Main Aspects of the Creation of Managing Information System at the Implementation of Precise Farming

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Abstract—**The paper presents the results of the research of the leading role of integrative information systems of management and accounting of agricultural production in the re-engineering of precision farming systems in agrarian enterprises. The authors determined the necessity, consistency, complexity and content of the main stages of the implementation of precision farming systems, analyzed the main problems and limitations of the implementation process, as well as the expediency of using a single software platform. The practical value of the work is to define the integration role of the management information system in the processing of data of various origins and generation of solutions options for the effective management of the agrarian enterprise.**

Keywords—precision farming; precise agriculture; digital technologies in agriculture; managing information system; GPS Monitoring; fields maps.

I. Introduction

In the era of post-industrialism, which replaced the previous agrarian and industrial waves of civilization, information and development of infocommunications on the basis of network technologies became one of the main productive resources [1].

Agrarian production is the most conservative industry and its informatization is uneven, especially in countries that have not reached the level of post-industrialism. However, objective factors characterized by a sufficient degree of uncertainty (climate change, cost growth, high level of exploitation of natural resources, redistribution of traditional markets, etc.) stimulate this industry to find innovative methods of agricultural production based on the using of information technologies and systems. From the mid. 1970s into the early 1980s, a better awareness of soil and crop condition variability within fields have grown from better field investigation methods including soil survey, soil sampling, aerial photography, and crop scouting. An important outcome was to perceive potential benefits of management within fields by zones rather than whole fields for increasing profitability. At the same time, the microcomputer became available and has made possible the acquisition, processing, and utilization of spatial field data as well as the development of a new kind of farm machinery with computerized controllers and sensors. This was the beginning of a new agricultural management concept called initial farming by soil types then site-specific management. If globalization impacted countries, industries, and a variety of businesses, it would start to impact agriculture, or more generally natural resources management, as well. Site-specific management (SSM), also called precision agriculture (PA) or precision farming (PF), is one of the best tools to answer this major challenge facing agriculture [2].

Exact agriculture has great potential and can radically change agribusiness, significantly increase agricultural productivity and reduce the level of environmental, material and other costs for growing crop production.

The purpose of this work was to present a generalized concept of the main stages of the introduction of precise farming systems and the creation of a universal model of information management system of agricultural production. The main attention was paid to the functional components of information systems in the execution of all operations of collection, storage, processing and transfer of information for the needs of agro-enterprise management. The results are based on the study and generalization of the experience of introducing precise farming systems in the economically developed countries of America and Europe as well as in Ukraine.

II. Analysis of Recent Studies and Publications, Which Discuss the Problem

The interest in the topic of precise agriculture is constantly growing in the world of scientific literature. A detailed analysis of the content of various precise farming definitions (precise agriculture, precise farming) as well as trends, forms and prospects for its implementation in most countries of the world was given in the works of P. Robert, R. Plant, M. McAretty et al. [2-4]. From the technological point of view, precise agriculture is defined as the concept of the introduction of arable farming technologies based on soil mapping units, the use of accurate remote data - satellite images or drones as well as the use of technologies for processing these data. From the manager's point of view, precise agriculture is a management strategy in agricultural production that is maximally based on modern information technologies to obtain accurate data from different sources of information, to prepare and make effective decisions for maximum profits. The purpose of implementing precise farming is to determine the decision support system for managing the entire economy in order to optimize profits with maximum conservation of resources [4].

For estimating and detecting particular areas of the field with specific characteristics or features the latest technologies are being used such as GPS positioning systems, special sensors, aerial photographs and satellite images as well as special programs for agrarian management based on geographic information systems (GIS) [4]. A detailed description of technological tools for precise farming, economic and environmental aspects of its implementation as well as a promising plan for supporting farmers in the European Union for the period 2014-2020 is outlined in a collective work, prepared by the European Parliament's Committee on Agricultural and Rural Development [5].

Three approaches for separation of control zones in the implementation of precise farming systems have been researched and summarized in work [6]. The first one is based on soil properties determined by different selection methods and / or landscape information, including soil inspection maps, landscape features, as well as soil and landscape factors. The second approach is based on crop yield maps. At the same time, there are three classes of zones on the field: high yielding and stable zone, a low yielding and stable zone, and unstable zone. However, several years of research and comparison have shown that the third approach is the most effective and efficient - the integrated approach of combining soil, landscape and spatial trend and temporal stability of information was reasonably efficient and more consistent in accounting for these three sources of variability [7]. The results of gathering and processing information presented in various sources show that the period of collection, accumulation and processing of information is long, and the determination of effective methods and tools of precise agriculture cannot be implemented without the use of a management information system, which will allow the calculations for all types of work and the necessary decision making. This aspect of the continuation of precise agriculture planning in publications was not highlighted enough.

