SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2026
ORGANIZATION AND MANAGEMENT SERIES NO. 253

ESSENTIAL FUNCTIONALITIES OF A DECISION SUPPORT SYSTEM FOR SMALL FARMS: A QUALITATIVE APPROACH

Jacek PUCHAŁA

Hugo Kołłątaj University of Agriculture in Krakow, Department of Statistics and Social Policy;
jacek.puchala@urk.edu.pl, ORCID: 0000-0002-7671-411X

Purpose: The purpose of this article is to determine to which extent young farmers from small farms use information technology (IT) solutions in farm management, to document the expectations of the surveyed group of farmers regarding this type of software, and to identify the management functions that should be prioritized in the design of digital decision-support tools. The third research question concerns the management functions to which digital solutions for farm management should be dedicated.
Design/methodology/approach: The study was conducted using the Computer-Assisted Personal Interviewing (CAPI) method among a group of 37 farmers aged 40 or younger who had received funding to start their agricultural businesses.
Findings: According to the results, one in two young farmers reports using innovations in production, technology, or management; six out of ten respondents use a computer for farm management. Online information retrieval, government agency communication, financial-flow recording, and market-seeking activities are characterized as operational-record-keeping tasks focused on day-to-day work organization, administrative duties, and financial control. Only one farmer—operating a larger agricultural enterprise—employed herd-management software and dedicated farm-management software. Farmers' expectations regarding an IT system for farm management are primarily linked to the implementation of planning and control functions in the management process, with particular emphasis on financial performance monitoring, plant protection product application, animal-production deadline tracking, and regulatory compliance.
Research limitations/implications: The Agency for Restructuring and Modernization of Agriculture (ARiMR) did not provide the contact information of young farmers, citing personal data protection regulations; this decision—cited by the agency—limited the size of the research sample.
Practical implications: The expectations of the surveyed group regarding software supporting the management of small farms are useful for IT companies. It is reported that every second farmer surveyed would be willing to pay no more than 200 PLN per year for a program supporting farm management, and the program should be designed for installation on a computer, not for running in a browser. In addition, the system is expected to incorporate geospatial layers for plot-level mapping, to collate yield data, and, in the context of ongoing climate change, to automate the collection of temperature and precipitation records, thereby supporting data-driven adaptation strategies.

Originality/value: The results presented here are based on pilot studies conducted across a diverse sample of smallholder operations. No comparable studies in the literature focus exclusively on young farmers—identified as a key group determining the future of European agriculture (European Commission, 2020).
Keywords: Farm Management Information System (FMIS), agricultural software, agricultural decision-support systems (DSS), information management in agriculture.
Category of the paper: Research Article.

1. Introduction

With the declining proportion of young farmers among farm owners, it would be advisable to increase the use of digital decision support systems (DDSS), which would not only improve farm productivity but also encourage young people to engage in agricultural activities. In the European Union (EU), approximately 11% of all farms are run by farmers under the age of 40, which represents a decline compared to 14% according to earlier data from the review of the Common Agricultural Policy (CAP) reform for 2014-2020 (Figurek et al., 2023). In light of ongoing demographic transitions, the widespread adoption of IT solutions supporting decision-making is particularly important for young farmers, who do not have as much farming experience as their parents. A well-considered response to the documented demographic aging and the limited appeal of agriculture to young people is the promotion of agricultural software among the latter. Digital management support in agriculture—by integrating sensor networks, cloud-based analytics, and predictive modeling—not only increases productivity but also proves to be a strategic mechanism for attracting and retaining young people in rural areas (Ronzhin et al., 2025). Young people, generally eager to adopt digital devices, can be effectively targeted by agricultural advisory services that promote decision-support systems, and the digitization of agriculture (Agri-Tech) thus occupies a central position within global trends in agricultural development.

