Information Support for Predictive Modeling of Agroecosystems

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Abstract. In recent years, the anthropogenic load on the environment has been growing. This leads to the aggravation of environmental problems. To solve such problems, different concepts are needed that will allow nature and man to coexist stably. To make the right decision in any area that determines human activity, it is necessary to predict actions and their consequences. At the present stage of the development of science, simple intuition is not enough. High-quality recommendations are also often lost their relevance. In recent years, with the use of information technologies, a fundamentally new approach to working with agroecosystems has been growing - process modeling. At the same time, the created models can provide the solution of the assigned tasks with very high accuracy. Such models take into account soil and climatic conditions, weather factors that determine the area of consideration. The introduction of high-performance computers made it possible to create a reliable base for the development of such models.

1. Introduction

Any model should be created with a specific purpose. The ideal would be to have a clear goal. But it should be noted that very often there is no idea about the tasks set. Modern soil science is no exception. The general trend - mathematization and modeling of scientific research - has become a characteristic feature of this area as well. If earlier in soil science they were limited only to the use of methods that allow statistically processing data, now, with the rapid development of information systems, more and more attention is paid to system analysis - methods of modeling complex dynamic systems [5].

When modeling, as a rule, there is no criterion for achieving the goal. The goal is usually very general. It is necessary to identify and study those factors that would have a significant impact on the behavior of the system. The dynamic components of the system must take into account the variability of parameters and the results of the decisions made. The main attention in forecasting is paid to practical usefulness, accuracy, comparison of modeling results with the set goal. Analysis of the work on modeling processes in agroecosystems shows that today information support is one of the priority areas for the development of the digital economy both in Russia and abroad.
2. Methods

The intensive use of soils is becoming more and more large-scale. With the strongest influence, there is a change in their fertility, properties, structure. In order to be able to identify changes in soil processes, it is convenient to create and consider its mathematical model.

Soil refers to complex systems, the modeling of which is determined by the objectives of the study. Various mathematical models will represent a description of a system developed for various, including special, purposes. Such models will play a special role in planning and setting up new experiments, forecasts and observations.

Recently, more and more situations have arisen in which it is necessary to form the soil cover anew. For this, ways of creating targeted soil structures are being developed [1-21]. Currently, two approaches to soil design are proposed. The first is stationary experiments that allow the development of specialized designs. The second is a mathematical modeling method. It allows you to make forecasts of changes in soil moisture and simulate the processes of moisture movement, taking into account the influence of various anthropogenic and climatic factors. The solution of such problems makes it possible to choose the optimal control of the soil regime.

Water has a profound effect on the soil-forming process. Under its influence, the agronomic properties of the soil, air, water, heat, nutritional regimes change. As a consequence of its effect on the soil, water also has an effect on plants and their yields. The positive side of irrigation is reflected in the improvement of the nutrient regime of the plants, since being a good solvent, water enriches the root system with nutrients faster and better. Along with the positive effect of irrigation on the soil, irrigation can also cause negative consequences. With land-based irrigation methods. During sprinkling, the structure of aggregates is destroyed, and the air and nutritional regimes deteriorate. Water seepage into the depths transfers silt particles to the lower layers, which leads to the formation of an interlayer that prevents the penetration of plant roots and air into deeper soil layers. Excessive, unregulated irrigation causes loss of nutrients, waterlogging, which can lead to reduced yields. As a result, it is necessary to correctly and timely conduct irrigation measures.

The purpose of our work was to consider moisture transfer in mathematical models, with the subsequent possibility of creating soil soils. The basis for the work of the software and hardware used by information technologies was the concept of A.D. Voronin. This concept allows you to work with soil hydrological constants:

- porosity $\varepsilon \Rightarrow P=0$;
- yield strength $W_{ys} \Rightarrow p_{F}=2.17$;
- least moisture capacity $W_{lmc} \Rightarrow p_{F}=2.17 + W_{lmc}$;
- maximum molecular hygroscopic capacity $W_{mmhc} \Rightarrow p_{F}=2.17+3 \cdot W_{mmhc}$;
- maximum hygroscopicity of the soil $W_{mh} \Rightarrow p_{F}=4.45$.