III. MAIN RESULTS OF THE STUDY

A. *A comprehensive approach to the formation of the stages of implementation of the precise farming*

Precise farming methods were first used in the 1990s in the most developed economies and information areas - the United States, Canada, Japan and Western Europe. In Ukraine these methods began to be applied in the late 2000s, but even today we cannot talk about their mass implementation. The large enterprises or holdings were the first companies, which were able to make the transition to new technologies of precise farming, invested in the purchase of technical and digital equipment, software. But, there was still no established concept for the introduction of precision farming, so many algorithms had to be developed independently and for the first time. This formed the set of necessary preparatory stages and the immediate steps to implement this method of agribusiness. Most enterprises, as an initial stage, carried out a detailed agro-chemical analysis of soils, studying a sufficient number of samples in agrochemical laboratories [8]. Then there was a need to systematize all the information and make it accessible to all interested enterprises. Individual enterprises came to the idea of creating a so-called enterprise geoportal with its own database of accumulated data [8]. On the basis of the initial processing of the data obtained, there was made an analysis about the influence of various factors on the process of crop formation, calculations of optimal fertilizer application rates. In some cases, an analytical center was created, in which they developed schemes for differentiated fertilizer application, counted potential yields for each field, determined the list of necessary operations to achieve the desired result. During the calculations they took into account information on the influence of weather conditions, technology of cultivating culture, characteristic features of soils, and so on. Summarizing the experience of enterprises, that were the first to become involved in digital technologies in agriculture [7-9], we can isolate the main stages of implementation of precise farming technology in the form of the diagram shown in Fig. 1.

The experience gained by the first enterprises is quite valuable, on the basis of which methods and ways of introduction of precise farming technologies were formed by many enterprises with different bank of land, characteristics of soils, climatic conditions and other features. At the same time, technical and technological capabilities are also being changed, progressed. Today, Ukrainian agribusinesses, which actively innovate, already have computer maps of crops, spraying, agrochemical analysis of soils, aerial photographs of drones, yield maps. Now for many agrarians a tablet or smartphone becomes an indispensable attribute of work both in the office and in the fields. At the same time, agro machines become more intelligent, obtaining autopilot, GPS-navigation, automation for precise land treatment on the basis of electronic maps of cultivated fields.

A general trend that needs further development is the introduction of an electronic document management system in enterprises that operate a precise farming system. If, for example, in Germany, up to 20% of farms fully automated the processes of forming of the entire reporting documentation of enterprises based on the introduction of enterprise management systems together with precise farming systems [9], then in Ukraine this percentage is no more than 5% among large and medium-sized enterprises. The experience gained by the first basis of which methods and ways of enterprises is quite

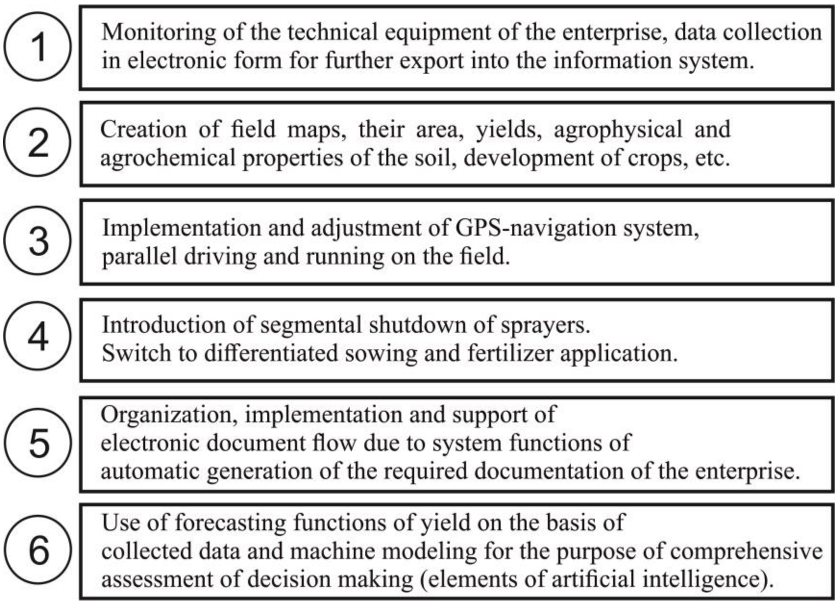

Figure 1. The main stages of the introduction of precision farming technology.