Precision agriculture (PA) and digital technologies—here treated as synonymous with information and communication technologies (ICTs)—are identified as a key direction for the development of modern agricultural production on large farms that possess the financial resources to invest in new, innovative technologies. Within this digitalization trend, technologies deployed in crop production—yield-mapping systems, drones for monitoring and spraying, soil-moisture sensors, and automated-machine control—are undergoing transformation, as are livestock-production tools such as automated-milking systems, feeding robots, and animal-welfare monitoring devices. Data management plays a key role in the digitization of agriculture, and DDSS is an integral part of this.

Small farms lack the funds for such investments, although non-commercial IT solutions exist. According to Gacek et al. (2025), the deployment of these solutions not only helps improve the profitability of agricultural operations by reducing the use of fertilizers and plant protection products but also contributes to environmental protection by reducing the risk of excessive transfer of chemicals into ecosystems. Given these benefits, free or low-cost digital decision-support systems (DDSS) are recommended for promotion among small farms, which—lacking the capital to purchase drones or soil sensors—can instead utilize service providers that offer digital data. Free decision-support programs, partially non-commercial solutions (e.g., SatAgro), and commercial services—including those provided by harvesters equipped with yield-mapping functions—are therefore reviewed as potential data sources. Young farmers with small farms struggle with insufficient equity capital due to limited cultivated areas and traditional technological equipment, yet their age-related digital proficiency confers a demonstrable capacity to absorb new knowledge and innovations

2. Objectives, materials, and methods

This article is exploratory in nature and serves as groundwork for explanatory research, as well as for the practical goal of organizing an EIP (European Innovation Partnership) operational group based on the needs of farmers. The aim of the article is to determine the extent to which young farmers use digital solutions and to understand their expectations regarding an IT program supporting farm management.

The research sample included 37 farmers who are beneficiaries of an EU program aimed at supporting those starting agricultural activities. These are individuals assessed according to relevant criteria by the Agency for Restructuring and Modernization of Agriculture and selected for public funding as entities with high development potential. The sampled farmers are predominantly drawn from the northern agricultural zones of the Małopolskie Province; their contact details were obtained, with ethical approval, from local village leaders—primarily from the districts of Kraków, Olkusz, and Proszowice.

Computer-Assisted Personal Interviewing (CAPI)—deployed in the present study—was used as the primary data-collection method, thereby increasing the reliability and consistency of the dataset, shortening the overall duration of the study, enabling the deployment of an online questionnaire, and improving quality control of the research process. Descriptive statistical methods were employed for data analysis, including examination of frequency distributions and characterization of the study population's structure.

Literature searches were conducted through "Consensus.app", "Scite.ai", and "Zotero", and the resulting corpus was imported into Zotero for unified management. Subsequent literature screening, conducted through Zotero and complemented by Internet searches, resulted

in the identification of 48 FMIS/DSS solutions; of these, 7 were selected as suitable for small farms, with their characteristics aggregated from manufacturer websites and the existing literature. The aggregated dataset was subjected to statistical processing within the Python environment, with ChatGPT-generated code facilitating data wrangling, and the resulting summary statistics are reported in Table 1; the associated prompt is accessible at https://chatgpt.com/share/69fac8d0-357c-832d-a792-6979364d9a2a. The programs identified through the literature review but not subjected to Python-based analysis are: AfiFarm, Ifarma, FARMnet, Kilo, Fieldtouch, WIDHOC, FARMA, Mark online, SIG AGRO, AGRIMI, Crop360, myCrop, eDWIN "Virtual Farm", and FarmSmart.

3. Innovation of young farmers

Significant milestones in the development of agriculture have been the transition from three-field rotation to crop rotation, as well as the use of synthetic fertilizers and plant protection products. In modern agriculture, such a milestone is precision agriculture—often also referred to as Agriculture 4.0, smart, or digital agriculture—which is an innovative agricultural production system that utilizes information technologies and analytical tools to precisely determine the application rates of inputs—fertilizers, plant protection products, and water. The application rate of these inputs is adjusted to changing environmental conditions and the needs of the crops being grown. In animal production, environmental conditions are adapted to the individual requirements of the stock, thereby enabling the optimization of production processes and the enhancement of animal welfare (Gacek et al., 2025). The non-adoption of Agriculture 4.0 solutions results in decision-making based on incomplete data.

