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Analysis of Information Technology Adoption in Polish Agriculture

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Abstract. This study explores the adoption of information technology (IT) in Polish agriculture, focusing on its impact on efficiency, profitability, and farmers' perceptions of associated costs. A survey conducted among 106 farmers from all Polish provinces assessed their use of IT tools, including farm management software and automatic machine navigation systems. The results highlight the varying degrees of IT adoption based on farm size, with larger farms demonstrating greater integration of these technologies. Farmers' views on the cost-effectiveness of these systems were mixed, indicating room for improvement in affordability and functionality. The study underscores the potential of IT to enhance agricultural practices but notes the barriers faced by smaller farms in adopting such technologies.

Keywords: Polish Agriculture, Farm Management Software, Intelligent Systems, Information Technology.

1 Introduction

Intelligent systems leverage advanced technologies such as artificial intelligence (AI), Internet of Things (IoT), robotics, and big data analytics to optimize agricultural operations. They enable farmers to increase efficiency, reduce costs, and address challenges such as climate variability, resource management, and labor shortages.

Below, we describe key applications of smart systems in agriculture.

Precision Farming

Precision farming integrates IoT devices, GPS technology, and AI algorithms to enhance farm management practices. Sensors embedded in the soil measure moisture, nutrient levels, and pH, while drones and satellite imagery assess crop health and detect stress early. These technologies enable site-specific crop management, allowing farmers to apply fertilizers and pesticides only where needed. This targeted approach reduces environmental impact and maximizes yield potential [6, 17, 26].

Smart Irrigation

Smart irrigation systems leverage real-time data from soil moisture sensors and weather forecasts to optimize water usage. These systems can automatically adjust irrigation schedules based on evapotranspiration rates and rainfall predictions. Advanced AI models help prioritize water allocation in drought conditions, ensuring critical areas receive sufficient resources. This reduces water wastage and improves plant health [11, 17, 26].

Autonomous Machinery

Robotics and autonomous vehicles streamline labor-intensive farming operations. For example, robotic harvesters equipped with machine vision identify ripe fruits and vegetables, ensuring minimal damage during collection. Autonomous tractors and planters improve planting accuracy and reduce fuel consumption. These systems not only address labor shortages but also operate continuously, increasing productivity [3, 7, 12].

Crop and Livestock Monitoring

Crop monitoring uses AI-powered imaging systems and IoT sensors to identify pest infestations, diseases, and nutrient deficiencies early. Predictive analytics suggest the best remedial actions. For livestock, wearable IoT devices monitor health metrics like temperature, heart rate, and activity levels. Farmers receive alerts on abnormal conditions, enabling timely intervention and reducing animal mortality rates [3, 16, 17].

Data-Driven Decision Making

Big data analytics integrates information from weather stations, market trends, and on-farm sensors to provide actionable insights. For instance, AI algorithms analyze historical yield data to recommend optimal planting schedules and crop varieties. Real-time dashboards display performance metrics, helping farmers make informed decisions on resource allocation and marketing strategies [2, 12, 17].

Climate Adaptation

Intelligent systems support farmers in adapting to climate change by analyzing historical weather patterns and current data. These systems predict extreme weather events, helping farmers implement preventative measures such as soil conservation techniques or crop diversification. They also recommend sustainable practices like reduced tillage or cover cropping to improve soil health and sequester carbon [2, 6, 11].

The aim of this article is to present the extent to which today's farms in Poland are computerized and to learn farmers' opinions on the functionality of the systems they use and the costs associated with it. For this purpose, a survey was conducted in which farmers commented on this topic and then it was analyzed using Statistica [22]. The survey involved 106 farmers from all the provinces of Poland. The respondents were also asked about the size of their farm, gender and age. In total, farmers answered 16 questions. Some of the most important questions were those concerning the extent to which they use information technology on their farms, as well as those that directly concerned the topic of their use of farm management programs or the use of solutions for automatic machine operation.