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B. Factors that limit the implementation of precision farming systems in agrarian enterprises

During scientific conferences, roundtables and seminars dedicated on problems of precise agriculture, we conducted interviews, discussions, surveys and questionnaires of managers and leading specialists of a large number of agricultural enterprises of different forms of ownership, different land banks to find out objective and subjective reasons for the low percentage of application of precise farming systems in Ukraine. On the basis of the own analysis and different companies' data [10] (for example, AgriLab is a consulting company that develops and implements comprehensive solutions to increase the efficiency of agribusiness) we can give a generalized list of the main factors that impede the implementation of precise farming systems and formulate recommendations for their changes towards transition to innovative methods in crop production.

Factor 1: management zones. Management zones are part of a field that reflects a relatively homogeneous combination of factors of profitability limitation. Usually, agronomists of agrarian companies consider all their fields as one farm and continue to use fertilizers and other resources for the entire economy or a large array of fields, which leads to a suboptimal result. Such an approach is far from the effectiveness of the application of precise farming elements.

The direction of change (improvement of situation): agronomists need to consider the fields in several smaller "management zones", which should be separated according to the system analysis of data, the characteristics of the fields (different zones have different quality of soil and potential), topographical data, humidity and requirements to use fertilizers, seeds, etc.

Factor 2: data collection. There is a significant list of technologies and technical equipment for data collection - soil analysis, unmanned aerial vehicles, satellite images, meteorological stations, various controllers and sensors for measuring of properties in soil and plants, etc. These technologies are capable of gathering a large amount of data, but many enterprises, especially small and medium-sized enterprises, still lack the technological infrastructure and sufficient expertise to consolidate and analyze the data.

Direction of change (improvement of situation): There is a need based on the reengineering approach of selecting technical means for information gathering, adequate in terms of price and opportunities, studying the proposals for the use of information systems for information processing and decision making support. Many companies, together with information gathering tools, develop separate software applications for information gathering and decision making support.

Factor 3: different standards. More and more developers are releasing new tools, individual software applications and platforms and interoperability quickly becomes an issue. A common situation where a particular software application is not compatible and did not receive data from sensors and other primary data collection devices. Leading manufacturers of seeds, plant protection products, mineral fertilizers and agricultural equipment are trying to combine the standards of various devices and tools on compatible platforms, such as Bayer. Potential clients are offered a package of services together with the Field View information system. However, this system has only English-language interface does not contain built-in dictionaries of data related to agrarian production in general (for example, all sorts of fertilizers, all types of plants protecting tools, etc.).

Direction of change (improvement of the situation): The task is to transform intelligent stand-alone devices and gateways into integral, farm-based platforms and the selection of compatible necessary equipment for the integrated implementation of precise farming systems.

Factor 4: Availability and Quality of Internet connection. In many distant rural areas and fields there is no strong connection to the Internet. This impedes the qualitative application of precise farming systems.

The direction of change (improvement of the situation): the recognition of the need to choose a reliable provider and ensure secure access to the network, taking into account the geographical features of the area.

Factor 5: Processing of Large Data. Digital farm technology is useful only when users can "understand" the available information and use it. It is impossible to monitor and manage each of the thousands of data points and view them daily / weekly throughout the entire growing season. Applications that simply provide information about heterogeneous zones or the general state of plant development in the fields are not very useful, because there is a need for more forecast tools: “monitoring and management”.

Direction of change (situation improvement): System analysis of historical data such as yield, weather, soil trends, input resources, etc. along with a control of actual data in real time must be made and accumulated in a single information system. In this case, they can give to agronomists powerful tools for making informed decisions and risk management, for prediction and avoidance of losses.

Factor 6: Training and retraining of staff. Accurate farming involves the implementing of cutting-edge technologies and tools for increasing the productivity of crop production. For engineers and agronomists, especially in small companies, the setup and use of the necessary software, the network of sensors for its fields, special equipment and other precise farming systems can be very complicated.

