Precision Farming in the Republic of Belarus: Existing Problems and Future Prospects

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Abstract: Belarus has a high potential for introducing precision farming systems in agricultural production. One advantage is the availability of more than 1380 agricultural enterprises, with an average area of agricultural land of 5.3 thousand hectares, and an average area of arable land of 3.5 thousand hectares. Nevertheless, along with the advantages, there are both objective and subjective reasons that impede the widespread implementation of precision farming systems in the country's agricultural production. One of them is the existing system of on-farm land management, focused on traditional energy and resource-intensive farming. Based on the current situation, the development of precision farming systems should focus on large agricultural enterprises, and not private farms. Implementation of these measures when introducing differential fertilizer application allows increasing the profitability by: 2.2 % for winter crops, 1.3 % for sugar beets, 1.1 % for rapeseed for oilseeds and 0.8 % for malting barley.

Key words: Precision Farming, Agricultural Enterprises; Land Management; Farming System; Profitability.

Given the constant rise in the cost of energy resources and raw materials for the production of mineral fertilizers, as well as shortage of organic fertilizers, identifying ways of increasing the economic efficiency of land use is becoming urgent. The introduction of precision farming as a modern concept of agricultural management using digital methods to monitor and optimize agricultural production processes is one of the methods for its successful solution [1], or mitigation of the associated problems. The International Society of Precision Agriculture (ISPA) defines precision agriculture as: «management strategy that gathers, processes and analyzes temporal, spatial and individual data and combines it with other information to support management decisions according to estimated variability for improved resource use efficiency, productivity, quality, profitability and sustainability of agricultural production» [2]. Optimization of all production processes is the key point and driving force of precision agriculture, the result of which is the rational use of resources, cost savings and reduction of negative environmental impact.

Belarus has a sufficiently high potential for introducing a precision farming system or its individual elements in agricultural production. Among its main advantages is the existence of 1382 agricultural enterprises with an average land use of more than 5.3 thousand hectares of agricultural land and over 3.5 thousand hectares of arable land [3]. A positive factor that contributes to the implementation of precision technologies is the concentration of agricultural land mainly in the ownership of the state, as well as the fact that 22% of the total number of agricultural organizations is state-owned. Furthermore 42.2% of privately-owned agricultural organizations have different share of state property in the authorized capital [4]. This opens up wide opportunities for agricultural producers in obtaining state financial support in the implementation of precision farming systems, in particular, in the modernization of production and the purchase of high-precision agricultural equipment.

A significant advantage is that Belarus has highly developed agricultural machinery and manufactures its own combines and tractors equipped with Trimble precision GPS positioning systems, which significantly reduces the cost of purchasing precision machinery for agricultural producers. Examples of this technique are the Palesse GS2124 combine harvester manufactured by Gomselmash OJSC, equipped with a yield mapping system and a tractor manufactured by Minsk Tractor Plant OJSC, equipped with the Trimble Autopilot auto-driving system.

It should be noted that there are 1,357 agricultural organizations and 2,652 peasant (farmer) enterprises operating in the Republic of Belarus. However, only 2.55% of agricultural land is owned by peasant farms, while 97.45% is owned by agricultural enterprises of various forms of ownership that are land users or tenants, but not landowners. Based on the current situation in the sphere of land ownership, the development of precision farming systems in Belarus can be carried out in large agricultural enterprises, and not in private farms, as is common in Europe and the USA.

Nevertheless, along with the advantages, there are both objective and subjective reasons that impede the widespread implementation of precision farming systems in the country's agricultural production (Fig. 1). One of them is the existing system of on-farm land management, focused on traditional energy and resource-intensive farming, and not taking into account the presence of heterogeneities within a single field or land parcel - key factors for precision farming. It should be noted that on-farm land management is an element of land management that has been preserved in the Republic of Belarus since the USSR because of the preservation of both state ownership of agricultural land and agricultural enterprises that existed in the Soviet period as the collective farms and state farms. However, currently land management related to inter-farm land management is dominated in Belarus. These works consist mainly in updating the data of the land information system, developing draft land allotments, preparing technical documentation and establishing the boundaries of land plots on the ground in connection with the formation of agricultural and non-agricultural land uses.