First of all, we will present the most popular examples of the use of information technology and intelligent systems in Polish agriculture. Then we will present and describe the answers to selected questions from the survey. Before concluding, we will discuss the results of the correlation analysis between selected indicators such as farm size, level of use of management systems, automatic navigation and others.

2 Information technology used on farms in Poland

Nowadays, agricultural farms [25, 23, 20] are increasingly struggling with very high costs of running their businesses, which is why they are looking for newer solutions that will allow them to reduce these costs without losing the volume of crops. IT technology meets the needs of farmers and provides them with new solutions [9, 21], including software to help them manage their farms. These programs allow farmers to keep full records of the agrotechnical treatments they perform on their fields, support planning crop rotation and creating fertilization plans based on the collected data. They also allow them to create virtual farm maps and virtual warehouses which makes gathering and accessing information much easier and more reliable especially in comparison to traditional notes made on pieces of papers. In addition to supporting farmers producing crops, these programs also support animal breeders which have to record data on the history of treatments and offsprings. An example of such solutions is the map from the xFarm [27] program shown in Figure 1, on which the sowing areas have been

marked. Each area has its own color depending on the plant. At the bottom the percentage of each plant in relation to the entire area is given. Of course it is only an example, the programs have much more very useful functionalities. Some of them can even manage crop irrigation systems themselves based on a network of sensors. Other examples of farm management solutions include eAgronom [10], Agroasystent [5] and RolnikON [19].

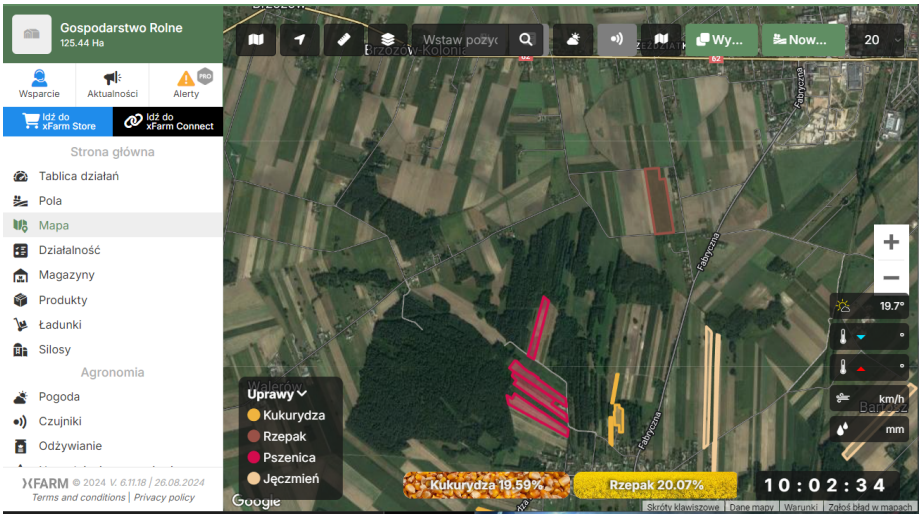

Figure 1. A map from the xFarm program showing various sowings. Source: own elaboration.

IT also supports farmers in field work through automatic machine control systems. They are often known as agricultural navigation because the tractor is controlled by signals for positioning objects that are mainly used in geodesy. To be controlled using such signals, tractors are often equipped with electric steering wheels, but also with hydraulic blocks with solenoid valves. These systems are mainly used by farmers to guide these machines on parallel paths. The farmer has several types of such paths at his disposal: AB lines, curves, and A+, thanks to which he is able to perfectly cover his entire field, avoid bypassing or overlapping. These systems also support the farmer in creating perfectly straight technological paths but can also automatically turn on the headlands. It is also worth mentioning that these systems are increasingly equipped with universal ISOBUS terminals [8, 14]. In Figure 2 an example of such a solution from John Deere [1] is presented. There is an antenna on the top, normally mounted on the roof. Below it a control terminal is visible, and right under it we see an electric steering wheel. Other solutions that were analyzed based on the survey were Topcon [24], Raven [18], AgOpenGps [15], AgroOsa [4] and Trimble [13].