Direction of change (improvement of situation): The need for training of practicing agronomists and other specialists in short trainings as well as an introduction of new training courses at universities. For example, Poltava State Agrarian Academy since 2016 launched a large-scale cooperation project aimed at preparing modern agronomists with the latest information technologies in agriculture [11].

The analysis of world trends and experience of introducing precise farming systems at Ukrainian enterprises as well as some of the factors outlined above, allow us to formulate a basic recommendation that in the case of implementation will make it possible to simplify and consolidate the management processes of the software and hardware that provide the system precision agriculture in the enterprise as a whole.

C. Integrative Role of the Uniform Managing Information System in the Complex of Planning of Implementation Measures for Precise Farming

For the placement of primary data, further processing for decision making, it is extremely important to use the company's single software platform, which enables receiving and processing of data from systems with different software and hardware solutions. For example, data obtained from a GPS-monitoring system for agricultural machinery should be provided not only in the form of MS Excel tables or be able to export to the software for financial calculations, but also be used in a system that can simulate a particular agricultural technology operation or creation of the production plan of the enterprise itself. At the same time, such a highly specialized platform should contain a well-designed database for general purpose, be flexible, scalable and provide users with sufficiently convenient access.

On the basis of in-depth analysis of already existing most popular both foreign and domestic digital platforms (Field View, Soft.Farm, Cropio), we can say that the most optimal, economical and geographically accessible systems are those which based on cloud services.

As an example, it's logical to consider domestic IS Soft.Farm - free software for the organization and management of agricultural activities. The main advantage of this system is that it is based on cloud technologies and most of its modules are available for users for free. The basic scheme of organization of IS, located on the Amazon platform, is presented in Fig. 2.

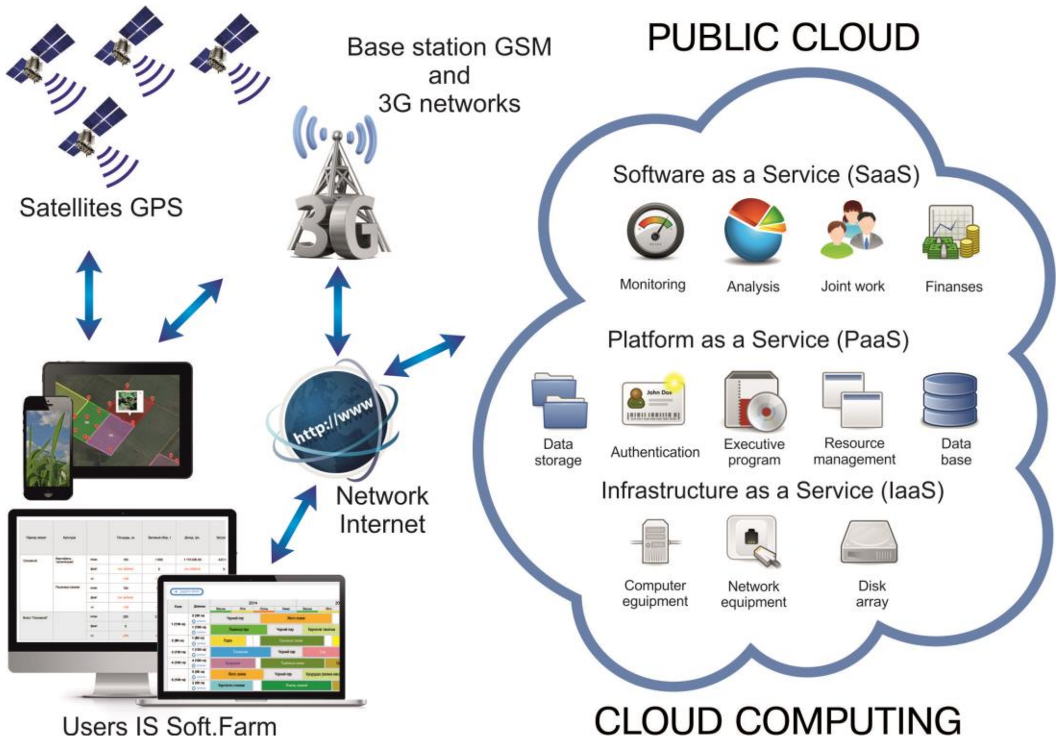

Figure 2. A scheme for constructing IS Soft.Farm and cloud services on the Amazon platform [11]

The system is developed for the needs of domestic agricultural producers (the database of reference books on the main components of agriculture, such as soils, pesticides, etc., the generation of electronic documents in accordance with the list and requirements of the current legislation).

