PRECISION FARMING IN THE REPUBLIC OF BELARUS: PROBLEMS AND PROSPECTS

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Belarus has 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. Based on the current situation, the development of precision farming systems should focus on large agricultural enterprises, and not private farms. The 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.

Keywords: agricultural enterprises; land management; farming system; profitability.

ТОЧНОЕ ХОЗЯЙСТВО В РЕСПУБЛИКЕ БЕЛАРУСЬ: ПРОБЛЕМЫ И ПЕРСПЕКТИВЫ

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Беларусь имеет большой потенциал для внедрения систем точного земледелия в сельскохозяйственное производство. Одним из преимуществ является наличие более 1380 сельскохозяйственных предприятий со средней площадью сельскохозяйственных угодий 5,3 тыс. га и средней площадью пашни 3,5 тыс. га. Исходя из текущей ситуации, развитие систем точного земледелия должно быть сосредоточено на крупных сельскохозяйственных предприятиях, а не на частных фермерских хозяйствах. Реализация данных мероприятий при внедрении дифференцированного внесения удобрений позволяет повысить рентабельность на 2,2% по озимым культурам, 1,3% по сахарной свекле, 1,1% по рапсу по масличным и 0,8% по пивоваренному ячменю.

Ключевые слова: сельскохозяйственные предприятия; землеустройство; система земледелия; рентабельность.

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 European Parliament’s report on Precision agriculture and the future of farming in Europe defines precision agriculture as: «an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment» [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 over 1380 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 as well as the concentration of agricultural land mainly in the state ownership (87.6% of the total area) [3]. In addition, a positive factor, which should be taken into consideration, is the concentration of agricultural land mainly in the state ownership (87.6% of the total area) [4]. This opens up for agricultural producers the opportunities to receive government financial support for the implementation of precision farming systems, in particular for the modernization of technological processes and the purchase of high-precision 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. 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. 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 in the form of 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 the 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 chemical reclamants, while maximizing the potential of the soil (Table 1).

Table 1. **Functions of on-farm land management in the implementation of elements of the precision farming system in Belarus**

Precision farming system element	Function of on-farm land management	The degree of implementation of the function
Digital contours of crop rotation fields	Creation of vector models and a database of geospatial data on field boundaries	Partially implemented
Monitoring of intra-field variegation of soil fertility	Creation of a geo-positioned network of monitoring observations	Not implemented
Digital mapping of intra-field variegation of soil fertility	Creating predictive models of the spatial distribution of agrochemical,	Not implemented

Precision farming system element	Function of on-farm land management	The degree of implementation of the function
	physicochemical and agrophysical soil properties	
Digital yield mapping	Creating digital maps of the dynamics of intra-field crop productivity	Not implemented
Creation of task maps for the differential application of mineral fertilizers	Identification and delineation of zones homogeneous in the agrophysical and agrochemical properties of soils and agrotechnological characteristics of land parcels	Not implemented

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 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. It should be noted that management zones mean field subregions, which are determined by the relative uniformity of productivity of crops grown within its boundaries and/or soil parameters, and requiring the application of the same fertilizer rate, dose of pesticides, etc. [8, 9].

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 was developed. The management zone 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. The strategy of differential fertilizer application, taking into account, in particular, national characteristics of the right of ownership of agricultural land, is the most acceptable in modern socio-economic conditions prevailing in Belarus. This strategy is based on fertilizing in the management zones in such a way that the quantity and ratio of nutrients, taking into account their soil reserves, is sufficient to obtain the planned crop yield. 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 of the dose of fertilizers for the planned crop yield taking into account the identified management zones. 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. 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. 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. However, the use of agricultural drones has not found wide application for a number of reasons of an objective and subjective nature (Figure 1). 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 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.

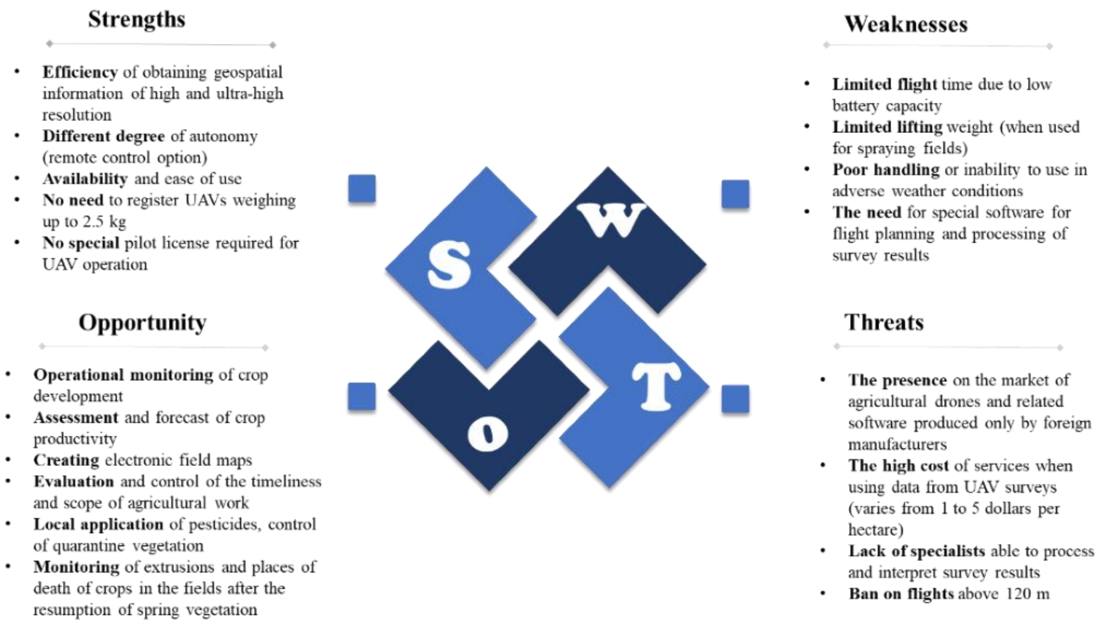

Figure 1. **SWOT analysis of UAV use in agriculture of the Republic of Belarus** *(developed based on the results of author's own research)*

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 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 ultra-high resolution remote sensing data to monitor crop development and productivity forecast.

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