GEOINFORMATION TECHNOLOGIES FOR THE MANAGEMENT OF WATER REGIME OF AGRICULTURAL CROPS IN IRRIGATED AGRICULTURE

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In the article the algorithm of control of water regime of agricultural crops during irrigation is put, which consists in the fact that. The analysis of well-known and developed by the authors GIS-systems for monitoring and control of water regime of irrigated fields, mainly for acute arid conditions. The analysis of Russian and foreign developments showed that computerized systems based on GIS-technologies for monitoring irrigated agricultural land should receive and record data on humidity, soil temperature and wind speed on the irrigated area in real time. For the operational regulation of the water regime of plants in arid natural conditions requires a preliminary analysis based on adequate mathematical models of heat, salt and moisture exchange. This requires the creation of GIS-systems with blocks of mathematical processing, analysis and decision support, as well as forecasting the development of agrocenoses using the described mathematical models and the structure of the database.

Introduction. Modern resource-saving technologies of agricultural production, called "Precision Farming", actively developing all over the world since the end of the last century, are recognized by agrarian science as effective technologies that transfer agribusiness to a higher level. The use of modern IT-technologies allows solving a number of basic tasks that determine success in the conditions of the modern market: availability of up-to-date information, adoption of relevant management decisions and their implementation in practice. The solution of these three interrelated tasks is possible due to the use of specialized technical means and software (software).

Precise farming is the optimal management of crop production per square meter of field in order to maximize profits while saving economic and natural resources (Borodychev et al, 2018; Carvalho et al, 2006). To do this, it is necessary to use IT on the basis of agricultural machines controlled by on-board computers, precision positioning devices, systems for detecting local heterogeneities in soil massifs. In addition, subsystems are required for forecasting and recording yields, applying fertilizers and plant protection products using databases (DB) of remote sensing and automated mapping. All this requires the use of GIS-technologies, including a set of modules of specialized software.

Materials and methods. The maximum efficiency is achieved as a result of building a software package that includes the following subsystems:

1. Means of accurate farming (parallel driving systems, soil analysis, differential fertilizer application systems, crop sensors);
2. Monitoring of agricultural land (site boundaries, agrochemical and moisture availability of fields, mapping of productivity, analysis of agrolandscapes);
3. Monitoring of equipment (automated data collection, based on GPS navigation, visualization of location and movement of equipment, operational accounting of agricultural work, operational management of irrigation equipment);
4. Planning and management (technical and economic planning, operational planning, operational accounting of agricultural products).

The analysis of information technologies and software to support decision-making in the field of land reclamation has revealed the following directions for its improvement.

Improving the quality and scientific validity of the management of the creation and operation of land reclamation systems, preventing the degradation of irrigated soils is impossible without the use of modern software and information tools designed to analyze data on natural and technogenic indicators of the state of reclamation lands and sampling based on this analysis of ecologically and economically sound solutions for cultivation agricultural crops. For efficient and rational use of natural resources, support is needed for making decisions on the distribution of irrigated water to the fields.

Prevention of degradation of meliorative agrolandscapes, ensuring their stable ecological and meliorative state by improving the quality of management decisions in the field of irrigated land use, is possible due to the account of the individual characteristics of each irrigated area. To ensure these approaches, the use of automated fertility management technologies in each field or irrigated area is required to improve the quality of technological and management solutions.

Automated control technologies, including decision support systems (DSS), according to their functional purpose, are divided into information-reference, information-consulting and information-control (Borodychev et al, 2018; Xia et al, 2011; Mikailsoy et al, 2010; Gagarin et al, 2017; Kuznetsov et al, 2014).

Information and reference systems - provide information about the managed process, while the evaluation of the information presented, as well as the acceptance of the managerial decision of the decision maker. Information and advisory systems (ISS) - are characterized by a higher level of control automation. They ensure the receipt and evaluation of information on the management object and generate acceptable alternatives to management decisions that can be taken as the basis for the decision maker (Rogachev, 2009). Information management systems (IMS) provide the next stage of automation of management, implementing the development of executable management decisions (Gagarin et al, 2010). A variety of parameters describing the state of irrigated fields and factors determining the choice of types and parameters of technological operations, the existence of management stages with changing objectives and methods of impact, taking into account various technological, ecological and technical and economic constraints, determine the need to develop automated technologies for crop cultivation using ASC.

Individual automated systems use satellite remote sensing data and GIS technologies (Pronko et al, 2010; Gagarin et al, 2010).