3 Survey results

The subject of this study is the impact of information technology and tools on the development and improvement of farm profitability. Conclusions on this subject will be drawn, among other things, on the basis of farmers' opinions.

Figure 2. A complete control unit from John Deere. Source: own elaboration.

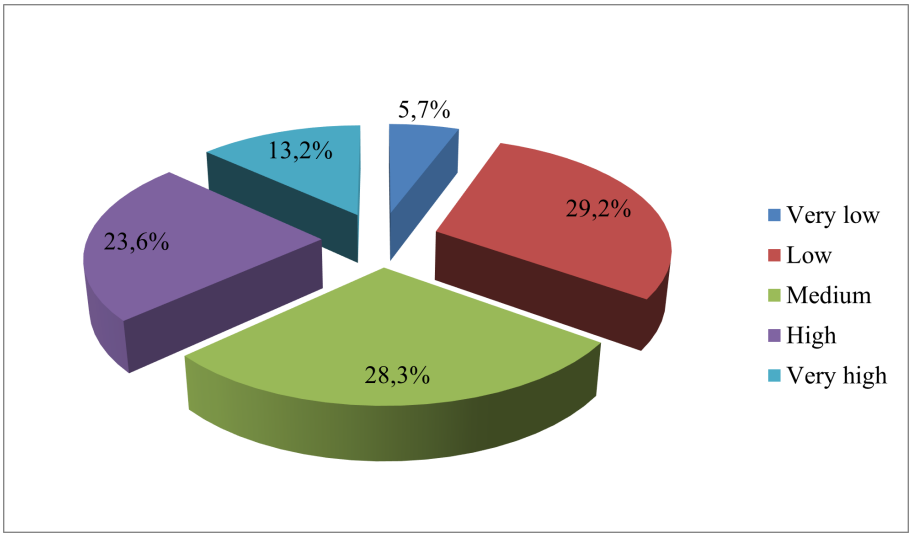

Figure 3. Survey respondents' responses on the degree of use of information technology on their farms. Source: own elaboration.

The purpose of the research is to show the extent to which today's farms are computerized and to find out farmers' opinions on the functionality of the systems and also the costs associated with them.

The survey was conducted using a Google Forms questionnaire. In total, we had 106 participants – polish farmers from all over the country. The largest number of respondents were from the Mazowieckie province – 22 people, and the smallest from the Śląskie province – 2 people. The questionnaire consisted of 16 questions about issues related to the informatization of agriculture.

Figure 3 shows the results of a question on to what extent respondents use information technology on their farms. The survey shows that 29.2% (31 people) of the respondents use information technology on their farm to a low degree, another group of 30 people (28.3%) indicated that they use it to a medium degree. Another 25 people (23.6%) of respondents indicated that they use these technologies to a high degree, while the answer "very high" was indicated by 13.2% (14 people) of respondents, and the least number of people, only 6 (5.7%), indicated the answer "very low".