Nearly 80% of farmers in the European Union utilize some form of digital solution on their farms. However, this statistic may be misleading due to the high proportion of young farmers in the sample. According to Tur et al. (approximately 79% of farms in the European Union (EU) have implemented at least one crop-specific digital technology, while only 29% have implemented three or more such technologies. Digital field records are the most commonly used (58%), while the adoption rate of other crop-specific technologies ranges from 3% to 22%. Digital technologies specific to animal husbandry are also used. Approximately 83% of farmers have implemented at least one such solution, while only 17% have implemented three or more (Tur et al., 2025). It is worth noting that the above data comes from a research sample that included a higher proportion of young people than is reflected in statistics on the general population of farmers in Europe; therefore, given the documented age-related innovation gap (Kielbasa, Puchala, 2015), the reported adoption levels may be slightly overestimated.

Small-scale farmers report a knowledge gap concerning precision agriculture (PA) tools, although a substantial majority express interest in acquiring such expertise. An analysis of the CAWI survey results, conducted by the Polish Space Industry Foundation (https://www.pfpk.org.pl, 2025) on a sample of 432 farmers, indicates that, among respondents running farms with an area of ≤20 ha, a lack of awareness regarding precision agriculture is a common phenomenon. Within this same subpopulation, 65.2% of respondents indicated interest in both conceptual training and practical implementation guidance, whereas, across the full sample, only 34.3% demonstrated pre-existing awareness of precision agriculture principles. Only 33.8% of all respondents currently employ precision agriculture (PA) on their farms (Rolnictwo precyzyjne w Polsce, 2021). By comparison, in Germany, over 80% of farmers already use this technology (Gacek et al., 2025). The indicator could be improved through the popularization and enhanced availability of digital solutions in agriculture for small farms.

Digital management support in agriculture needs not be limited solely to precision farming; it also encompasses the utilization of digital technologies available to all stakeholders in the operation of a farm. Young agricultural entrepreneurs in Indonesia, when surveyed, reported using the Internet to identify new markets (52% of respondents), search for information (31% of respondents), and communicate online (20% of responses). The study group consisted solely of farmers aged 20 to 23, who made up 63% of the total sample (the remainder of the sample consisted of individuals from processing and marketing). Young farmers mostly seek information about agriculture and crop production (32%), including land cultivation, fertilization, crop care, and harvesting, followed by market information (29%), prices (20%), and information on agricultural product processing (19%) (Nurlaela et al., 2022). It is worth noting that the respondents were part of a special project called "Young Agricultural Entrepreneurial Growth", which aimed to encourage young people to work in agriculture.

The generation of first-time farmers is characterized by innovative adoption of approaches that combine traditional methods with modern ones. European young farmers are ready to embrace innovation, smart farming, and the adaptation of scientific research findings to practice (Kielbasa, Puchala, 2015). Modern tools for the digitalization of agriculture offering opportunities to harness existing potential for agricultural development, e.g., through the use of the Internet of Things IoT are being deployed in context (Figurek et al., 2023). Connecting "things," for example, can entail the retrofitting of satellite-navigation guidance to legacy tractors – a physically feasible practice already documented on farms managed by young farmers – and such incremental digitization, when applied to existing production means, is expected to safeguard the long-term stability, profitability, and efficiency of European agriculture.