At the same time, it is necessary to note the exceptional importance of conducting on-farm land management in the context of the transition to digital farming, because this particular type of land management creates the territorial basis for the efficient use of land, its protection and introduction of advanced management systems. The most important condition for the effective implementation of precision farming is the creation of relevant management-zone maps, which reflect the real state of land quality and make it possible to differentiate the application of mineral fertilizers and other agrochemical, while maximizing the soil potential (Fig. 2).

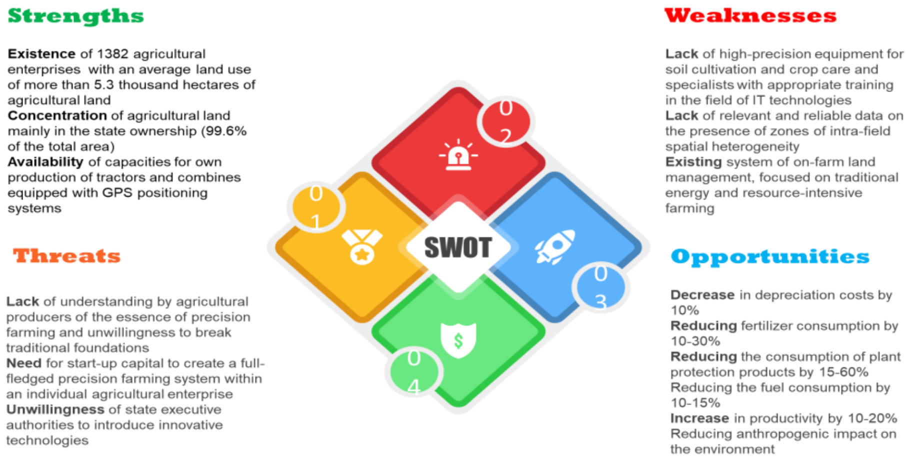

Figure 1. – SWOT analysis of the introduction of precision farming in agriculture of the Republic of Belarus (developed based on the results of author's own research)

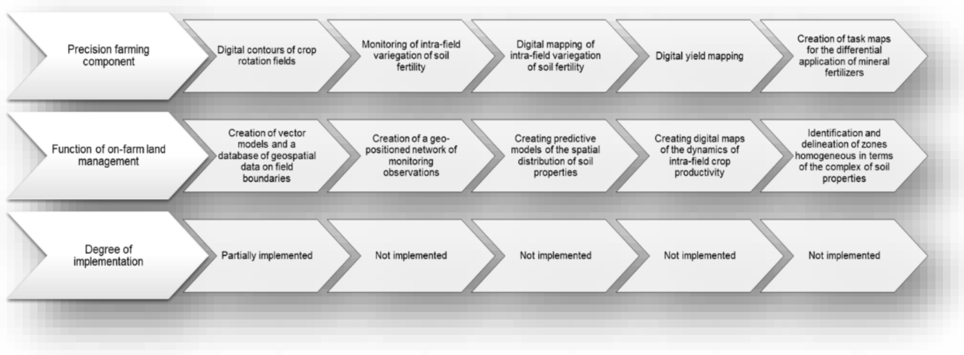

Figure 2. – Functions of on-farm land management in the implementation of elements of the precision farming system in Belarus

In this regard, the main task of land management in the current socio-economic conditions of Belarus in the context of the introduction of precision farming is the development of a methodology for the creation of appropriate cartographic materials and differentiation of land use by the totality of land quality indicators. It is also extremely important to create geospatial databases on the available indicators of the quantitative and qualitative state of agricultural soils. According to analysts' forecasts, the market for such products in the structure of elements of the precision (developed based on the results of author’s own research)farming system in the EU countries will grow by 12% annually, showing a steady upward trend [5]. The global market size of smart agriculture is expected to grow from approximately 9.58 billion U.S. dollars in 2017 to 23.14 billion U.S. dollars by 2022 [6]. The maximum market growth in the last decade is observed in countries such as the USA, Germany, Great Britain, France and other highly developed countries [7].