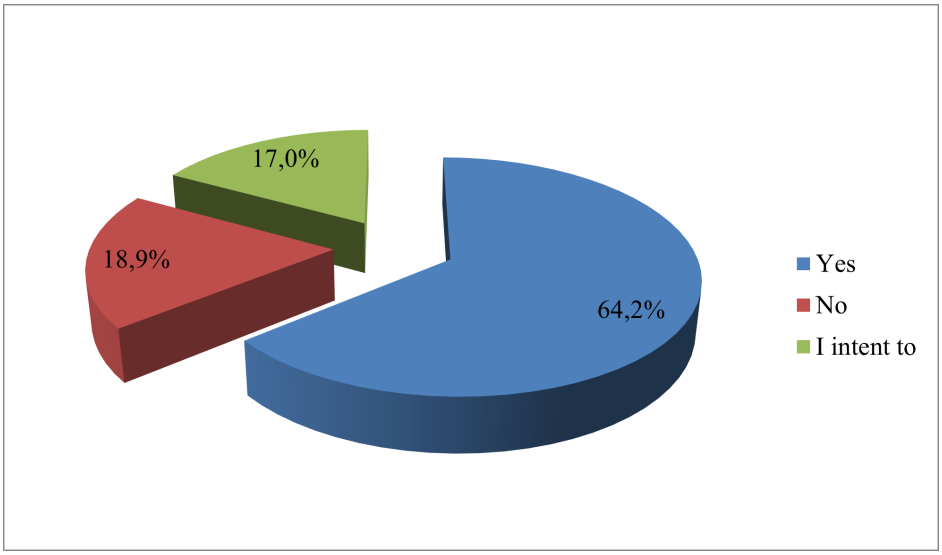

Figure 4. Survey respondents' responses on the use of farm management software. Source: own elaboration.

Figure 4 shows the results of the question on whether respondents use farm management software on their farms. The survey shows that as many as 64.2% (68 people) marked the answer "Yes" stating that they use such solutions, while the answer "No" was indicated by 18.9% (20 people), and the answer "I intend to" was selected by 17% (18 people) of the respondents.

Figure 5 shows the results of the question regarding to what extent farm management programs affect farm efficiency and profitability. As can be seen in the chart, the largest number of respondents indicated that such programs have a great impact on efficiency and

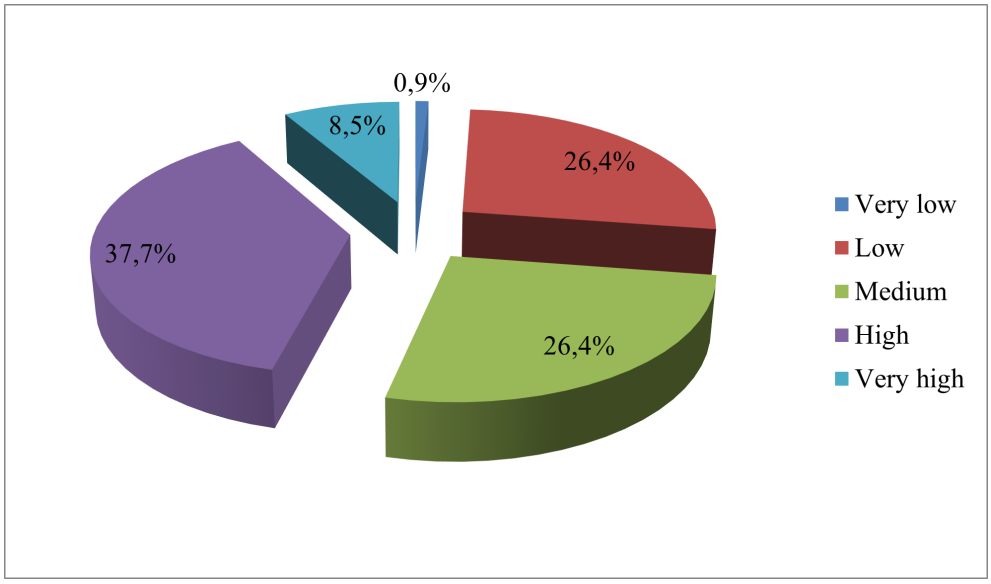

Figure 5. Responses to the question regarding the extent to which farm management programs affect farm efficiency and profitability. Source: own elaboration.