The adoption of these solutions is nonetheless capital-intensive, a barrier that limits uptake by small farms and small non-agricultural enterprises. The Central Statistical Office in Poland (GUS) reports that the highest share of entities using Artificial Intelligence (AI) tools was

recorded among large entities (33.0%), while the lowest was among small entities (4.0%) (https://naukawpolsce.pl, 2025). The situation is similar regarding the use of digital solutions on farms, as smaller farms are less likely to adopt digital solutions that support decision-making in agricultural operations, and most farmers with farms under 10 hectares were unable to explain what digital and precision agriculture entails. Farmers' awareness of digital and precision agriculture was reported to be the highest among the youngest age cohort under 40 years (Ropek, 2025), and this positive association was confirmed in a separate meta-analysis, an increase in size is consistently accompanied by elevated awareness and utilization of digital technologies. Large farms implement 10% to 84% more digital technologies than small farms (Tur et al., 2025), yet when such young managers operate small holdings, the financial barrier to technology adoption remains prohibitive (Ropek, 2025; Tur et al., 2025). Software suites for yield-and-growing-condition data management are priced between 2000 and 10,000 PLN per year, while aggregated soil-monitoring sensor arrays range from 10,000 to 30,000 PLN (ursus.pl, 2025).

The digitization of businesses has been better studied than that of farms, as an Enterprise Digitization Index (EDI) has been developed, but no such indicator exists for agricultural holdings (https://naukawpolsce.pl/, 2025). The findings underscore that, in the absence of targeted financial incentives, young farmers operating small holdings remain unable to absorb the up-front costs of precision-agriculture suites.

Young farmers' decisions regarding innovative smart farming technologies differ by gender. For example, in Taiwan, young male farmers had a greater intention to use IoT technologies for crop management and solving agricultural problems than young female farmers (Chuang et al., 2020). Unfortunately, similar studies are lacking in Europe.

Despite these knowledge gaps, there remain young women and men who express a desire to remain in agriculture, and many of them adopt an innovative approach to developing and managing their farms; the choices they confront, however, will depend on farm-specific factors – including size, maintenance history, and modernization status – that shape technology adoption trajectories (Rooij, 2006). Greater digital inclusion of rural youth, achieved through the aforementioned infrastructure investments, enables the combination of agricultural work with non-agricultural activities—income diversification—that is particularly important for small farms (Licciardo et al., 2024). With improved digital inclusion, rural youth can combine agricultural work with non-agricultural activities, a crucial step for small farms seeking income diversification.

Current research findings confirm the results of studies from the 1990s, which indicate that younger farmers with higher levels of formal education are more likely to use more advanced Farm Management Information Systems (FMIS) (Lewis, 1998). The findings are consistent with the diffusion theories, which link innovative behavior to younger, better-educated individuals who tend to gather information from scientific, impersonal, and local sources. Conversely, older, more experienced farmers exhibit lower demand for management

information – and, consequently, for digital agricultural support – relative to their younger colleagues (Lewis, 1998). Consequently, further research on digital inclusion among young farmers – who will determine future agricultural digitization trajectories – is recommended.

4. Software for managing farm operations

The literature on farm-management software (FMS) employs numerous abbreviations that require initial clarification, a task undertaken at the outset of this section. The analyzed articles reference FMS - Farm Management Software (Nikkilä et al., 2010; Carrer et al., 2015, 2017; Munz et al., 2020; De Souza Filho et al., 2023) and FMIS - Farm Management Information Systems (Lewis, 1998; Nikkilä et al., 2010; Fountas et al., 2015; Tummers et al., 2019; Ammann et al., 2022).

Another commonly used term related to IT-based management support is DSS (Decision Support System), which also plays a key role in digital and "smart" agriculture (Hayman, Easdown, 2002; Verleye, De Marez, 2005; Wenkel et al., 2013; Sampurno et al., 2014; Giusti, Marsili-Libelli, 2015; Navarro-Hellín et al., 2016; Aiello et al., 2018; Nestel et al., 2019; Rupnik et al., 2019; "AgroDSS", 2019).

According to a systematic literature review conducted by Cavazza et al. (2023), DSS is identified as the most frequently discussed topic regarding digital technologies deployed in agriculture, and, according to that analysis, 19 out of 37 articles on the state of the art in artificial intelligence (AI) in agriculture refer to it. DSS represents the predecessor to the latest solutions, such as BI (Business Intelligence) applications, some of which already offer artificial intelligence (AI) support.

