its simplified form the agrarian irrigated system has the following components: climate, soil, plants and the control action of a person. Each of the above components represents independent complex, open, dynamic, nonlinear, self-organizing systems. Since each of them has its trajectory and different time scale of development, the result of their interaction (agricultural products) for forecasting represents a quite tough management task. Considerable uncertainty, which was overcome by strong-willed intuitive influences, was typical for such management. At the present stage of economic development it is not enough since the crop yield requires considerable resources.

Climate represents a special complexity. It is extremely dynamic, impossible to control by a human and acts as a separate self-organizing system. Stochastic behavior, instability of certain parameters and processes combining different temporal scales, etc. are typical for it against the background of cyclic changes.

The following are key indicators of agriculture: average temperature, amount of precipitations, number of sunny days and other variables, which can be measured for a particular geographical location [6].

The average annual temperature over the last 25 years grew in Russia on some climatic contours up to 1.6 °C per a decade. Some regions are noted by the unevenness of these changes. All largest agricultural regions of the country are located in the zones of the growing average annual temperature, i.e. they are subject to climatic changes.

86 cases of the absolute maximum of day temperature rise and 23 cases when the absolute minimum of night temperature was blocked were registered in 2012 [7].

In general, the rise in temperature is more noticeable in Russia in winter and in spring (the trend made respectively 4.7 and 2.9 °C over 100 years), in warm season the temperature rise is weaker. Besides, the areas of warm climate alternate with the regions of a noticeable cold wave [8].

The moisture content of the territory of the country is also changing due to climate warming. According to some data, in southern latitudes in steppe and forest-steppe zone the amount of precipitation will decrease, the climate will become more arid. In the forest zone and in northern areas the moisture content will increase, and by 2050 the atmospheric precipitation may increase, according to preliminary forecasts, by 10--15 % in comparison with the recent period [9].

Due to constantly changing atmospheric processes the exact long-term weather forecast is almost impossible. There are objective predictability limits even when exact sciences are used. For example, using modern nonprobabilistic mathematical models it is possible to forecast daily weather for 10 days. But the probability of such forecast after 3 days is considerably decreased. The speed of meteorological changes with various lag effect has an impact on other components of the agrosystem. It seriously affects human economic activity.

The reliability of forecasts of future climate changes depends on many factors, each of which has some share of uncertainty. The main sources of uncertainty are as follows [10, 11]:

1. major difficulties of to forecast long-term development of power engineering and technologies in the world and the related uncertainty of estimates of future concentration of greenhouse gases and other radioactive impurities in the atmosphere;

2. impossibility of a priori accounting of natural external impacts on the climate, such as future volcanic eruptions and change of solar radiation flow on the outer fringe;

3. insufficient knowledge and hence inaccuracy of descriptions of climatically important processes and feedback in physical and mathematical models.

Ground air temperature. Increase of average annual temperature in the territory of Russia is expected much bigger than across the globe. By 2020 its increase will exceed inter model range (1.1 ± 0.5) °C, and in the middle of the century (2041--2060) the increase will be even big (2.6 ± 0.7) °C, especially in winter (3.4 ± 0.8) °C.

Atmospheric precipitation. The increase in rainfall across Russia is expected in winter, and in summer the change of rainfall depends on the region. By the middle of the century the annual rainfall will decrease in the south of the European part. At the same time we shall expect the increase of heavy precipitation in summer almost in all territory of Russia, especially in the southern regions [12].

Software products to forecast possible technologies for the yield of irrigated crops were designed in various institutions: All-Russian Research Institute of Hydraulic Engineering and Amelioration (Ostapchik V.P.), Rainbow All-Russian Research Institute (Olgarenko G.V.), Bryl S.V., Kapustina T.A., Bochkaryov A.I. [2--4].

Such program complexes are aimed at automated solution of operational management tasks. This includes operational planning of irrigation modes, on-line forecasting of moisture dynamics, determination of biologically optimum terms and norms of watering, creation of watering schedules in case of insufficient resources, and reporting on irrigation. The main blocks include the following: database of source data on actual meteorology and settlement forecast block. They are used to make recommendations on the irrigation modes.

The information support systems hold a special place within specialized information systems. In the course of modeling they generate various data for management decisions. Such information can be used either in practical activities, or taken into consideration.

However, the existing information technologies do not consider the quickly changing climate, especially as the nature of such changes on the territory of the European part of Russia is diverse. Therefore, the Ministry of Agriculture of the Russian Federation set the task to close this gap. It is particularly important when the conditions of economic management chance due to the changing climate. In these conditions there is a need for alternative forecasts to adopt competent, economically justified management decision.

To create databases of meteorological information the study is focused on one region -- the European part of Russia, the choice of meteorological stations in this territory is reasonable, long-term meteorological data were collected, climate changes according to key parameters were studied: air temperature and an atmospheric precipitation over different periods [2].

As a result it is established that according to air temperature the climate of the European part of the Russian Federation changes towards warming. The analysis of the amount of atmospheric precipitation in the European part of the Russian Federation did not reveal the general increasing or decreasing tendency of natural moistening -- each meteorological station shows its own trend.

The developed information support system is based on three blocks. The first block includes databases for all planned meteorological stations: actual retrospective long-term meteorology.

The second block -- standard information. This includes numerical data of various soil characteristics, information on crops.

The third block -- knowledge base. This includes the calculation models of natural moistening and the need for irrigation of a given territory, recommended combination of chosen options, forecast solutions, recommendations.

