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PRECISION FARMING AS AN ELEMENT OF THE 4.0 INDUSTRY ECONOMY

Key words: precision agriculture, information systems, navigation technologies, industry 4.0, megatrends

ABSTRACT. The study attempts to determine the place of precision farming in Poland, in conditions of the emergence of new megatrends in a globalizing, digital society and the economy entering the industry 4.0 era. The understanding of the concept of megatrends by various authors, their main types, as well as the basic technologies relevant to the 4.0 economy are presented. The concept and scope of precision farming as well as the necessary conditions and benefits of its use are briefly discussed. It was found that at present, the dissemination of solutions of this agriculture in Poland is still limited. This is due, inter alia, to the small share of large-scale farms (especially large agricultural land), which is a condition for obtaining favorable economic effects from using this form of farming. Progressive improvement in the area structure of agricultural enterprises, the growing concentration of production in them and the relatively lower prices of machinery and equipment for precision farming will, however, be conducive to its expansion in scope. The technological knowledge of producers is also improving. Therefore, it can be expected that the importance of this type of farming will increase in the near future.

INTRODUCTION

Agriculture is widely recognized as a traditional department, not very modern, and even marginal in the richest countries. At the same time, very serious changes are taking place throughout the world, known as megatrends. The leading sectors of the economy are moving faster and faster from the phase known as industry 3.0 to industry 4.0.

Like any kind of economic activity, agriculture must also adapt to external conditions. As part of the adaptations, precision agriculture was created and disseminated. Precision agriculture creates an opportunity for agriculture to become a modern, efficient and absorptive department on technological progress, thanks to the combination of modern technology (especially high-performance and precision machines) and rotational means with IT systems, using the achievements of agronomic knowledge. Precision farming was initially treated as a novelty in many countries and enterprises and its practical application were small. Currently, it is becoming a more promising and widely used method of farming.

The research aimed to determine the location of precision farming in conditions of new megatrends and the advent of the industry 4.0 era in Polish conditions. The study is a review. Polish and foreign literature and available statistical data were used to prepare the article.

MEGATRENDS IN THE GLOBAL ECONOMY

There have been many phenomena in the history of the world that have caused groundbreaking changes. Examples are the domestication of animals, the conversion of the nomadic mode to a settled one, the replacement of slavery with work for the feudal lord, or the invention of other sources of propulsion than human labor and the use of animals or natural forces. In recent years, the term "megatrends" has been used to illustrate this phenomenon. The American futurologist John Naisbitt [1982] is considered the precursor of the concept. The list of megatrends he created was developed using observations of contemporary phenomena, reading thousands of local newspapers and other articles, culminating in the isolation (with a group of analysts) of important directions of society's development. Originally, the issue concerned changes in the American economy, for which John Naisbitt distinguished 10 megatrends: from an industrial society to one based on information, from strength technology to ultra-technology, from a national economy to a global economy, from short-term thinking to long-term thinking, from centralization to decentralization, from institutionalized assistance to self-help, from representative to participatory democracy, from hierarchy to network, from north to south, as well as from the "either-or" scheme to multiple-choice [Pieriegud 2015].

Megatrends are considered as significant and permanent changes in economic, social, political, and technological developments that slowly shape but affect all areas of life. They can occur in parallel, superimposed upon each other or counter-trends may be formed. Natalia Hatalska [2014] mentions: megatrends, leading trends, counter-trends and microtrends.

Today, there are various megatrends. The dominant megatrend becomes a connected living, in which many human activities and behaviors are associated with their connection to the internet, cloud, or the use of big data. Unlimited amounts of information are acquired and processed, which allows for the individual treatment of people, thus creating opportunities and threats. Threats are those related to the manipulation of people, while an opportunity may be e.g. the creation of smart cities (cities and individual houses) or logistics solutions.

The earliest and strongest new megatrends occur in activities requiring high mobility, which include logistics, communication, and the most technologically advanced industrial production sectors. This phenomenon also applies to agricultural production, especially on a large scale.

INDUSTRY 4.0: KEY TECHNOLOGIES

The first revolution was associated with the use of steam engines and mechanization, the second revolution – with the introduction of production lines and electrification, and the third with the use of IT systems and digitization. The following technologies are considered as basic technologies that determine changes during the 4P period [Dmowski et al. 2016]: autonomous robots, i.e. operating without the need for ongoing human control, and even cooperating with other robots, simulations, vertical and horizontal integration, the Internet of Things, cybersecurity, the use of 3D printers, augmented reality, Big Data and analytics, and the cloud.