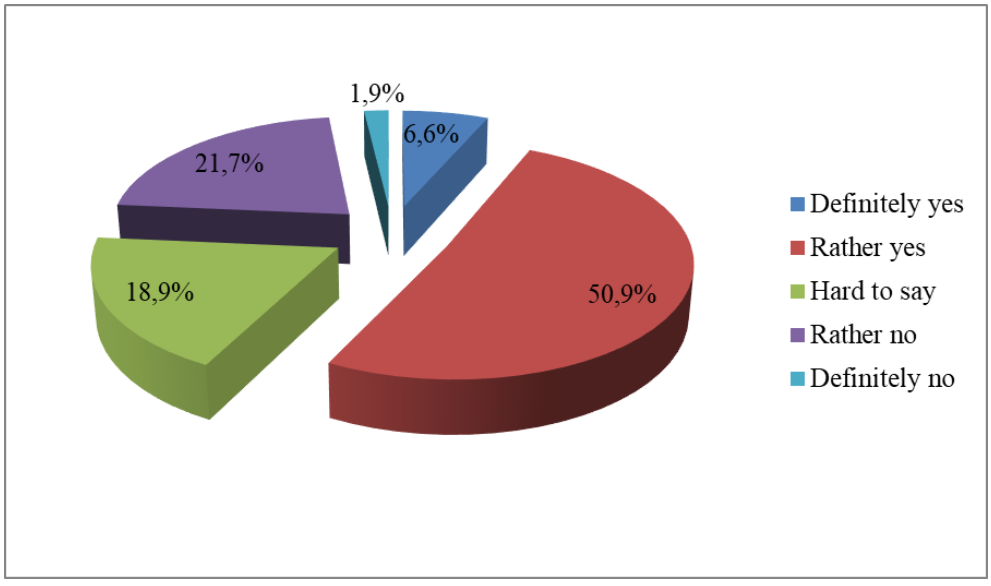

Figure 6. Survey respondents' answers to the question of whether the cost of farm management programs is adequate for the functionality they offer. Source: own elaboration.

profitability, as it was 37.7% (40 people). The next equally ranked were two responses, the first being to a "medium" degree and the second to a "low" degree, which each received 26.4% (28 people). 8.5% (9 people) answered that they have an impact to a very high degree, while one person (0.9%) said they have a very low impact.

Figure 6 shows the results of a question on farmers' opinion of the cost of farm management software relative to its functionality. 50.9% of respondents (54 people) said "Rather yes" that the prices are at the right level in relation to functionality, and 6.6% (7 people) rated "Definitely yes" 21.7% of respondents (23 people) said "Rather no" while 2 people (1.9%) said "Definitely No" 20 people (18.9%) chose "Hard to say".