The climate-irrigation information support system was designed using Visual Basic for Applications (VBA) and standard Microsoft Office. The system is intended for a wide use by consumers of different level of training and technology in the European territory of Russia.

Functional purpose. The climate-irrigation information support system is aimed to solve tasks to assess the influence of climate changes on the need for irrigation of lands in various agroclimatic conditions of the Russian Federation. It gives an opportunity to forecast changes of meteorological parameters in modeling of their intra annual and mean annual distribution and assessment of variability in the long-term period.

The information support includes the acquisition of source data, processing, analysis, calculation of indicators and preparation of results received on the basis of modeling to prove the most efficient option for irrigation in either region of the European part of the Russian Federation.

The climate-irrigation information support system allows its user carrying out the following functions:

1. On the basis of hydrothermal indicators to climatic trends with regard to the following:

- rise or fall of temperature (average in a year, average for cold and warm periods);
- growth or reduction in the amount of rainfall (sum in a year, cold and warm periods);
- definition of probabilistic climatic characteristics and possible climatic situations for the chosen period;
- growth or fall of temperature and the amount of precipitation over the vegetative period;
- definition of probabilistic climatic characteristics of vegetative periods;
- definition of heat and water availability trends.

2. On the basis of hydrothermal assessment of climate to define the need for hydrotechnical amelioration.

3. To present values received as a result of analysis and data processing in terms of the climate change and to define the need for irrigation in tabular and graphic forms.

4. To forecast possible productivity of crops.

Used technical means. The application is operated on the IBM PC.

Meteorological data from 13 meteorological stations of the European part of Russia was collected over a long-term period to verify the program: from 50 to 83 years. The program allows analyzing and assessing various periods ranging from 50 to 83 years. It enables printing the obtained results. Intermediate forms with various digital material are available for the analysis [2].

4. Conclusion

1. The region of study is defined -- the European part of Russia, the choice of the meteorological station in this territory is justified, long-term meteorological data are collected, research method are chosen.

2. The study of climate changes according to key parameters is conducted: air temperature and rainfall for various periods. The study showed that the climate of the European part of the Russian Federation changes towards warming. The analysis of the quantity of atmospheric precipitation in the European part of the Russian Federation did not reveal the general increasing or decreasing tendency of natural moistening -- each meteorological station shows its own trend.

The information support system for management decisions on optimization of economic activity in the sphere of irrigated crop production is developed. It covers a wide range of changing conditions both across the territory (the European part of Russia) and in time (current and forecast periods).

The software for irrigation of lands in various agroclimatic conditions of the Russian Federation taking into account the changing climate is developed.

The database that includes the retrospective of climatic parameters is designed: temperature, humidity, precipitation, is created. The study period may range from 50 (minimum) to 83 years (maximum possible) of meteorological observations. For correct use in the models all data are presented in a uniform format for all meteorological stations.

The developed models are verified based on independent data.

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References

[1] Borodychev, V.V., Lytov, M.N. (2015). Solution algorithm of managing soil water regime in irrigation of crops. *Melioration and water management*, vol. 1, pp. 8--11.

[2] Cheremisinov, A.A., Radtsevich, G.A., Cheremisinov, A.Yu., Tolstykh, A.A. (2018). Information system of climatic influence on the development of irrigation for the European part of the Russian Federation. *Bulletin of Voronezh State Agricultural University*, vol. 4(59), pp. 59--70.

[3] Olgarenko, I.V., Selyukov, V.I. (2011). Software of water use planning in irrigating systems. *Environmental Engineering*, vol. 4, pp. 38--40.

[4] Ostapchik, V.P., Kostromin, V.A., Venkel, K.O., Maye, H.V. (1981). Automated online help for operational planning of irrigation. *Hydraulic engineering and melioration*, vol. 3, pp. 60--65.

[5] Ross, S.S. (1981). Automated Control System (ACS) of agricultural fields. *Modern problems of hydrology of irrigated lands*, vol. 1, pp. 141--157.

[6] Rankova, E.Ya., Gruza, G.V. (1998). Indicators of climatic changes in Russia. *Meteorology and hydrology*, vol. 1, pp. 5--18.

[7] Cheremisinov, A.Yu., Burlakin, S.P., Zemlyanukhin, I.P. (2013). Calculation of water consumption of crops under irrigation in the conditions of the Chernozem zone. *Melioration, water supply and geodesy*, pp. 37--42.

[8] Izrael, Yu.A., Sirotenko, O.D. (2003). Modeling of impact of climate changes on agricultural efficiency in Russia. *Meteorology and hydrology*, vol. 6, pp. 5--17.

[9] Moiseev, Yu., Nosov, S., Rodina, N. (1997). Global climate change: production of food. *International agricultural journal*, vol. 5, pp. 30--34.

[10] Krivenko, V.G. (2003). Forecast of climate changes in Eurasia from the perspective of its cyclic dynamics. *World conference on climate change: theses of reports*, pp. 514--515.

[11] Meleshko, V.P., Golitsyn, G.S., Govorkova, V.A. (2004). Possible climate changes in Russia in the 21st century: estimates on the ensemble of climatic models. *Meteorology and hydrology*, vol. 4, pp. 38--49.

[12] Semyonov, S.M., Anisimov, O.A., Anokhin, Yu.A. et al. (2008). Estimated report on climate changes and their consequences in the territory of the Russian Federation, vol. 2. *Consequence of climate changes*, pp. 288.