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Necessity and ways to improve the systems of irrigation management on a resource basis

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Abstract – **The necessity and ways of improving irrigation management systems are considered. An analysis of international and native experience in the development and implementation of information systems to support management decision-making in irrigation has been carried out. The current changes in conditions and requirements to irrigated agricultural production are described. Primarily in terms of the critical shortage and increasing cost of water and energy resources, which necessitate the improvement of existing methods and means of water use planning for irrigation on a resource basis. Appropriate resource-based solutions are proposed.**

Keywords — improvement, planned water use, irrigation, resource optimization.

I. INTRODUCTION

The situation in irrigated agriculture and its further development are influenced by existing global and local challenges and threats that are emerging in Ukraine's water and agricultural sectors, playing a significant role in the development of land reclamation science and practice. These challenges are caused by changes in the natural and socio-economic environment: climate change, water and energy crises, changes in water and land use conditions, reforms in public administration and individual sectors of the economy, scientific and innovative development, as well as, undoubtedly, Russian military aggression. [1; 3 etc.].

The continuous increase in the cost of material and technical resources involved in irrigation, as well as the need to involve investments in the restoration of irrigation systems, have led to higher requirements for the management of technological processes in irrigated agriculture.

As a result, it became necessary to move from planning and decision-making in irrigation using traditional approaches to planning and decision-making based on a significantly larger amount of information using information systems and taking into account not only the assessment of the effectiveness of the technological decisions made, but also the actual operating conditions of the facility, the level and direction of agricultural production, and, above all, the amount of resources spent to ensure it.

The need for further development and improvement of the principles, models, methods and means of water use planning in irrigation is due to the ever-increasing requirements for the quality and efficiency of its implementation in view of the necessity to increase the overall efficiency of water resources use by optimizing management processes, expanding information support, improving the efficiency, quality and overall level of technical operation of water resources [2; 3; 4, etc.].

Experience in developing and implementing information systems to support management decision-making in irrigation shows that the main trends in their development are the provision of services via the Internet and mobile applications, and the development of web database interfaces in the form of Internet portals. Examples of this type of information system to support management decision-making include: IRRINET and IrriSat (Italy), IrriSatSMS (Australia), Anglia River Basin (United Kingdom), IRRISA (France), etc.

At the same time, information systems for supporting management decisions are distinguished, which analyze remote sensing data, use modelling of processes in the 'soil-plant-atmosphere' environment, based on the processing of direct measurements of meteorological conditions, plant development parameters and soil moisture using various types of sensors, automated weather stations and devices [2, 5 etc.]. Such systems have their advantages and disadvantages in terms of achieving high productivity in the use of water and energy resources and do not always meet modern conditions and requirements for the implementation of such tasks.

II. STATEMENT OF THE PROBLEM

Modern processes of reform and innovative development in irrigation management are shaping new requirements and opportunities for the development of irrigation management methods. Flexible systemic approaches are needed that take into account the conditions of actual production, spatial and temporal

variability of natural and economic factors, as well as the ongoing transformation processes in irrigation system management.

In recent years, irrigated agriculture in Ukraine has faced significant changes in conditions and realities of its implementation – the increase in air temperature and overall climate aridity predicted in the context of climate change (which are already being actively observed and felt today) are leading to an increase in the frequency and intensity of droughts, a critical reduction in the natural moisture provision of territories and soil moisture content, an increase in total evaporation and the overall water demand of agricultural crops. All this takes place against a backdrop of growing scarcity and rising costs of water and energy resources that are available and suitable for irrigation. In addition, we are facing military aggression, which has led to a significant reduction in cultivated areas, exacerbated the critical problem of water scarcity, and restricted access to and the ability to collect information, including remote sensing data, which forms the basis of most modern information systems.

Recent changes in the operating conditions of irrigation systems necessitate changes in the methodological approaches to their creation and operation, which should be based on a resource-oriented approach, primarily with regard to the strategic importance of saving water and energy resources. This determines the need for further development of irrigation based on nature-based and environmentally efficient solutions through the development of regime-technological and technical resource-saving measures and means, taking into account the entire set of variable natural, agricultural and meliorative conditions.

It is necessary to further develop and improve existing principles, methods, models and means of irrigation management, which are driven by ever-increasing demands for quality and efficiency in terms of optimizing management processes, expanding information support, improving operational efficiency, quality and the overall level of irrigation system operation.

III.SOLUTION TO THE PROBLEM

To further development of existing approaches and solutions for operational irrigation planning information systems, as well as the currently developed principles for automating planned water management of drained lands [1; 4], we propose a ***complex automated planned water use system (CAPWS)***. In contrast to existing solutions, ***CAPWS*** offers the possibility for existing irrigation systems to consider planned management in a comprehensive and interconnected manner by developing long-term ***water use plans (WUP)*** for the technological preparation stage for the next season (strategic planning level) and operational management by correcting ***WUP*** in real-time based on short-term forecasts (tactical planning level) using ***information systems for operational water use planning (IS OWUP)***.

At the same time, in line with our previous research on the justification of optimal solutions in the design, reconstruction and operation of irrigation systems as complex natural-technical, ecological and economic systems, a resource-based approach can be implemented using a comprehensive optimization model [6; 7]

$$\begin{cases} U_0 = \underset{\{i\}}{extr}\, U_i, i = \overline{1, n_i}; \\ R_{0j} = \min\limits_{\{i\}} \left| R_{ji} - \hat{R}_j \right|, j = \overline{1, n_j}; i = \overline{1, n_i}, \end{cases} \quad (1)$$

where U_o – extreme value under the accepted condition of the selected criterion of economic optimality U, which corresponds to the optimal technical and technological solution based on a set of possible options $I = \{i\}$, $i = \overline{1, n_i}$; R_{ji} – a set $\{j\}$, $j = \overline{1, n_j}$ of criteria for the use of resources for the relevant technical and technological solutions; $\hat{R}_j$ – relevant justified indicators of the level of use of this resource.

The system of equations in a general implicit form allows, on the basis of resource optimization, to theoretically justify the possibility of setting the task, search for and determine sequentially optimal operational, technological and technical solutions for diverse components and the system as a whole in their interconnection, both at the empirical and empirical-functional levels of determining the relationship between them.

This combination makes it possible to improve the efficiency of water use management in irrigation by improving the assessment of various types of resource capabilities of water and land users in each individual case, primarily the limited availability and suitability of water resources for irrigation.

CONCLUSIONS

Changes in the operating conditions of irrigation systems and agricultural production in general require improvement of approaches to water use planning and the creation of effective water management strategies in irrigation.

It is necessary to further develop and improve existing principles, methods, models and means of implementing water use planning in irrigation, which are driven by growing demands for quality and efficiency in its implementation in terms of optimizing management processes, improving the efficiency, quality and overall level of operation of irrigation systems, and expanding information support.

The improved ***complex automated planned water use system*** in irrigation has been proposed. This system makes it possible to consider planned and operational water resource management in a comprehensive and interrelated manner. It is based on the development of long-term ***water use plans*** at the stage of technological preparation of the system for the next season across the entire spectrum of variable natural, agricultural and meliorative conditions and their subsequent adjustment in real-time conditions based on short-term forecasts using ***information systems for operational water use planning***.

The availability of such a tool makes it possible to improve the effectiveness of management decisions on

irrigation by improving the assessment of various types of resource capabilities of water users in each individual case, primarily with regard to the growing shortage and cost of water and energy resources, which corresponds to modern conditions and requirements for irrigated agriculture.

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