Within the context of sustainable precision agriculture, FMIS (Farm Management Information Systems) are defined as integrated software platforms that aggregate data from fields, machinery, markets, and financial ledgers into a unified decision-support environment. The primary goal of these systems is to reduce costs, improve yields and quality, and assist farmers in meeting regulatory standards. Initially, FMIS were not fully computerized and did not always utilize digital media or the Internet.

In the early phase of digital agriculture, the first comprehensive system that assisted farmers in decision-making was the Canadian program Canfarm, which was developed in the 1970s and which organized services into three categories - cash flow control, cost management, and production planning – thereby linking recording and planning functions within a single framework. These systems were not always fully computerized or based on digital data storage and the Internet. Decision-support logic was executed on the basis of data and records transmitted to the central facility in Guelph via traditional mail or telephone – the Internet was not yet operational, although the Advanced Research Projects Agency Network (ARPANET)

was already in use. The Guelph center maintained a central computer-data-processing system for analyzing data sets, and feedback was therefore provided only after about 15 days (Thompson, 1976).

The next, more advanced program was CALEX, an early, innovative computer system for its time that integrated data and expert knowledge to manage agricultural operations. It ran on personal computers (IBM-compatible PCs) and was developed as part of work on artificial intelligence (Plant, 1989). This first solution, Canfarm, represents the Agriculture 2.0 era; the Agriculture 3.0 era, spanning the 1990s to 2010, encompasses the CALEX program. Agriculture 4.0 – discussed since 2010 – has been associated with a dynamic development of FMIS. By 2015, 141 FMIS solutions were already available, commercially offered by 75 providers from the United Kingdom, the United States, Canada, Australia, France, Germany, and Italy (Fountas et al., 2015).

In the early stages of DSS development, information from farmers was collected by telephone or mail; the agricultural advisor then utilized software that generated indicators based on the entered data to aid in rational decision-making. A streamlined DSS, in which farmers manually enter data via a web portal, could – given appropriate data-validation routines – calculate decision-relevant indicators and their interpretations, thereby reducing cost barriers for small holdings. Such a configuration, although representing a deliberate step back to previous technologies, aligns with the resource constraints typical of small holdings that lack Internet of Things (IoT) sensors, farm-data-collection software, or the financial capacity to deploy complex systems.

Farm management software (FMS) is a centralized platform that integrates data from various sources, allowing farmers to remotely monitor their entire farm and optimize operations for efficient resource use. These tools provide real-time analytics and support decision-making (Tilak et al., 2024).

According to the scientific literature, the main functions of FMS/FMIS are: collecting, storing, analyzing, planning, and documenting data related to the management of crops, fields, machinery, and finances (Fountas et al., 2015; Saiz-Rubio et al., 2020; Tummers et al., 2019) Typical FMS/FMIS modules include: record keeping, crop planning, inventory, machinery utilization, traceability, quality and compliance, finance, and decision support. Advanced systems – integrating sensor-driven data pipelines – include additional precision-agriculture features, such as variable-rate irrigation/fertilization and yield-mapping capabilities, alongside predictive models (Baseca et al., 2019; Nikkilä et al., 2010; Rupnik et al., 2019; Zhang et al., 2022).

In addition, the expectations of small farm owners regarding FMS/FMIS functions, as well as the funds available for investment in DSS, are reported to be lower than those of larger farms, a finding that, when coupled with targeted functionality reduction, may permit a corresponding decrease in system pricing.

The development trajectory of agriculture has been nonlinear and systemic, encompassing parallel changes in land-use organization – from slash-and-burn agriculture, through three-field rotation, to crop rotation – as well as in technology and means of production. The current shift primarily concerns the logic of production management, in which decision-making is data-driven (data-driven agriculture). Agriculture 4.0 – often abbreviated as Ag4.0 – paves the way for the next evolution of agriculture, encompassing unmanned operations and autonomous decision-making systems. Agriculture 5.0 (Ag5.0) will be based on robotics and (some form of) artificial intelligence (Digital Farming: what does it really mean?, 2025).