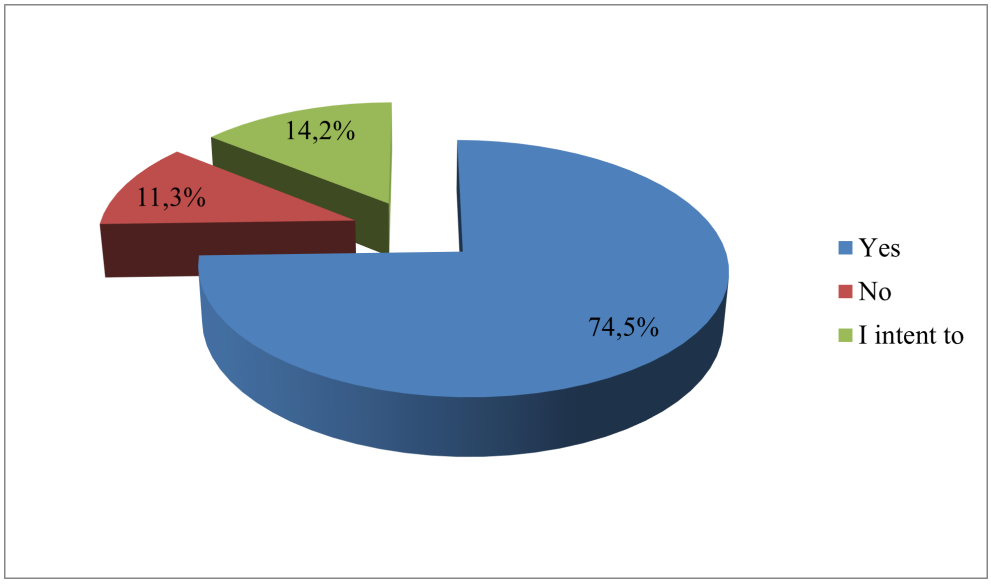

Figure 7. Responses to the question regarding the use of systems for automatic guidance of machines. Source: own elaboration.

Figure 7 shows the results of the question whether respondents use automated guidance systems on their farms. The survey shows that as many as 74.5% (79 people) marked the answer "Yes" stating that they use such solutions, while the answer "No" was indicated by 11.3% (12 people), and the answer "I intend to" was selected by 14.2% (15 people) of the respondents.

Figure 8 shows the results of a question about their view of the cost of automated guidance systems relative to their functionality. 50% of respondents (53 people) said "Rather yes" that the prices are at the right level in relation to functionality, and 18.9% (20 people) rated "Definitely yes". 16% of respondents (17 people) said "Rather no" while 6 people (5.7%) said "Definitely no". 10 people (9.4%) chose "Hard to say".

The results of the question presented in the Figure 9 show that the most useful functions for farmers are automatic path guidance and also automatic turning. These two functions significantly relieve the work the farmer has to do in the field. On the other hand, the fewest

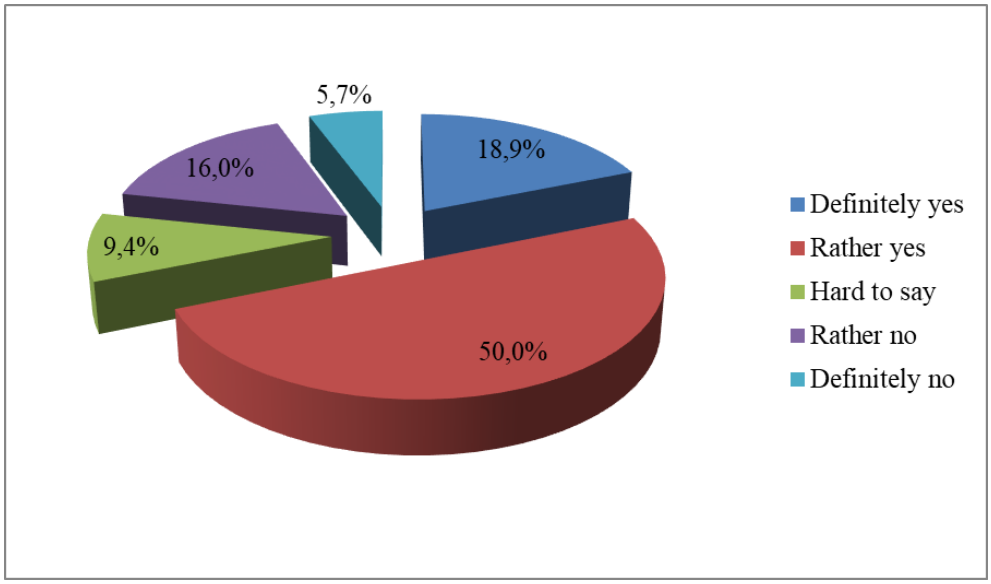

Figure 8. Responses to the question of whether the cost of automated guidance systems is adequate for the functionality they offer. Source: own elaboration.