The task of automating the management of the irrigation regime of agricultural crops includes the choice of the irrigation method and calculation of the irrigation regime. The choice of the method of irrigation depends on the following main factors: the need for moistening the soil, its granulometric composition, the need for regulation of plant phytoclimate, the level of groundwater occurrence and the slopes of the field surface.

(Gagarin et al, 2017) proposed an algorithm for controlling the water regime of the soil in irrigation of crops, which allows: to plan the irrigation regime, to formulate and adjust the irrigation demand with an estimate of the likelihood of forecasting, to compile operational-current plans, and to analyze the need for irrigation using the accumulated information.

Results and discussion. The recommended flowchart for selecting the irrigation method is shown in Figure 1.

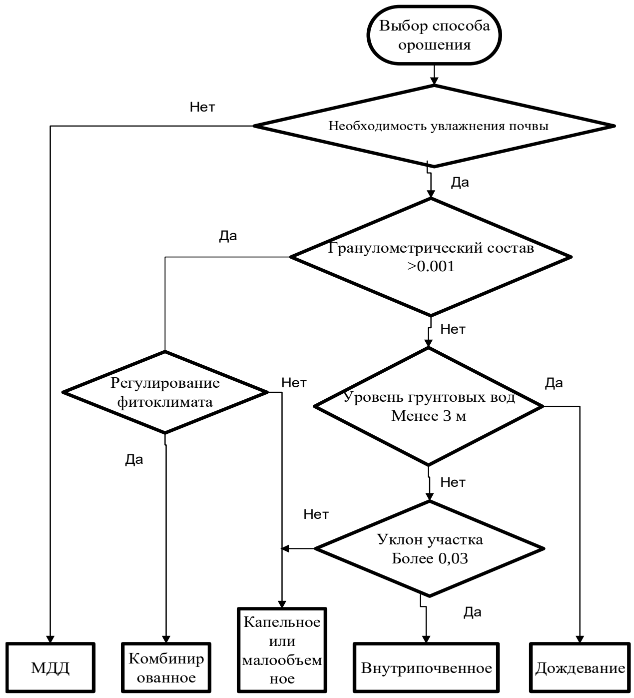

Figure 1. Flowchart for selecting the irrigation method

To implement the DSS in the field of irrigated agricultural production on the basis of GIS technologies, a specialized database was developed, including the following relational tables, which form the following blocks: soil, meteorological, biological, technological, and calculation (Fig. 2).

Various approaches are known to form the irrigation regime in land reclamation (Mikailsoy et al, 2010; Pronko et al, 2010; Rogachev, 2009).

The authors of (Borodychev et al, 2018; Gagarin et al, 2017) consider the use of modern solutions in monitoring the water regime of the soil within the irrigated area and propose a calculation method using agrometeorological information, as well as increasing the accuracy of predictive and retrospective calculations through the use of multiparametric models for determining the total water consumption of agricultural crops.

The information and advisory system for managing the fertility of irrigated soils (Pronko et al, 2010) can be used both as part of an integrated system for designing technologies for growing crops and for managing them, and independently - for the design and management of operations for the application of organic and mineral fertilizers. In its development, relational databases (DB) were used, which made it possible to unify various directories and sets of procedural rules for assessing the soil-meliorative state of the irrigated area, rules and algorithms for determining species, doses and terms of fertilization. The system is focused on preserving and improving the fertility of irrigated plots and efficient use of resources. This is achieved by optimizing the composition and parameters of the technological process of applying organic and mineral fertilizers. They are able to ensure the receipt of planned crops, to prevent dehumification of the soil.

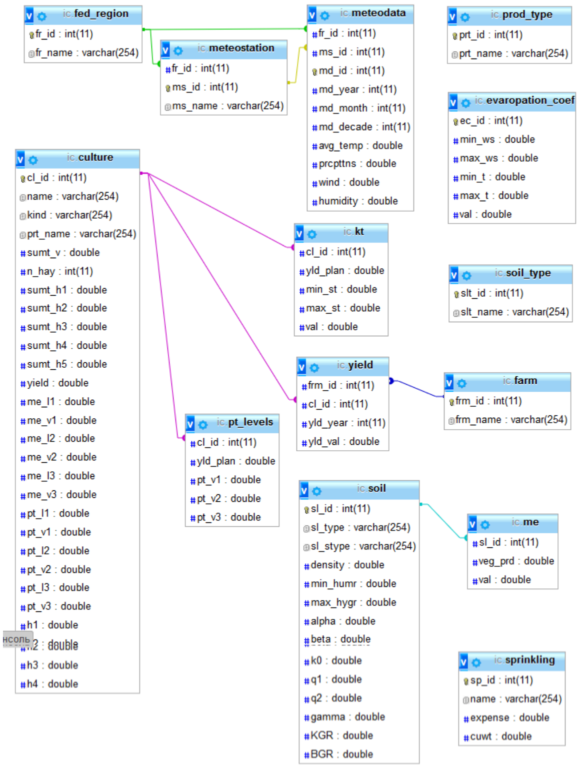

Figure 2. Structure of the relational database of agro-meliorative and technological parameters