Calculation of soil-hydrological constants makes it possible to reconstruct the main hydrophysical characteristics of soils from the data on the granulometric composition of the soil. In this case, the soil-hydrological constants are associated with the density $\rho$, porosity $\varepsilon$ of the soil and the content of fractions of the grain-size composition $\omega$, by regression equations:

$$
\varepsilon = 0.805 - 0.183 \omega_1 + 0.285 \omega_2 + 0.057 \omega_3 - 0.266 \rho
$$
$$
W_{ys} = 0.082 + 1.163 \omega_2 - 0.287 \omega_3 + 0.057 \omega_5 + 0.312 \varepsilon
$$
$$
W_{lmc} = 0.15 + 0.055 \omega_1 + 0.514 \omega_2 + 0.142 \omega_3 + 0.145 \omega_6
$$
$$
W_{mmhc} = 0.053 + 0.941 \omega_2 + 0.139 \omega_3 + 0.031 \omega_6 + 0.165 \varepsilon
$$
$$
W_{mh} = 0.009 + 0.198 \omega_1 - 0.059 \omega_2 - 0.04 \omega_3 + 0.078 \omega_5
$$

where $\omega_1, \omega_2, ..., \omega_6$ – fractions of soil granulometric composition from silt to coarse sand according to the classification of N.A. Kachinski [1].

3. Results

Currently, any substantiation of projects and calculations for projects in urban infrastructures is impossible without the use of computers and computer programs [12]. It should be remembered that it is necessary in mathematical modeling to take into account all the factors of the preliminary study of
territories. Since complex models require a large set of parameters and characteristics for describing soils in detail, and are also expensive, we propose to consider one of the possible ways of modeling according to the main hydrophysical characteristics of soils. This model requires fewer parameters and is easy to use.

The software package developed by us allows to significantly reduce the calculation time, and also provides a visual representation of the predicted processes. To load the main window of the program, the agrofizika.exe file, written by the software package, is launched. A window appears on the screen, with which the user is invited to work (Figure 1). The window shows a model of five layers of soil structure with which to work.

![Figure 1. Main program window](image1.png)

To enter the data with which we are going to work, select the "Edit" menu and then "Enter data". This opens the "Table" window (Figure 2), in which you can work with both new entered data and those previously saved in the database (Figure 3). All new data can also be saved.

![Figure 2. "Table" window for working with data.](image2.png)
Figure 3. Presentation of table results.

We take as a basis the basic hydrophysical characteristics and soil-hydrological constants [6]. A visual representation of the distribution of moisture along the horizons is conveniently viewed in the form of graphs of these processes (Figure 4). After filling in the tables, we select the function "Build a graph" and it is possible to predict the dependence of the pressure of the soil potential on the moisture content by the change in the granulometric composition of the soil (Figure 5).

Figure 4. Main hydrophysical characteristics of soils. Figure 5. Pressure dependence from soil moisture.

From the point of view of forecasting processes, it is also interesting to solve the inverse problem - finding the ratio of soil particles. This task is relevant, since soil structures, which are increasingly located in industrial zones, are of great value. But from an agroecological assessment, they are imperfect. It is necessary that such structures have the desired properties for the course of natural soil-forming processes. Knowing the optimal water-holding capacity of the fertile soil layer, porosity and specific gravity, it is possible to predict the quantitative content of soil mixture components. The selection of the particle size distribution, in accordance with the composition of the local soil, will provide optimal conditions for plant growth on structures. To do this, in the software package, select "Find data", in the window that appears (Figure 6), enter the characteristics necessary for solving the problem and click "Calculate". The calculation results are presented by the final table and the visual distribution of soil particles of the mixture (Figure 7). The end result of the simulated agroecosystem seems to be a complex system that includes a set of many processes, many of which we have not yet touched on in our work.
4. Conclusion

In conclusion, we note that the state of soil processes is greatly influenced by human economic activity. To predict and prevent negative impacts, it is necessary to create mathematical and computer models of agroecosystems. It should be remembered that any models are of balance nature. So, for example, in our case, when taking into account the water regime, it is necessary to take into account all water inflows into the soil. But even under this condition, no model, no matter how complex it is, is able to answer all the questions posed. Therefore, when solving problems of agroecology, both practical and theoretical, the task of building a system of models will always be relevant [11]. This is possible due to the improvement and implementation of digital technologies in agricultural production.

5. References

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