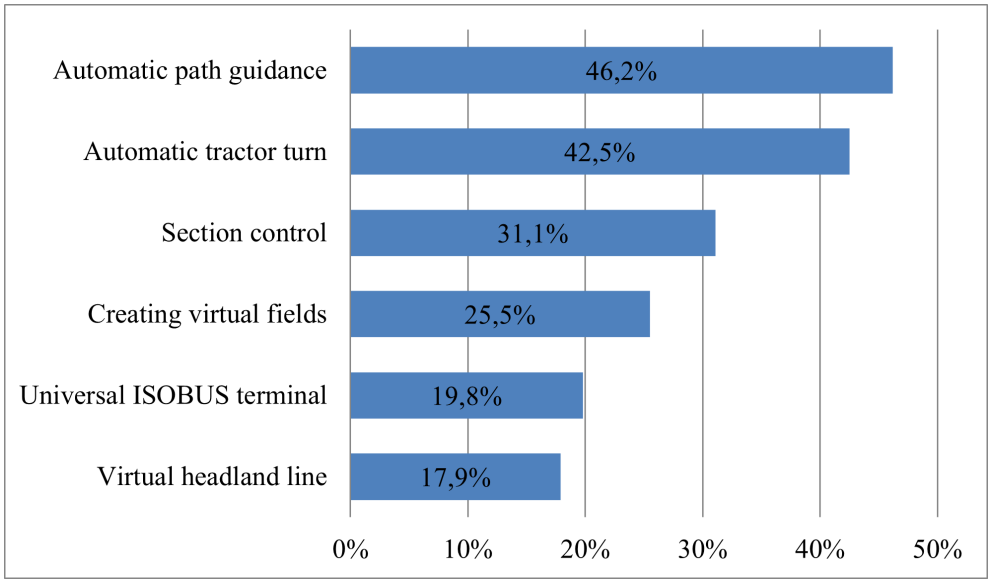

Figure 9. Most useful features of automatic guidance systems according to respondents. Source: own elaboration.

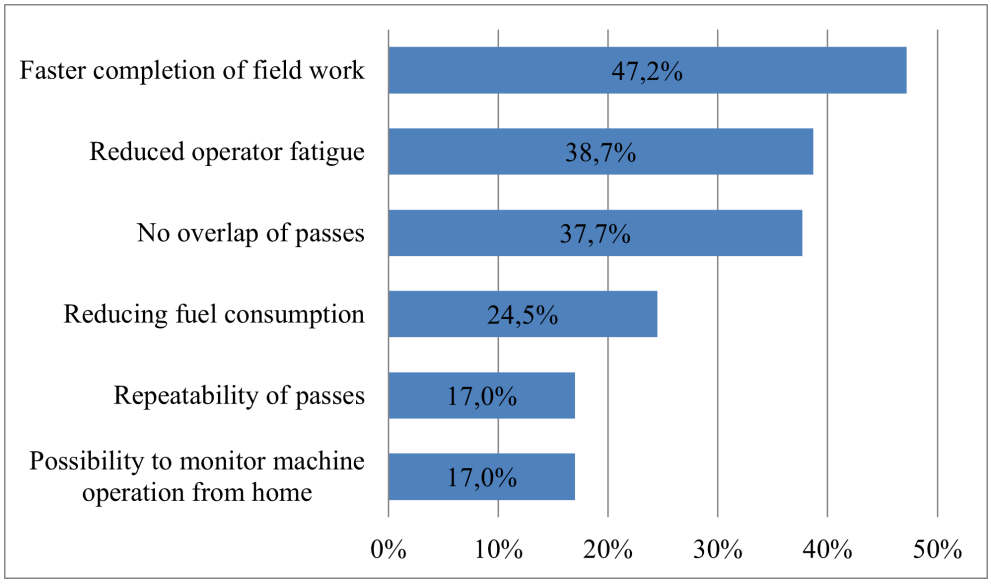

Figure 10. The most important benefits indicated by the respondents that result from the use of automatic guidance systems. Source: own elaboration.

farmers chose the virtual headland function may be due to the fact that when using the aforementioned functions, this function is unnecessary, as it indicates where we should turn back manually.