According to the authors of (Gagarin et al, 2017), for the management of the water regime of agricultural crops, it is necessary to carry out an imitation modeling of the development of plants taking into account the type of crop, the method of irrigation, agroclimatic conditions, including the characteristics of the soil, the phases of plant development associated with the sum of accumulated temperatures and FAR,

The basis of the calculation in the model used is the modified dependence for the total water consumption of the Penman-Monteith formula:

$$ET_0 = \frac{0{,}408\Delta(R_n - G) + \gamma \frac{900}{t+273} U_2 (e_s - e_a)}{\Delta + \gamma(1 + 0{,}34U_2)} \qquad (1)$$

where ET_0 is the reference evapotranspiration, mm / day; R_n - net radiation on the plant surface, mJ / m^2 per day; G - heat flux density of soil, mJ / m^2 per day; t - average daily air temperature at a height of 2 m; U_2 - wind speed at a height of 2 m, m / s; e_s - saturation vapor pressure, kPa; e_a - is the actual vapor pressure, kPa; Δ is the slope of the vapor pressure curve, kPa/^{0}C; γ - psychrometric constant, kPa/^{0}C.

The solution system includes models for optimizing and searching for an effective option for specified criteria based on information about the need for financing, material and technical resources, etc., necessary for evaluating the options for a repair plan. A distinctive feature of this subsystem should be the implementation of a "measure of comparison" of alternatives based on GIS technologies, in particular, the solution of the stochastic task of technical and economic optimization of parameters of complex technical objects, for example, irrigation systems. Consider the formulation of the general problem of optimizing a design object based on linear programming: Find a plan x such that

$F(x) = cx \to$ max max under the following conditions:

$Ax \le b, x \ge 0$

Where $\boldsymbol{x}$ = (*xi*) – is the vector of the unknown variables,

A - matrix of technical and economic coefficients of production costs,

b = (bj) is the vector of free constraint members*;*

c = (cj) is the vector of the coefficients of the objective function.

In stochastic problems, A, b and c can be random. Stochastic programming allows you to choose a plan that would be best, taking into account all possible realizations of the random parameters of the problem and their probabilities. In most cases, as a criterion of optimality is the maximum (minimum) of the mathematical expectation of the objective function M [F (x)] or the minimum of its variance D[F(x)]. In stochastic programming, the described general approach, depending on the nature of the problem being solved, can be realized by applying one of the following optimality criteria:

$$F(x) = M\,(cx) \to \max \qquad (2)$$

A) The maximum of the mathematical expectation of the effect. In this case, the variance of the effect is not taken into account. This optimality criterion is used in most known applied problems of stochastic programming. It corresponds to the planning and economic tasks for which the criterion of optimality is the maximum of profit or other maximized indicators.

B) The maximum probability of exceeding a certain fixed value of the effect.

$$P[\Phi(x,\xi) \geq \Phi_0] \to \max, \quad (3)$$

where Φ_0 - is a given threshold sign of the effect, the decrease of which is undesirable. One-stage problems are such stochastic problems in which the optimality criteria are: variance of the effect; probability of exceeding the specified threshold value of the effect; linear combination of the mathematical expectation of the effect and its variance. Two-stage tasks are characterized by the fact that the process of making a planned decision involves two stages: the adoption of a priori solution X and then, after the concrete r-th realization of the random conditions becomes known, the a posteriori soluteon yr (r = 1,2, ..., n).

Functional capabilities of the field monitoring subsystem: creating custom vector maps in vector format, updating current field maps (Fig. 3) with specification of their boundaries, splitting or merging; input of GPS data with quality control by the number of satellites used in operation and the geometry of their position, affecting the accuracy of positioning; display on the map in real time of data received from GPS; the measurement of distances and areas on a map; definition by simplified technology of a part of the field, processed by agricultural machinery; correction of the accompanying information for each field.