THE PLACE OF PRECISION AGRICULTURE IN THE DEVELOPMENT OF AGRICULTURAL SYSTEMS

Researchers of the megatrend phenomenon have not paid particular attention to agriculture thus far. Meanwhile, it seems that it is on the verge of a great breakthrough because it is possible to use the achievements of the latest technologies in agriculture, especially information and localization. At this point, it is worth briefly returning to the history of agriculture itself, which appeared in the Fertile Crescent region of the Middle East around 9500 BC [Arseniuk 2018]. It included the cultivation of wild cereals, especially wheat, barley, and legumes as well as flax. Around the same time, agriculture began to develop in China, North Africa, America, and New Guinea. It reached Europe about 8000 years ago.

Agriculture underwent some modifications, but they were not fundamental. The use of irrigation, crop rotation, fertilizers, and pesticides only began in the 18th and 19th centuries. This is when the era of agriculture currently referred to as conventional or intensive began. In the twentieth century, the draft force of animals was converted into mechanical energy. The chemization of agriculture began and developed, and the use of the achievements of genetics in the improvement of plants and animals spread. Agriculture has now become dependent on industrial means of production, and there has been strong agricultural pressure on the environment.

Currently, there are several systems of agriculture, differentiated internally, such as [Arseniuk 2018]:

- conventional agriculture: is focused on maximizing profit, plant and animal productivity as well as specialization; it is technologically advanced, mechanized and labor-saving; it uses high inputs from the outside, while simultaneously achieving high efficiency,
- organic farming is managing the use of natural forces, using natural resources, striving to maintain soil fertility, animal and plant health, and high-quality agricultural products without industrial means,
- integrated agriculture is an attempt to combine the use of modern technologies, including biological progress, to achieve both economic and ecological goals,
- precision farming is a relatively recent system that uses advanced navigation and IT technologies, including satellite location systems (GPS) and GIS (Geographic Information System) methods.

In the European Union, precision agriculture (PA) is defined as an approach to managing the entire farm using information technology, data acquisition using satellite positioning (GNSS), remote detection, and the collection of proximal data [Brase 2006, European Parliament 2014]. The technologies used in precision farming are aimed at optimizing the use of inputs while reducing the negative impact of agriculture on the environment.

According to Robin Gebers and Viacheslav Adamchuk [2010], precision farming includes a set of technologies that combine sensors, information systems, improved machinery and conscious management to optimize production by taking variability and uncertainty in agricultural systems into account. Precision farming provides a means to monitor the food production chain and manage the quantity and quality of agricultural products.

The advantage of this system over other forms of farming results from the precise, optimal use of classic measures in plant and animal production, adapted to specific farming conditions, using current scientific knowledge and its practical application.

According to Stanisław Samborski [2018], precision agriculture is a system in which individual areas of the arable field are treated with different inputs of means of production (doses of fertilizers and plant protection products, dose rates for irrigation, sowing density or planting). The purpose of such action is to ensure the better adjustment of inputs to the needs of plants and soil rich in nutrients in a particular part of the field, thus improving the efficiency of their use and reducing its negative impact on the environment.

According to Ancha Srinivasana [2006], the distinguishing feature of precision farming is the effective precise combination and use of highly advanced IT systems, modern technology (in the field of biology and technology) and modern management methods.

The most important elements of precision agriculture in plant production are the collection of detailed information on the variability of nature for a selected field and their use for precise fertilization and plant protection treatments. Field maps are prepared using GPS, GIs and remote sensing devices. They make it possible to assess the yield level in various parts of the field, as well as to obtain economic benefits resulting from the differentiation of input doses or yield increase. In this agriculture, a departure from understanding the field as a unitary unit takes place and is followed by fieldwork automation and optimization of farm management, taking into account environmental protection requirements [Dominik 2010].

THE RANGE OF PRECISION FARMING

There are many types of precision farming operations. The following can be considered as the most commonly used [Samborski 2018]:

- automated soil sampling with the registration of geographical coordinates,
- the use of a variable dose of production means,
- parallel running tractors and machinery,
- automatic adjustment of the working width of machines to field acreage, where fertilizer was already sown, or pesticide spraying was applied previously,
- yield mapping,

– yield quality mapping,
– machinery and tractor control
– collecting, processing and analyzing field data collected during field work in spatial information systems.