Important and interrelated components of the registering and reacting precision farming technologies are the identification of management zones and their use for the differential application of phosphorus and potassium mineral fertilizers [8, 9]. The management zone, in our opinion, is a subsystem of precision farming and a combination of input parameters, which are the basis for its definition and which form a response as an economic effect that manifests itself in various aspects. On-farm land management is a universal mechanism for identifying management zones and ensuring interaction between their input and output parameters. The implementation of the functions of land management for the identification of management zones can be carried out through the use of the functional capabilities of geoinformation systems, in particular the capabilities of geospatial statistics, cluster analysis and geoinformation analysis (Fig. 3).

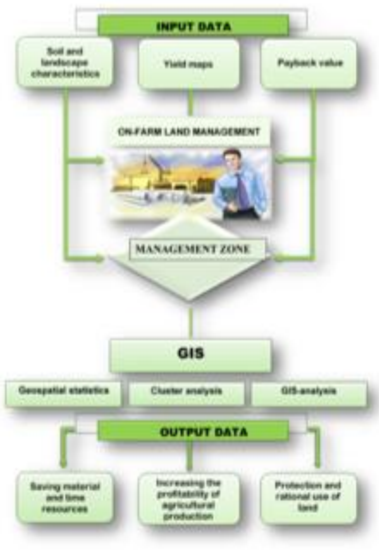

Figure 3. – The structure of the management zone as a subsystem of precision farming

On the example of land use with an area of more than 8 thousand hectares, a methodology for the formation of homogeneous territorial management zones during on-farm land management with the introduction of precision farming has been developed. The management zones identification algorithm provides: exploration geostatistical analysis; determination of the required number of gradations of land quality; assessment of data clustering and analysis, search for data outliers; construction of interpolated rasters for a specific set of soil parameters; reclassification of rasters and multivariate analysis; converting the final raster into vector layers and determining the areas of the selected zones. As input parameters, it is recommended to use the data of agrochemical soil survey performed centrally every 4 years for every agricultural enterprise. The most acceptable for modern socio-economic conditions prevailing in Belarus is the strategy of differential fertilizer application which based on fertilizing in the management zones in such a way that the quantity and ratio of nutrients, taking into account their soil reserves, will be sufficient for obtaining the planned crop yield. The researches confirmed that within the individual crop rotation fields on the area of 1411.76 ha, it is possible to save from 2.5 to 21.8 kg/ha of the active substance of phosphorus and from 0.9 to 26.7 kg/ha of the active substance of potassium due to the redistribution the dose of fertilizers which is calculated for the planned crop yield taking into account the identified management zones (Fig. 4).

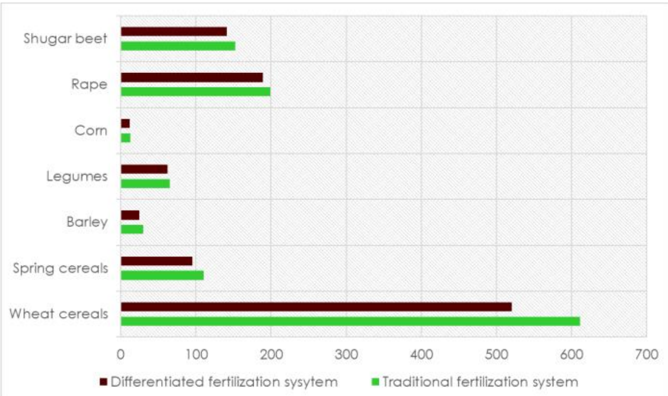

Figure 4. – Costs when using various systems for applying phosphorus and potash mineral fertilizers, thousand BYN

The maximum saving of phosphorus fertilizers is achieved when applying them for winter wheat, corn for silage and peas grown for grain while potash fertilizers provide maximum saving when applying them for winter wheat, sugar beets and spring triticale (Fig. 5).

The differentiated use of mineral fertilizers by reducing the cost of their purchase and use makes it possible to increase the profitability of growing winter grains by 2.2%, sugar beets by 1.3%, rapeseed for oilseeds by 1.1%, and malting barley by 0.8% [10].