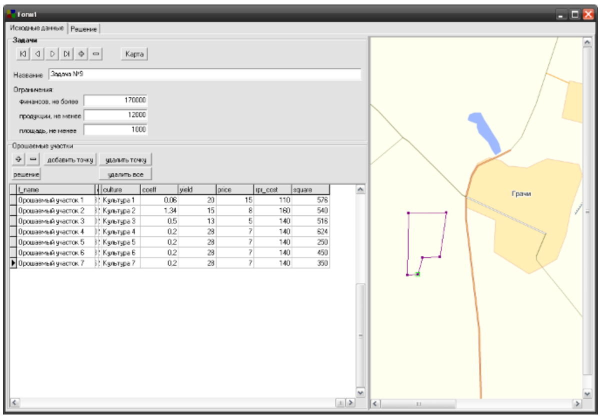

Figure 3. Creating custom vector maps in vector format

For each irrigated area, information on the coordinates, area, cultivated crop rotations (precursors), mechanical and agrochemical composition, soil degradation, terrain features (slopes), etc. are recorded.

Data of agrochemical analysis of soils for each working area of the field can be obtained:

- agrochemical surveys conducted by specialized laboratories;
- own research.

In the first case, the data is provided in the form of an electronic report. Information on the agrochemical state of soils should be conducted at least once every 5 years.

In the second case, it is possible to reveal the local features of each section of the field, according to the distributed data. However, for a number of calculations, it is necessary to operate with uniform indicators of nutrient levels in the soil within the site. The program allows you to calculate a single value by a different method using different methods. The second method of agrochemical monitoring is more promising, since it prepares data for differential fertilization.

The meliorative state of the irrigated area depends on many natural and climatic conditions (moisture availability of the year, air temperature, soil during the growing season of crops, wind speed, terrain, etc.). To conduct timely irrigation, it is necessary to monitor, preferably daily, these indicators promptly. For this, appropriate sensors and measuring and recording equipment are required.

Currently, there are many programs using GIS-technologies: QGIS, GEOGRAF, MapINFO, Map 2005, etc., allowing to implement and computer monitoring, which is an effective method for determining and visualizing changes in humidity and productivity on the fields of the economy. Taking into account the data on which area of the field will bring a greater yield, proceeding from optimization of costs and extraction of maximum profit, a decision is taken on differentiated field processing. It is possible to set the opposite task - to reduce costs in accordance with the potential of the harvest on poor lands. If desired, at any time, the system of computer yield monitoring can easily be turned into a yield mapping system.

Based on topographic data on the location of the working areas of fields and field passports, the system makes it possible to determine the following indicators:

- slopes of terrain (averaged, longitudinal and transverse);
- exposure (direction) of the slopes (to the north, to the south, to the east, to the west);
- the degree of erosion;
- mechanical composition of soils.

By combining these data with agrochemical data, yield maps, precipitation levels, surface runoff, etc., it is possible to determine local areas characterized by some assessment: leaching or fertilizer application and NWP, swamping or lack of moisture, up to yield forecasting.

Data analysis technology is provided by means of spatial analysis of GIS Map 2005. The user is presented with a wide range of powerful functions of spatial modeling and analysis. The analysis is based on the functions of constructing and transforming vector data into matrix (raster) and vice versa. Spatial analysis includes:

- Conversion of vector data into matrix data.
- Creating buffer zones by the distance and proximity of objects.
- Creation of density maps of objects.
- Creation of continuous surfaces by points.
- Construction of isolines (interpolation), calculation of tilt angles, exposure of slopes, washing of relief.
- Analysis of the matrix map.
- Performing algebraic operations and logical queries to a series of maps and matrices.
- Execution of overlay operations (entry, intersection, proximity).

Conclusions. Thus, the conducted analysis of Russian and foreign developments showed that the software for monitoring irrigated agricultural land based on GIS technologies should take into account data on soil moisture, temperature and wind speed in the irrigated area, for the operative regulation of the water regime of plants in arid conditions. For this, it is necessary to create GIS-systems with blocks for mathematical processing, analysis and decision support, as well as forecasting the development of agrocenoses using the described mathematical models and the structure of the database.

REFERENCES

Borodychev, V.V., and Lytov, M .N., 2018, System «Analysis – Data Visualization – Decision-Making» Consisting of Irrigation Management Geographic Information System. Proceedings of Nizhncvolzhskiy agrouniversity complex: science and higher vocational education. 2 (50), pp 37-44.

Carvalho, F. P., and Carvalho, F. P., 2006, Agriculture, pesticides, food security and food safety. Environmental science & policy. 9 (7 – 8), pp. 685-692.