Autonomous agricultural machinery (AAM) – often identified as Agriculture 5.0 – comprises automated tractors with navigation, unmanned aerial vehicles, and agricultural robots, which execute and support services commissioned by farmers. Research is already at the stage of an Autonomous Agricultural Machinery Management Platform (AAMMP) with Internet of Things (IoT) support (Zhang et al., 2022). As a result of this progress, the machine operator is removed from the production process and replaced by AI.

It is impossible to cover all Agriculture 4.0 solutions in a single article; therefore, this paper focuses on software programs that support farm management – understood as monitoring agricultural operations, tracking and counting products, determining production efficiency, financial analysis, energy-consumption analysis, technology integration, and decision implementation – by leveraging Decision Support Systems (DSS). A DSS ¬– an intelligent system that supports decision-making regarding specific requirements and problems – is defined here as a software environment that delivers actionable answers to stakeholders and potential users by extracting useful information from raw data, documents, personal knowledge, and/or models (Figure 1). Such systems can be underpinned by data, models, communication, documents, and knowledge (Abbasi et al., 2022), thereby enabling evidence-based decision-making; nevertheless, the final decision remains with the farmer, who interacts with the platform through the DSS interface.

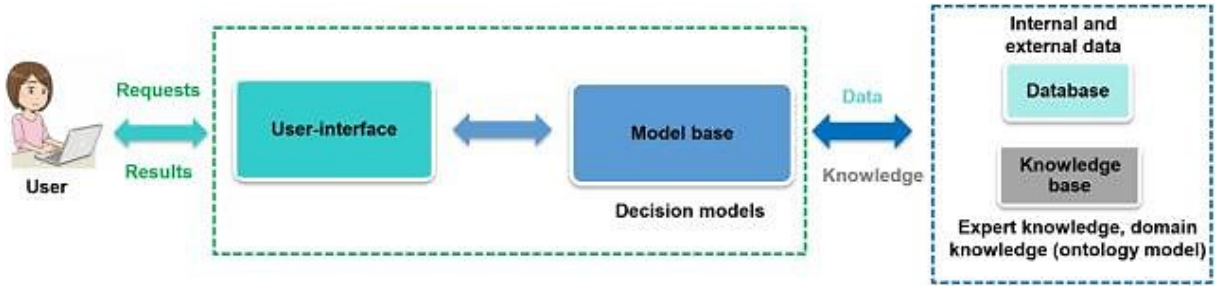


Figure 1. The general architecture of a decision support system.

Source: Abbasi, R., Martinez, P., Ahmad, R. (2022). The digitization of agricultural industry – a systematic literature review on agriculture 4.0. Smart Agricultural Technology, 2, 100042. https://doi.org/10.1016/j.atech.2022.100042.

Modern DSSs tailor their decisions to specific crops and not only collect information from various sensors but also send commands to actuators in the IoT network. Saiz-Rubio et al. (2020) provided a very accessible description of a data-driven management system along with AI-based data analysis. Such a system is grounded in objective field data and in intelligent, AI-augmented decision-making, and its operational framework commences with a specific crop that requires management, exploiting its internal spatial and temporal variability (Figure 2). The platform depicted in Figure 2 – referring to the physical layer through which information is obtained – consists of sensors, the specific components from which objective data are derived. The dataset encompasses information directly collected from parameters measured within the crop, soil, or environment (Figure 2).

Data retrieval from sensors can occur in many ways, ranging from using a USB flash drive to download files to retrieving data from applications synchronized with the Internet. The link between the data and the decision-making stage involves filtering procedures and AI algorithms that allow only relevant data to be obtained and help the farmer make the right decisions.

Actuation – implemented by advanced equipment capable of receiving commands from a computer control unit – constitutes the final layer of the decision-execution stack. The cycle, thus, begins and ends at the crop level (Figure 2), thereby ensuring closed-loop feedback and continuous improvement of management prescriptions. The crop's response to the decision is then recorded by specialized sensors, and the loop repeats systematically until harvest—which marks the end of the crop's life cycle (Figure 2; Saiz-Rubio et al., 2020).

