DESIGN OF THE INFORMATION TECHNOLOGIES FOR VARIABLE RATE APPLICATION OF FERTILIZERS

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The foundations of the design of information technology for the differential impact on soil and plants in the system for precision farming are presented.

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Agriculture in Russia, despite the existing difficulties is in need of innovative approaches that use information technology. For developed countries, precision farming is no longer an innovative technology, but in Russia it is still novel and has not been applied broadly.

The Russian agricultural sector, particularly in the area of arable farming and plant cultivation experiences an acute shortage of modern technologies and facilities equipped with computers and modern means of communication. The application of innovative information technologies in this area will improve crop production, reduce costs, the usage of resources and the negative impact on the environment.

The most widely used information technology in agriculture is precision farming, which allows an efficient management of crop production. Precision agriculture uses global positioning systems (GPS and GLONASS), geographic information system (GIS), special sensors, aerial photography and satellite imagery.

The basis of precision agriculture is to characterize soil heterogeneity within the same field. The main purpose of precision farming is to increase the effectiveness of technological operations, the quality of agricultural products and to reduce losses due to variable soil fertility. This naturally implies a differentiated approach to the problem of fertilization, crop protection and seed application rates.

Scientists have long been tackling the issues of optimal resource use in the cultivation of crops based on average values, but not considering the temporal and spatial variability.

With the advent of GPS, electronics and Geoinformation systems (GIS) it became possible to think how to expand the concept of “precision” agriculture to systems with large spatial and temporal variability. Therefore, instead of “precision" agriculture (Precision Agriculture) it is better to use the term “site-specific farming”, the agricultural production that considers temporal and spatial variability in fertility parameters.

The main stages in the development of information technology for the differential impact on soil and plants in precision agriculture are:

- Definition of a goal;
- Formulation of the tasks that need to be accomplished to reach the goal;
- Assessment of the initial information required to solve relevant problems;
- Identification of the tools necessary to obtain, process and interpret the information;
- Definition of the requirements necessary for the realization of technological process;
- Inventory of the human, physical and information resources that are available;
- Impementation of the preparations necessary for performance of technological process;
- Collection and analysis of additional data necessary for the implementation of the project;
- Modifications of the realization plan of the technological process after the analysis of the obtained data;

- Implementation of the modified plan;
- Repeat the process.

A successful realization of the technology for a variable rate application of fertilizers within the precision agriculture is possible using systems approach.

The first step is a definition of the goals that have to be reached. At this step it is necessary to consider labor, economic and ecological conditions. The goals have to be differentiated, realistic, and correspond to the opportunities of economy and the level of professionalism of its administrative personnel [1].

While designing a technological process it is necessary to take into account a set of factors, including a feasible ratio between expected profit and the requirements for environmental protection and possible risks.

The most typical factors are:

1. Receiving a maximum yield, disregarding existing restrictions. Such objectives are achieved by maximizing productivity at each field site taking into account the desired yield.

2. Maximizing profit. In this case, an optimization of the fertilizer doses takes into account their cost and expected profit. Such approach is more reasonable as it considers the causes of variability in the soil nutrient distribution and the costs associated with the mitigation of such variability. The problems associated with the existence of sites with low productivity are taken into account. When maximizing the yield, more fertilizers have to be applied to increase productivity. It is effective only when nutrients are a limiting factor. If limiting factors are, for example, soil compaction or proximity of ground waters, such an approach will lead to an unnecessary use of fertilizers. To maximize profit, it is better to reduce fertilization on marginal land. This approach increases the efficiency and reduces the negative impact on the environment.

3. To compensate for the lack of nutrients, fertilizers are applied to sites in strict accordance with the quantity of nutrients that have been removed with a harvest of previous culture. Doses of fertilizer application can be calculated on the basis of yield maps. In this case the maps of fertilizer application will be similar to the yield map.

4. The strategy towards maintaining the balance of nutrients is based on sampling soil nutrients and an assessment of the nutrient concentrations in the soil. Then nutrient concentrations in the soil are compared with the doses of fertilizers recommended for receiving a desired crop yield. The difference between these values is taken into account to further correct the doses of the variable rate application of fertilizers. Such approach is quite straightforward. To implement it, the data on the distribution of nutrients in soil and the recommended fertilizer dose are needed.

Depending on the goal and the formulated tasks different data sets may be needed. The most common ones are the data on productivity, soil characteristics, weather, technologies used, the history of fertilizer use, economic indicators, remote sensing data, etc.

A successful design of information technology for the site-specific use of fertilizers is only possible when adequate supporting information is available – the data on productivity of previous cultures, concentration of nutrients in the soil and the degree of heterogeneity in their distribution, the functions of responsiveness of crops to increasing doses of fertilizers, etc.

When designing such a technology, it is necessary to consider three types of heterogeneity of the fertility and productivity parameters - spatial, temporal and predictable. First of all, heterogeneity has to be measured, then analyzed and only then the correct, effective administrative decisions can be made. Furthermore, it is necessary to assess the performance of a technological process in the system of precision agriculture to achieve success at its realization. Exact and timely information on the character and the degree of

variability of parameters of fertility and productivity is necessary for the realization of this process [2].

Goal	Task	Information
Receiving a top yield	Application of necessary amount of fertilizers for the programmable crop's productivity	Model (Responsiveness functions)
Receiving the maximum profit	Optimization of doses of application of fertilizers	Economic model
Compensation of NPK	Input of nutrients (NPK), in proportion to productivity of previous culture	Yield maps and the experts' recommendation
Maintenance of nutrient concentration	Increase the level of limiting nutrients	Diagnostic data of soil parameters and expert advice
Maintaining the balance of organic matter in the soil	Application of traditional technology	Data on changes in the application history of organic fertilizers

Table – Tasks and necessary information for achieving a desired goal

Spatial variability of parameters of fertility and productivity can be measured by means of collecting and analyzing the data on the appropriate indicators in the accepted system of positioning with a strict binding to the chosen system of coordinates. Data on heterogeneity of productivity can be obtained with combines equipped with yield monitors that are now widely used in most developed countries.

It is possible to assess temporal variability of productivity and parameters of fertility by means of comparison, for example, the yield maps received for a number of years (3 or 5 years).

Predictable heterogeneity can be estimated as a result of comparison of planned, expected results with the actual results. This type of heterogeneity is, as a rule, caused by the wrong assessment of fertility of a field, an error in expected productivity and quality of the crop.

A successful implementation of technology requires appropriate resources. The degree to which a given technology can be realized depends on the availability of resources. First of all, the success depends on the education level, experience and motivation of the personnel. Consultants, suppliers of fertilizers and equipment can be extremely helpful in decision-making. For a successful introduction of new technology it is expedient to create a group (team) where everyone would be responsible for the achievement of specific objectives.

The availability of equipment has a large impact on decision-making and how effectively these decisions are implemented. Therefore it is necessary to devise a plan for the acquisition of the necessary equipment, taking into account financial opportunities of the economy.

When precision agriculture and the variable rate fertilizer application are mentioned, the first thing that a person thinks of is a global positioning system (GPS, GLONASS), Geoinformation systems (GIS), on-board computers and sophisticated machines for the variable rate application of fertilizers. Therefore, it is necessary to begin with the acquisition of a good computer with the memory and software sufficient for storage and processing of large volumes of information. To realize the technology for the differential use of fertilizers, an accumulation and storage of information from a field on crop productivity is one of the major factors. Then it is necessary to acquire reliable system of positioning of DGPS and learn how to work with a GIS system.

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