Regarding the question about the benefits of using automatic guidance systems (see Figure 10), it is apparent that the most important thing for farmers is the comfort of their work and also the time of this work. It is also important to them that successive passes of the machine do not overlap and do not leave unworked spaces.

4 Analysis of the collected data

Analyzing the results obtained from the Statistica program presented in Figure 11 we can conclude that there is quite a large number of correlations between the data. The program marked the statistically significant ones in red. The strongest of them is the one relating to the size of the farm and the degree of use of information technologies (*Degree_Technology_Rank*). Its value equals 0.57, which means that these data are strongly correlated with each other, and it gives us information that the larger the farms, the more they use different information technologies. Another correlation with a high relationship is also the one that depends on the size of the farm and the extent to which they use farm management programs (*Farm_-Managment_Programs_Rank*). Its value (0.4) means that the larger the farm, the more often it uses management programs. The case with the use of agricultural navigation (*Navi_Rank*) is very similar.

	Farm_Size_Rank	Degree_Technology_Rank	Farm_Managemnt_Programs_Rank	Effciency_FMP_Rank	Price_FMP_Rank	Navi_Rank	**Price_Navi_Rank**
Farm_Size_Rank	1,000000	0,579753	0,400014	0,089566	0,198051	0,350460	0,188335
Degree_Technology_Rank	0,579753	1,000000	0,462286	0,411895	0,272060	0,372467	0,160207
Farm_Managemnt_Progran	0,400014	0,462286	1,000000	0,216245	0,331179	0,214985	-0,027982
Effciency_FMP_Rank	0,089566	0,411895	0,216245	1,000000	0,200307	0,123492	0,079968
Price_FMP_Rank	0,198051	0,272060	0,331179	0,200307	1,000000	-0,026108	0,254356
Navi_Rank	0,350460	0,372467	0,214985	0,123492	-0,026108	1,000000	0,247545
Price_Navi_Rank	0,188335	0,160207	-0,027982	0,079968	0,254356	0,247545	1,000000

Figure 11. Research results from the Statistica program. Source: own elaboration.

There is also a strong correlation between *Degree_Technology_Rank* and *Farm_Managment_Programs_Rank*. It is at 0.46. Between *Degree_Technology_Rank* and *Effciency_FMP_Rank* (to what extent farm management programs affect farm efficiency), the correlation is 0.41, which also indicates a strong correlation. A slightly weaker correlation at 0.37, which can be described as moderate, is between *Degree_Technology_Rank* and *Navi_Rank*. There were also a few more correlations that we can describe as moderate. These are the correlations between *Farm_Managment_Programs_Rank* and *Price_FMP_Rank* (cost of farm management programs) at 0.33 and the correlation between *Farm_Size_Rank* and *Navi_Rank* at 0.35. The rest of the statistically significant correlations marked in red are weak correlations which are mostly at a level close to 0.2.

5 Conclusions

The results of the study clearly indicate that thanks to IT agriculture in Poland can become more effective. On the other hand, at least for now there are only a few solutions, which makes them quite expensive. Smaller farms decide not to use them because their cost would exceed the benefits that they could bring. That is why only large farms invest in IT solutions. There are some free alternatives on the market although they have quite limited functionality. The XFarm application provides some functions for free, while the rest only has free time-limited demo version. As for automatic management systems, AgOpenGPS provides the software for free because it operates on an open-source license. Investment in Poland's own, cheaper, and potentially even better solutions in this area would have a positive impact on increasing the level of computerization and automation of agriculture. Improving the efficiency and profitability of farms is of particular importance due to the forecasted rapid population growth.

The research presented here is a prelude to further analysis of the needs of farmers in Poland in terms of adopting IT and farm automation solutions. What functionalities they ought to have, what costs are acceptable, what the implementation and maintenance should look like — are just some of the many questions we are looking for answers to. The data collected will be used to build models to analyse the level, speed of development and potential for the application of intelligent systems in Polish agriculture.

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