The use of unmanned aerial vehicles in agriculture in the implementation of precision farming tasks is an innovation for the Republic of Belarus. The global agricultural drone market is projected to grow by 13% annually [11]. Among the most significant advantages of UAV utilization in Belarus it is necessary to underline the following: the efficiency of obtaining geospatial information of high

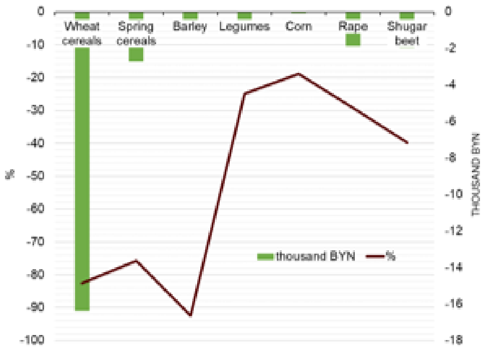

Figure 5. – Absolute and relative difference in cost between traditional and differential application of mineral fertilizers

and ultra-high resolution; different degree of autonomy (remote control option); the availability and ease of use; the absence of necessity to register UAVs weighing up to 2.5 kg; no special pilot license required for UAV operation. Meanwhile there are a range of disadvantages which limit the widespread introduction of UAV in agricultural practice: the presence on the market of agricultural drones and related software produced only by foreign manufacturers; the high cost of services when using data from UAV surveys (varies from 1 to 5 dollars per hectare); the lack of specialists able to process and interpret survey results; the ban on flights above 120 m. However, the reluctance of agricultural producers to introduce something new and change traditional technologies should be considered as a main limit factor of UAV utilization [12].

A promising area that is just beginning to develop in Belarus is the use of ultra-high-resolution remote sensing data obtained from UAVs for monitoring and forecasting the productivity of fodder and grain crops. Despite of the number of reasons of an objective and subjective nature nevertheless, this technique is gradually being introduced into agricultural production, primarily in conjunction with the introduction of elements of the precision farming system. It was found that the data obtained from the quadcopter Phantom-4ProV 2.0 survey in RGB mode are excellent for determining the height of the Silphium perfoliatum and Zea mays from the model of the vegetation cover surface with an ultrahigh resolution of 2.5 cm in the field. Plant height obtained from surface models based on UAV survey data is a reliable indicator for assessing biomass productivity, since the correlation coefficient between actual and forecasted productivity values was 0.98 and 0.97, respectively. Vegetation indices RGBVI (Red-Green-Blue Vegetation Index), VARI (Visual Atmospheric Resistance Index), GLI (Green Leaves Index) and NGRDI (Normalized Red-Green Difference Index) can also be successfully used to monitor and evaluate biomass productivity, and the most informative of them is the RGBVI index. However, long-term field research is necessary to ensure the reliability of predictive productivity models.

In conclusion it is necessary to underline that in order to ensure energy savings and the introduction of modern agricultural production systems in Belarus, the widespread introduction of the precision farming system or its individual elements is necessary. Among the factors contributing to the widespread adoption of precision farming in the country's agricultural production are more than 1380 agricultural enterprises with an average land use of more than 5.3 thousand hectares with state support and highly developed agricultural engineering resources. Impeding the widespread implementation of precision farming is the existing system of on-farm land management, focused on traditional energy and resource-intensive farming, which does not take into account the heterogeneities within a single field or land parcel. Since agricultural lands in Belarus are the exclusive property of the state, the introduction of land use precision farming is impossible without digital land management. In this regard, the primary function of modern on-farm land management is the identification and georeferencing of soils homogeneous in agrophysical and agrochemical properties and agrotechnological characteristics of arable land parcels in order to optimize agricultural land use while considering the needs of highly profitable crops. The most promising elements of precision farming technology for implementation in Belarus are the off-line differentiated application of mineral fertilizers and chemical ameliorants, as well as the use of ultrahigh-resolution remote sensing data to monitor crop development and productivity forecast.

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