According to Jacek Chotkowski [2012], the most important elements of precision farming are:
– mapping soil richness in potassium and phosphorus (using GPS),
– precise fertilizer spreading, adapted to soil richness,
– nutritional status assessment of plants with nitrogen, and severity of pests recorded by machine-mounted optical sensors,
– making decisions about technological operations based on information from aerial or satellite imagery,
– yield mapping, determining the productivity of various parts of the field.

The technologies, objectives and practical state of precision farming used holistically are presented in the specialized agenda of the European Union (Directorate-General for Internal Policies, Policy Department B: Structural Policy and Cohesion Policy, Agriculture and Rural Development). Its review is presented in Table 1.

Table 1. An overview of Precision Agriculture technology and applications

Lp.	Technology	Development objective	State of Technology
1.	Human-Machine-Interface Instruments	Terminal suitable for all PA applications	Stand-alone terminals for every single application
2.	Ownership of data	Facilitate the exchange of information between farmers, between farmers and contractors or suppliers and between the government and farmers	Data should be the property of the machine owner, but machine manufacturers use them for internal evaluation
3.	Machine Guidance	Automatically avoiding the overlap of the same tracks for every field operation, relieving the driver, reducing chemicals and fuel	Driver assistance, steering support, automatic driving
4.	Controlled Traffic Farming	Using the same tracks to minimize soil compaction.	Driver assistance, steering support, automatic driving
5.	Recording of farm machinery movement	Machine surveillance, operator safety, optimization of processes	Data needed to measure and store machinery operations
6.	Sampling location	Offline determination of soil quality, status of ground swell (pH-value, phosphor, potash, magnesium), soil composition	Detailed information about soil fertility and transmitted diseases for optimal management and legislation requirements

Table 1. Cont.

Lp.	Technology	Development objective	State of Technology
7.	Biomass monitoring	Mapping the state of plant growth and amount of nitrogen needed	Location-specific continuous or discrete crop phenology observations, optical sensors for canopy status and nitrogen content
8.	Sensor and sensor fusion development	Automated data fusion of different sensor information for real-time decisions based on multi-layer datasets	Sensors for the measurement of several parameters that are later integrated into products
9.	Machine Vision Systems	Guaranteeing the safety and security of food. Combining this data with producer operation records (for example, when, where, and what kind of chemicals were sprayed, what kind of fertilizers were conducted)	Monitoring and classifying/ grading fruit or vegetables
10.	Remote sensing (RS) techniques	Relating these images to yield potential, nutrient deficiencies and stresses	Recent aerial or satellite imagery
11.	Variable rate application/ technology	Application of seeding, fertilizing and spraying according to the accurate mapping of soil and plant information	Enables the specific treatment of areas within a crop parcel with variable levels of production
12.	Harvest monitoring	Localized harvesting information about crops and machine status to improve yield	Harvesting information (instant wet and dry readings, crop density, cutting and harvesting and yield information)
13.	Individual livestock tracking on a small scale	Information about animal health status and grazing behaviour, virtual fencing, understanding grazing pressure	Monitoring systems for animals through GNSS receivers, storing position data at regular intervals
14.	Tracking livestock transportation	Complying with legal regulations of animal welfare	Recording the movement of vehicles
15.	Electronic submission of area aid applications	Compliance of legal regulations	GNSS receivers allow for the measurement of an area, the perimeter of a parcel or changed portions of a boundary
16.	Farm Management and Decision Support	Software solutions for farmers for automatic documentation, telemetry, decision support and machine control	Data management and decision support solutions existing from machine manufacturers and providers of precision farming services

Source: [European Parliament 2014]

TERMS OF USE AND BENEFITS OF PRECISION FARMING

According to John Stafford [2005], the potential benefits of precision farming include areas such as the environment, operating economics, control and audit activities, driving, crop management and others. The author states that, so far, some expected benefits have proved to be insignificant, while others make a positive contribution to agriculture.

According to Monika Klimczak [2019], the benefits of precision farming include:
- insight into the operation of a farm,
- reliable forecasts of the variability of conditions in the field,
- easier decision making,
- tracking changes in real-time,
- using the appropriate amount of seeds for crops to achieve the planned yield,
- improving soil fertility in the field,
- better use of natural resources,
- more adequate investment in crops on a field.