Xia, J. and Tang, Z.X., 2011, An environment monitoring system for precise agriculture based on wireless sensor networks. Mobile Ad-hoc and Sensor Networks (MSN), Seventh International Conference on. – IEEE, pp. 28-35.

Mikailsoy, F. D., and Pachepsky, Y.A., 2010, Average concentration of soluble salts in leached soils inferred from the convective-dispersive equation. Irrigation Science, 28 (5), pp. 431–434.

Gagarin, A.G., Rogachev, A.F and Melikhova, E.V. 2017, Parameters for calculating the irrigation regimes of agricultural crops, taking into account the heat and moisture availability of the region. Certificate of state. register. computer software No. 2017620719.

Kuznetsov, Yu.V., Rogachev, A.F., Kuznetsova, N.V. and etal, 2014, Patent RU No. 2525610 "Method of cultivating vegetable crops during drip irrigation" .

Pronko, N.A., Falkovich, A.S., and Korsak, V.V., 2010, Application of geoinformation technologies for spatial modeling of water-salt regime of irrigated lands of the dry steppe Volga region. Agrarian Scientific Journal. 9, pp. 13-16.

Rogachev, A.F., 2009, Mathematical support of decision support system based on GIS-technologies. News of the Nizhnevolzhsk Agro-University Complex: Science and Higher Vocational Education. 2, pp. 144 – 151.

Gagarin, A.G., and Rogachev, A.F. 2010 г. Optimization of the choice of irrigated sites with interactive cartographic visualization .Certificate of official registration of the computer program № 2010612479

SUVARMA ƏKİNÇİLİYİNDƏ KƏND TƏSƏRRÜFATI BİTKİLƏRİNİN SU REJİMİNİN İDARƏ OLUNMASININ GEOİNFORMASİYA TEXNOLOGİYALARI

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Məqalədə suvarma dövründə kənd təsərrüfatı bitkilərinin su rejiminin tənzimlənməsi alqoritmi araşdırılır. Suvarılan sahələrdə, əsasən də kəskin quraqlıq şəraitində su rejiminin monitorinqi və tənzimlənməsi üçün geniş yayılmış və müəlliflər tərəfindən daha da təkmilləşdirilmiş GİS sistemlərinin analizindən istifadə edilmişdir. Həm Rusiyada, həm də xaricdə aparılmış tədqiqatların nəticələri göstərir ki, GİS texnologiyasına əsaslanan kompüterləşdirilmiş sistemlərdə real vaxt daxilində suvarılan sahələrdə torpaqların rütubətliliyi, temperaturu və küləyin sürəti ilə bağlı məlumat əldə etmək mümkündür. Quraqlıq şəraitində bitkilərin su rejmini tənzimləmək üçün istiliyin, duzluluğun və rütubət mübadiləsinin müvafiq riyazi modellərinə əsaslanan ilkin analizinin aparılmasına ehtiyac vardır. Bu isə, öz növbəsində, GİS sistemlərinin riyazi emal, analiz və təminat seçimi bloklarının yaradılmasını, həm də göstərilən riyazi modellərdən və məlumat bazası strukturundan istifadə etməklə aqrosenozların inkişafetmə proqnozunun verilməsini tələb edir.

ГЕОИНФОРМАЦИОННЫЕ ТЕХНОЛОГИИ ДЛЯ УПРАВЛЕНИЯ ВОДНОГО РЕЖИМА СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР В ИРРИГАЦИОННОМ СЕЛЬСКОМ ХОЗЯЙСТВЕ

Е.В.Мелихова, А.Ф.Рогачев, Ф.Д.Микайсой

В статье определен алгоритм управления водным режимом сельскохозяйственных культур при орошении, на основе анализа хорошо известных и разработанных авторами ГИС-систем для мониторинга и контроля водного режима орошаемых полей, главным образом для острых аридных состояний. Анализ российских и зарубежных разработок показал, что компьютеризированные системы на основе ГИС-технологий для мониторинга орошаемых

сельскохозяйственных земель должны получать и регистрировать данные о влажности, температуре почвы и скорости ветра на орошаемой площади в реальном времени. Для оперативного регулирования водного режима растений в засушливых природных условиях необходим предварительный анализ, основанный на адекватных математических моделях обмена тепла, соли и влаги. Это требует создания ГИС-систем с блоками математической обработки, анализа и поддержки принятия решений, а также прогнозирования развития агроценозов с использованием описанных математических моделей и структуры базы данных.