THE USE OF GEOGRAPHIC INFORMATION SYSTEMS IN AGRICULTURE TO INCREASE PRODUCTION

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Abstract. Due to the long production cycle, agriculture was not a business, which was attractive for investors for a long time. It is prone to natural risks and huge crop losses during cultivation, harvesting and storage, and the inability to automate biological processes and the lack of progresses in improving productivity and innovation. The use of IT in agriculture was limited to the use of computers and software mainly for financial management and business transactions tracking. Today, in industrialized countries, agriculture is put on an industrial basis. This means not only the use of powerful agricultural equipment, advanced agronomic methods and highly effective chemicals, but also the involvement of the most modern computer technologies. The introduction of computer technology in agriculture is somewhat behind industry, but today we can observe massive introduction of computer technology in agriculture in the United States, Europe and Russia. Agriculture is a perfect field to apply the information technologies. In this case, for effective and sustainable functioning of business enterprises in the new conditions, it is necessary to apply advanced information technologies to identify their internal reserves and attract external investments. This article discusses the importance of implementing information technology in the agro-industrial complex, agricultural problems, the need for the use of GIS systems will also be considered, the features of some systems will be analyzed. Based on the study, the authors propose solutions to some problems using GIS systems.

Keywords: agriculture, information technology, Geographic Information Systems (GIS), N-tester, increased production, fertilizers, vegetation index, winter wheat.

Introduction

For sure, computers and software alone cannot replace traditional agricultural tools, but they can provide very valuable information on their optimal use. Hints for the timing, places and volumes of fertilizers, pesticides, irrigation management, etc. given by special programs are already classic examples. The solution of such problems requires a rather large amount of input data, the receipt of which is the bulk of the cost of using information technology in agriculture. This is due to the fact that it is necessary to collect and maintain information databases on large areas over a considerable time period. Only the relevance, accuracy and completeness of the source data can ensure effective application of information technology in agriculture.

The peculiarity of using information technologies in agriculture is that almost all the data used are spatially (geographically) referenced. And, if we want, for example, to analyze the distribution of soil moisture along with productivity, then both of these data must be in the same coordinate system and have the necessary coordinate accuracy. Only such programs specialized in working with spatial information, namely, geographic information systems (GIS), can process such data [1; 2].

A geographic information system is a system for collecting, storing, analyzing and graphically visualizing spatial (geographical) data and related information about necessary objects.

The peculiarity of these systems is that they allow to integrate, maintain and jointly analyze the most different types of spatially distributed indicators and descriptive data. These systems are used to create and maintain land and water cadastres, property registers, environmental and weather monitoring, emergency management, production risk assessment, analysis of the various factor interaction, affecting crop yields and in many other applications based on spatially distributed information. The capabilities and flexibility of these systems ensure their applicability both nationwide and at the individual farm level.

Data for agricultural GIS are obtained in various ways. The main sources are direct field measurements followed by interpolation and processing the images from airplanes and space satellites. Direct measurements are mainly used at the individual farm or region level. Their advantage is the high accuracy and reliability of the results, the ability to measure a variety of indicators in direct contact with the ground. The disadvantage is the high cost, especially, when it comes to large areas. Space and high-altitude aerial survey data allow to control the volume of biomass, uniformity of plant

DOI:10.22616/ERDev.2020.19.TF506

growth, soil moisture, and other indicators. The most important advantage of such data, especially images from spacecraft, is their low cost with regular surveys of large areas.

Geographic information systems allow to analyze various factors [3]. For example, topographic analysis tools allow to build the maps of slope expositions, slope values on the basis of digital elevation models and to determine insolation coefficients; hydrological modeling tools allow to determine the direction and intensity of surface runoff, forming the basis for assessing the impact of agricultural activities on the environment. Based on the topographic analysis and soil maps, it is possible to build maps of erosion potential. Geostatistical analysis tools allow to identify spatio-temporal dependences of productivity on many factors, such as moisture, acidity, composition and other characteristics of soils, time and volume of fertilizers and pesticides, and many others. In general, GIS analytical tools allow us to solve a huge number of tasks to increase the sustainability of agricultural production and reduce its cost. It is most advisable to conduct such an analysis in regional centers that will be able to provide analysis results to farms in order to increase their efficiency and profitability.