Precision farming in Poland has not yet received detailed economic research, but many economic and environmental benefits can be expected from it. For agricultural producers, this may mean, among other things [Klepacki 2019]:
- the opportunity to reduce the consumption of direct expenditures in the form of mineral fertilizers and pesticides,
- obtaining knowledge about the state of plantation on its fragments, which allows improving plant yield by adapting treatments to plant needs,
- reducing the use of chemicals, which allows for a reduction of costs and environmental pollution,
- modern means of transport, tractors and combines facilitate faster, precise and more efficient work in the fields, avoiding additional journeys and soil structure destruction,
- the ability to collect a lot of detailed information about the state of plants, size, crop quality; their estimation for various field fragments gives grounds for rational decision making as well as easier and more effective farm management,
- properly used precision agriculture does not affect the threat to the conservation of the landscape or biodiversity, and therefore may be useful in large-scale enterprises.

The implementation of precision farming in Poland faces many difficulties:
- investment costs are high, especially at the stage of purchasing specialized equipment,
- there is area fragmentation of farms, while it is easier to use expensive machinery on large farms,
- the requirements for farmers regarding biological, technological, technical and information technologies are high,
- there is a need for the continuous improvement of knowledge, and advisory services are relatively poorly prepared in this area,
- there are no widespread models for the comprehensive use of such agriculture in Poland.

SUMMARY AND CONCLUSIONS

1. Precision farming is a relatively new way of farming, and its development is possible due to the use of opportunities created by current megatrends in the global economy and solutions entering agriculture as part of the 4.0 economy.
2. Precision agriculture is a combination of achievements of science and practice in the field of biology, technology and computer science. Under it, thanks to access to current production data, even at a level of a fragment of a field or a single animal, it is possible to make optimal decisions and achieve more favorable production results (yield, harvests, animal yield), lower direct costs, better use of machinery and equipment and better economic results.
3. The use of precision farming can bring measurable economic and environmental benefits. It facilitates the economical and precise use of agricultural production agents, especially the reduction of chemical consumption and an improvement of the natural environment.
4. The dissemination of precision farming solutions in Poland under current economic conditions is limited. This is due to the average small scale of production, which is a condition for obtaining favorable economic effects. Improvement of the area structure, the concentration of production and specialization, relatively cheap machines and devices necessary for the implementation of precision agriculture, an increase in knowledge and skills of farmers and agricultural advisors will be conducive to expanding its scope of application. It can be expected that the importance of this type of farming will increase.

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ROLNICTWO PRECYZYJNE JAKO ELEMENT GOSPODARKI 4.0

Słowa kluczowe: rolnictwo precyzyjne, systemy informacyjne, technologie nawigacyjne, przemysł 4.0, megatrendy

ABSTRAKT

W opracowaniu podjęto próbę określenia miejsca rolnictwa precyzyjnego w Polsce w warunkach pojawiania się nowych megatrendów w globalizującym się, cyfrowym społeczeństwie oraz wkraczania gospodarki w erę przemysłu 4.0. Zaprezentowano rozumienie pojęcia megatrendów przez różnych autorów, ich główne rodzaje, a także podstawowe technologie stosowne w ramach gospodarki 4.0. Skrótowo omówiono pojęcie i zakres rolnictwa precyzyjnego, a także niezbędne warunki i korzyści z jego stosowania. Stwierdzono, że obecnie w Polsce upowszechnienie rozwiązań tego rolnictwa jest jeszcze ograniczone. Wynika to między innymi z niewielkiego udział gospodarstw o dużej skali produkcji (zwłaszcza o wielkim obszarze ziemi rolniczej), co jest warunkiem uzyskania korzystnych efektów ekonomicznych ze stosowania takiej formy gospodarowania. Postępująca poprawa struktury obszarowej przedsiębiorstw rolniczych, rosnąca w nich koncentracja produkcji oraz coraz relatywnie niższe ceny maszyn i urządzeń do stosowania rolnictwa precyzyjnego, będą jednak sprzyjały rozszerzeniu zakresu jego prowadzenia. Poprawia się także stan wiedzy technologicznej producentów. Można więc oczekiwać, że znaczenie tego rodzaju gospodarowania w niedalekiej przyszłości będzie ulegało zwiększeniu.

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