Using the Main Hydrophysical Characteristics of Soils in the Development of Methods for Modeling the Prevention of Erosion Processes

A V Chelovechkova¹, I V Komissarova¹, N V Mirosnichenko¹

¹Kurgan State Agricultural Academy named after T.S. Maltseva, s. Lesnikovo, Ketovskiy district, Kurgan region, 641300, Russia

E-mail: chelovechkova_2011@mail.ru

Abstract. In the practice of agricultural production, there are enough examples in the field of agriculture, when non-observance and violation of the laws of agriculture did not receive positive results. These include unjustified land reclamation, chemicalization, intensive technologies, reforming the agro-industrial complex. Taken without taking into account mutual, systemic connections, factors and methods seemed to be quite reasonable, extremely necessary, ecologically justified, and as a result, they often led to negative results of the functioning of agricultural production. In addition, it must be borne in mind that the state of agriculture has a huge impact on all aspects of the life of society and the country as a whole. It should be reminded of food independence and self-sufficiency in food. The laws of agriculture are manifested in production conditions in the universal law of conservation of matter and energy, in the system man - nature. Attempts to solve problems without scientific substantiation, bypass or ignore objective economic and natural laws have always ended in failure. In order not to unreasonably harm agroecological landscapes, an increasing number of computer techniques are proposed for modeling soil processes.

1. Introduction

One of the important elements of the strategic development of agriculture is the introduction of digital technologies. Developments in nanotechnology and biotechnology are important factors that determine the competitiveness of the industry. The rapid acquisition of information of a new quality, minimization of the risks of business projects leads to an accelerated pace of digital transformation of agricultural production.

One of the ways to introduce digital technologies today is the development of methods for modeling, forecasting, and preventing various processes in soils using software. Software methods allow analyzes not only in real time. They make it possible to make predictions, which is important in the context of modern management of soil fertility and optimization of soil parameters for specified properties. Soil formation processes form a characteristic vertical soil profile. This profile allows for the visual recognition of the main differences and soil types. As you know, irrigation has a very intense effect on the processes occurring in the soil. This leads to a change in the morphological properties of soils. As a result of improper impact on the soil, a decrease in its fertility is increasingly observed. For soil fertility, erosion processes are the most dangerous.

The aim of the study was to study the geomorphological conditions of the territory of the erosion-
denudation landscape of the Trans-Ural forest-steppe subregion on the erosion terrace of the native bank of the Tobol River. As a result of the study, it was necessary to show the possibilities of working with methods based on the developed and implemented digital technologies.

2. Materials and methods
The harm caused by erosion is varied and enormous. In most cases, this process is irreversible. As a result of the impact of erosion processes, fertility decreases, the chemical and mechanical composition changes. Also, water-physical properties undergo changes. Changing the water regime of soils allows you to see the problems that arise when working with soil resources and take the necessary measures to prevent erosion processes.

Leached chernozem became the main object of research at the working site. The soil-forming rocks of the site are deluvial silty sandy loam. They overlap the eroded surface of Paleogene clays, which determines the sandy loam composition of the soils. In terms of working with the water-physical properties of soils, the basic hydrophysical characteristics of soils are very convenient and clear. It is a kind of "soil passport" that reacts to external changes and influences. And the effectiveness of using software products in soil science has been repeatedly confirmed in practice [1-3]. To work with a computer model [9, 12] within the framework of the developed methodology for constructing the main hydrophysical characteristics of soils [10, 11, 13], in different years, the basic physical properties (particle size distribution, density, porosity) are determined. The advantage of the developed computer technique for constructing the main hydrophysical characteristic is the speed and convenience of implementation. It is also possible to simulate soil processes based on virtual computer analogs. Subsequently, an analysis was made of changes in the hydrophysical parameters of chernozems that inevitably occur under the influence of irrigation. The hardware-software model was implemented using the regression equations of A.D. Voronin, reflecting the dependence of soil-hydrological constants with the density $\rho$, porosity $\varepsilon$ of the soil and the content of fractions of the granulometric composition $\omega$:

- $\varepsilon=0.805-0.183\omega_{1}+0.285\omega_{2}+0.057\omega_{5}-0.266\rho$
- $W_{ys}=0.082+1.163\omega_{2}-0.287\omega_{3}-0.107\omega_{6}+0.312\varepsilon$
- $Wlmc=0.15+0.085\omega_{1}+0.514\omega_{2}+0.142\omega_{3}-0.145\omega_{6}$
- $Wmmhc=0.053+0.941\omega_{2}-0.139\omega_{3}-0.031\omega_{6}+0.165\varepsilon$
- $Wmh=-0.009+0.198\omega_{1}-0.059\omega_{2}+0.04\omega_{3}+0.078\omega_{5}$

where $\omega_{1}, \omega_{2} \ldots \omega_{6}$ – fractions of soil granulometric composition from silt to coarse sand according to the classification of N.A. Kachinski [5].

3. Results
It should be noted that the complexity of the experiments required to obtain the basic hydrophysical characteristics is that many instruments and different methods are required to operate over the entire pressure range. Therefore, the methods of "restoration" of the hydrophysical characteristics in terms of particle size distribution and hydrophysical constants are increasingly used [7]. Our proposed method for constructing the main hydrophysical characteristics [8] allows to reduce the time required for calculations and plotting. A visual representation in real time shows how changes in physical properties are reflected in the water properties of the soil. Figures 1 and 2 show graphs of the main hydrophysical characteristic, which was constructed from the results of studies carried out in 1986 and 2020.
The analysis of the results obtained showed that the number of aggregates with a size of 0.25-0.05 decreased from 65 to 61%. Whereas there was an increase in the quantitative content of the fraction 0.005-0.001 and <0.001. In 1986, the content of these fractions was 3.40% and 10.0%, respectively. And in 2020, their content increased to 9.08% and 13.67%, respectively. For 34 years of use of the irrigated area, soil porosity has decreased from 55.8% to 49.9%. The value of the smallest moisture capacity also decreased from 20 to 18%. The value of the maximum hygroscopic moisture increased due to an increase in silt fractions in the granulometric composition of the soil. The favorable growth interval of plants has been reduced. If in 1986 it was in the range from 20 to 33%, then in 2020 it fit in
the range from 18 to 26% of soil moisture. An uncontrolled amount of irrigation during the growing season led to soil compaction, an increase in bulk density and a decrease in water permeability.

The software model proposed for operation allows one to predict the quantitative ratio of particles of particle size distribution taking into account the optimal values of soil-hydrological constants. The solution of such an inverse problem makes it possible to visualize the production of soil with desired properties that are optimal for growing crops.

4. Conclusion
Soil erosion has become one of the main problems in agriculture. The problem of soil protection from water erosion is becoming more and more urgent. The structure and composition of the soil changes. This process is accelerated by intensive land use. We propose to use a computer model to solve this problem. A visual representation of the processes allows not only to improve the structure of soils, but also to simulate soil structures with specified properties. This will allow the development of specific measures to prevent and eliminate erosion. In particular, at the first stage of work, there is a need to draw up geoinformation maps that provide spatially coordinated information with a comprehensive assessment of all processes. At the second stage of work, taking into account the information received, proceed to specific agrotechnical methods. Here it is necessary to take into account the indicators of the energy and economic component of production. In particular, the correct placement of agricultural, field crops, perennial grasses and the development of a reclamation system of agriculture.

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