The developed analysis capabilities and the high power of modern computers have led to the emergence of the so-called "precision" agriculture in developed countries, which collects data and analyzes the efficiency of agricultural production in very small areas, and the statistics collected on them allow for the most complete consideration of variations in soil characteristics, hydrological regime and other indicators. Based on this analysis, optimal irrigation, fertilizing and pesticides, other work, and even organization of a specific crop rotation are proposed for each microfield. The huge popularity of this technique is due to its high efficiency, while all other techniques have almost exhausted their potential to increase the yield and product quality. Processing and data analysis used in this approach are simply inconceivable without computers and geographic information systems - only they provide the necessary level of functionality for today.

Materials and methods

Let us test the hypothesis of increasing the productivity and reducing the fertilizer consumption using GIS systems on the example of winter wheat with the use of nitrogen fertilizer. The source of spatial data will be the UAV.

Initially, we will collect data. With the help of UAVs, four times from May to July, aerial photography was carried out in the infrared range. As a result, maps of vegetation indices and orthophotoplans were formed. Based on the generated data, information about the current state of the field is displayed [4; 5].

Fig. 1. **Map of the vegetation index obtained with the help of UAV with allocated sections No. 1, No. 2 and a four-year map of the vegetation index taken from the archive**

The first survey of the field was carried out on May 15. Using the four-year vegetation index map, two plots (No. 1 and No. 2) were allocated to calculate the number of plants and the need for fertilization of plants. The amount of fertilizer is calculated from the N-tester reading, which shows the amount of nitrogen [7]. The results are shown in Figure 2.

Fig. 2. **Results are checked by a device that detects the nitrogen level at two sites**

The next step is creating vector maps. With the help of GIS systems, the raster maps are converted to vector maps. On these maps, you can specify the amount of fertilizer needed, as well as create a task for the top-up Amazone ZG-B 5500 sprinter [8;9]. A map is shown in Figure 3.

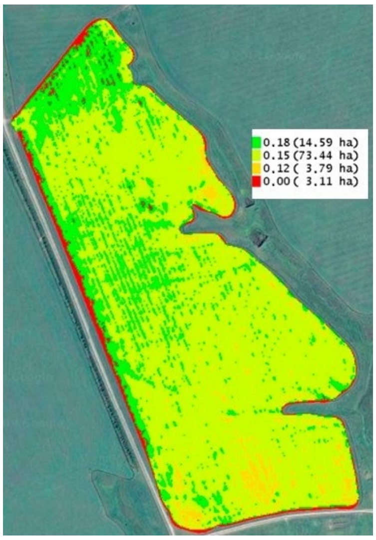

Fig. 3. **Vector map with the task of the first feeding; the values are given in tons of fertilizer per hectare**

In the experiment we used the technique developed at the Timiryazev Academy, which is that, knowing the readings that determine the amount of nitrogen in the soil, a feature of the variety and number of plants per unit area, it is possible to reduce the amount of fertilizer on heavily thinned plots. As well as increasing the number of plants to introduce more fertilizers [11]. The graph is shown in Fig. 4.

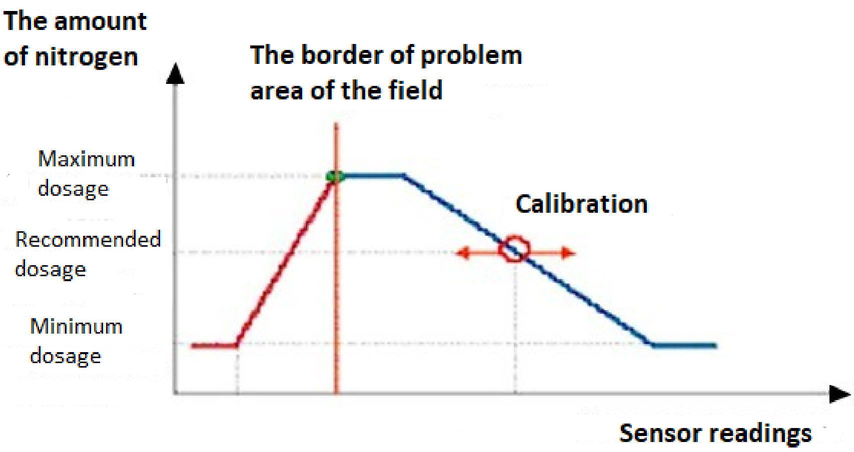

Fig. 4. **Experimental algorithm for applying nitrogen fertilizers on winter wheat according to the recommendations of the device, depending on the crop biomass**

The task for feeding the second section is shown in Fig. 5. In the main part of the field, differentiated fertilization is carried out. A section with an average norm is also formed [11]. The average amount of fertilizer on the site with uneven distribution was 60 kg·ha^{-1}. The result of the experiment is just the same, to establish the dose of fertilizer using GIS systems and precision farming.