The system provides users with the following online services (Fig. 2): SaaS (fields monitoring, data analysis, data interoperability, financial analysis); PaaS (data storage, authentication, resource management, databases, and access to the executive program); IaaS with corresponding sets of functional.

The generalized model of an information system should reasonably include the following set of functional modules: Land Bank, Agrotechnology, GPS monitoring of equipment, Satellite images, NDVI index, Cartograms, Meteorological irradiation, Online cost control, Works Planning and some others as well as mobile application.

The system database has already included a wealth of valuable information on all types of soils, fertilizer and plant protection tools, agricultural and power machinery in the form of dictionaries. All dictionaries can be supplemented by new data relevant to the particular enterprise by the users themselves.

The “Land Bank” module with the help of appropriate tools allows users to keep track of land lease agreements, to control the timing of contracts and to visualize the location of units on the field, conduct an audit of land plots and lease agreements.

The module "Differential introduction" carries out the accumulation of data of satellite monitoring of crops and properties of soils during the last years and then helps the agronomist to identify problem areas for the development of a map of tasks for the introduction of a variable norm. The algorithm of the system suggests calculating the differential inputs and the amount of the required solution, taking into account the characteristics of each field, which will ensure the efficient use of mineral fertilizers and plants protecting tools and reduce the cost of the economy as a whole.

The module "GPS monitoring technology" provides planning and control of fieldwork. Based on the timing of the implementation of the agricultural operations specified in the technological maps the system module creates a graphical representation of the fieldwork plan in the form of a Gantt chart. Such visualization will help to identify bottlenecks where agro-operations are carried out by the same type of agricultural machinery, change the start of the implementation and to distribute work effectively between the mechanics.

Implementation of fieldwork control unlike the standard set of GPS monitoring functions the Soft.Farm system module additionally gives the user the opportunity:

— automatic calculation of treated hectares, taking into account the overlays and self-moving, when several units of equipment work on the field;
— distribution of fuel on the crossing and work;
— operative receipt of information on performed work and fuel consumption in the context of agricultural operations, fields, equipment, machinery.

This module must include data from pre-filled dictionaries "Workers", "Agricultural Machines", type of technological operation on fieldwork. In separate fields entries are derived - results of calculations of data on fuel consumption, distance traveled total calculated and actually processed areas.

Different companies use Wialon, Wialon Hosting, Wialon Pro, SKT Globus, DozoR or Control Plus GPS monitoring systems then the system integrates quickly and provides the opportunity to use the new possibilities of GPS monitoring and fuel control.

The module “Satellite Snapshot, NDVI Index” allows you to monitor crops using images of artificial earth satellites. Satellite images reflect the distribution of vegetative mass in the field, which makes it possible to identify areas with low vegetation and develop agro technical measures to eliminate them. Analyzing the NDVI index over the years helps to identify productive and unproductive fields, and this information will help optimally form crop rotation.

Fig. 3 shows the image of NDVI Analysis Module Functionality on the example of a separate enterprise registered in Ukraine.