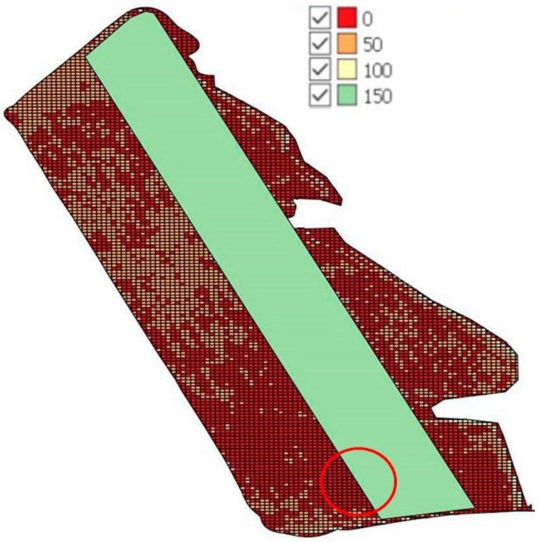

Fig. 5. **Vector map with a task for the second feeding. Values are given in kilograms per hectare**

Results and discussion

The yield map shows the border of the control area. The average yield values in the control area are lower, which clearly illustrates the correctness of the selected strategy of differentiated fertilization. The average yield on plot 1 was 59 C·ha^{-1}, on the control - 56.15 C·ha^{-1}, the average for the field-56.52 C·ha^{-1}. in total, for two fertilizings on 30 ha of experience, 2741 kg of ammonium nitrate was made less, which on average was 92 kg·ha^{-1}. The increase in the yield by 3.45 C·ha^{-1} and the saving of fertilizers allowed to get additional 3500 rubles·ha^{-1}.

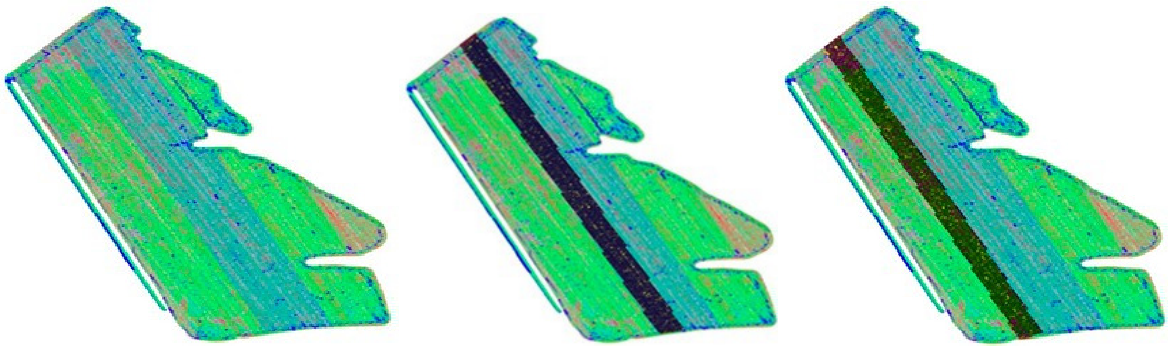

Fig. 6. **Vector maps showing the yield: general view, selected control area (“control”), selected area with differentiated input (“section 1”)**

Table 1

Economic efficiency of distributed nitrogen fertilizer application

Parameter	Top dressing No. 1		Top dressing No. 2	
	Plot 1	Control plot	Plot 1	Control plot
Square, ha	30	17	30	17
Average dose	149	150	59.9	150
Introduced	4470	2550	1797	2550
Difference to control, kg over the entire area	-30	0	-2703	0
Productivity c·ha^{-1}	58.04	56.37	-	-

Conclusions

1. Using GIS in this experiment, the yield was increased by 3.45 $C \cdot ha^{-1}$.
2. In addition to increasing the yield, 3500 $rubles \cdot ha^{-1}$ of fertilizers were also saved.
3. With the help of geographic information systems, it is possible for people involved in agriculture to easily integrate and use available sources of tabular and cartographic information to improve the quality of decisions.
4. GISs are quite flexible and can be used both for an individual economy and for the whole state.
5. It becomes clear from open sources that the payback period for investments aimed at the implementation of applied GIS is from 1 year to 3-5 years depending on the scale of the system being implemented, and the first effect of the system implementation is clearly visible already at the end of the first application season. Competitiveness grows with the profitability of the business as a result of lower costs and increased efficiency in the use of available resources.

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