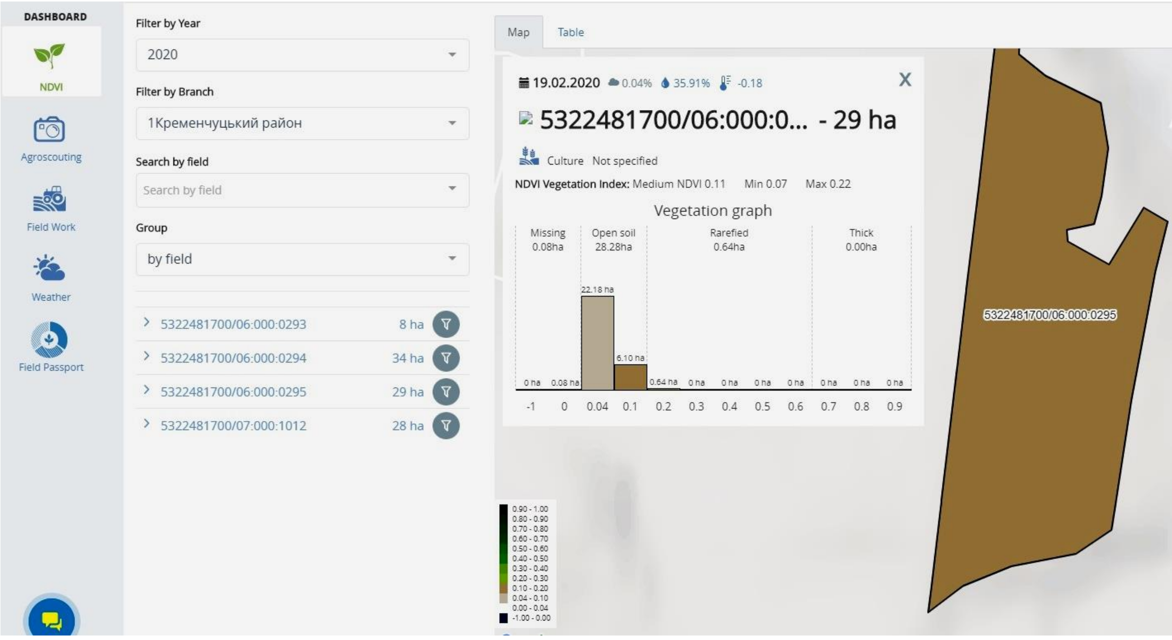

Figure 3. The image of NDVI Analysis Module Functionality on the example of a separate enterprise registered in Ukraine. [12]

The system is developed for the needs of domestic

Mobile application of the system, through which it is possible to monitor the implementation of tasks and to analyze their quality, during a planned field survey and report generation. The agronomist steps out into the field, examines the crops and while identifying problem areas, pests, diseases, and weeds makes a picture with an application, the mobile device captures the GPS coordinates of the photo and adds information to the report: pests, diseases, weeds found; phase of plant development; determines the risk group; describes the state of crops. After saving the review data, the mobile device will automatically download photos and GPS coordinates to the system portal when connected to the Internet and the information will immediately be available to other employees and will be stored in the field history. The mobile application also performs the function of the Navigator fields and problem areas that were identified with satellite monitoring and the NDVI index.

The module "Cartograms" of the system allows you to evaluate the soil through the analysis of the NDVI index in a few years identifying the problem areas of the field and then to investigate them carefully. It is foreseen to load the obtained results of chemical analysis or measurement the soil compaction (using a penetrometer) into the module and as a result a map of the distribution of indicators in the field, from the sample to the soil sample will be created. Thus, the user will be able to determine the properties of the soil at any point in the field, which is much more economical than the survey on the grid. The module provides storage and retrieval of information on the nutrients content (N P K and others), mechanical composition or soil moisture. In addition, the system module allows you to apply layers of soil properties to the layers of seeding cards or yield maps and compare them with each other.

The "Meteorological" module provides access to satellite data and integrates information from weather stations of different manufacturers in one interface. It is also possible to receive data with the help of soil moisture and temperature sensors, which are installed in the field at a depth of 50 cm to 1 m and for 20 years, transmit information to the server. The module provides enough information to carry out fieldwork in favorable weather conditions and not to spend unnecessary costs.

Cost-control module ON-LINE provides collection, processing and analysis of information from various sources on the progress of work on each of the technological operations, meaning an actual plan-fact analysis. In the next stages of implementing the concept of precision agriculture, such an information system will serve as an integration center for analysis, information processing and decision-making.

IV. Conclusion and Future Work

Consequently, the use of achievements in innovative information technologies in all spheres of the agro-industrial complex is complicated and multifaceted. Data collection, processing, management and technology of agricultural activities contribute to increasing of its efficiency, product quality, rational use of plant and fertilizer protection, saving energy and protecting the environment. This perspective direction of development of agricultural enterprises creates a favorable environment for the effective use of resource potential and the formation of competitiveness.

At all stages of the implementation of precision farming systems, the awareness of users of the need for a systematic approach is an important element. The key to efficiency, profitability is not only the selection of the necessary equipment for the maintenance of technological operations, but also the processing of data in the management system environment for the coherence of the work of all components and further decision-making.

The state needs to promote the introduction of more environmentally-friendly technologies by all players in the agrarian sector, focusing primarily on the needs of medium-sized enterprises and farmers and by organizing of targeted financial support as well as developing of advisory services.

In the future work, we plan to carry out an in-depth analysis of the functionality of each of the proposed modules of a typical information system structure and to supplement our analytical studies with a description of the scenarios of interaction between the data obtained and the directions (methods) of their application in the organization of automated process management of enterprises and organizations.

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