Thus, FMIS have evolved from simple programs used for recording and calculating indicators (Canfarm), when farmers had to wait 15 days for analysis results, to complex systems supporting real-time crop management with AI assistance (for example, in irrigation; Navarro-Hellín et al., 2016).

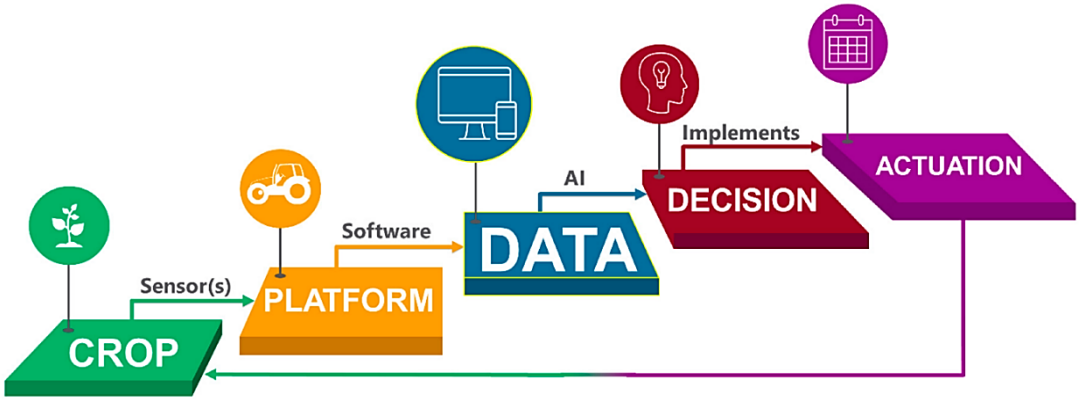


Figure 2. Information-based management cycle for advanced agriculture.
Source: (Saiz-Rubio et al., 2020).

For advanced management systems in precision agriculture to function effectively, standardization of communication protocols within the IoT system is essential. Hence, a key element of agricultural digitization is the Agricultural Industry Electronics Foundation (AEF)—which developed the ISOBUS standard for tractor-to-machine communication, based on

ISO 11783—and which, through its dedicated Farm Management Information Systems (https://www.aef-online.org, 2025).

Equipment manufacturers receive the appropriate certificate of compliance with the ISOBUS standard, and their products are entered into a knowledge database, which, in turn, allows farmers to verify the digital compatibility of equipment – e.g., whether a tractor will communicate digitally with a machine they intend to purchase. For small farms collaborating within a shared machinery pool, investment in machinery that each of the agricultural tractors belonging to the group of agricultural producers can communicate with is essential.

Current digital agriculture solutions can be applied not only to crop production but also to livestock farming, where, with the appropriate software, milk can be analyzed for signs of mastitis in cows, and, in the case of pigs, artificial intelligence can identify sick animals based on their movement patterns. For both livestock and crop production, large amounts of data are collected and summarized in an accessible way so that the farmer can better understand them (Wrzecińska et al., 2023) . Based on the collected data, the farmer can make better production decisions, which translates into the farm's financial performance and product quality.

One company supporting livestock production is Afimilk (Israel). Afimilk's solutions enable farmers to actively detect costly conditions such as mastitis, nutritional issues, and difficult births (https://www.afimilk.com, 2025). The company offers the "AfiFarm" program for managing and automating dairy farms.

In Malawi, a pilot-project deployment – documented in Munthali et al., 2022 –demonstrates a field-ready data-collection workflow whereby agricultural advisors, during on-farm visits, use the "Rapitest 4-in-1 soil tester" to capture soil-health indicators, which are then automatically synchronized with a cloud-based storage platform. Subsequent review of the farm-management portal by extension workers then supports farmers in production decision-making (Munthali et al., 2022).

Module (ProFit), an innovative software component designed to quantify the economic benefits of precision farming applications under varying environmental and operational conditions. In terms of architecture, "ProFit" is embedded in the cloud-based farm-management information system (FMIS) "Ifarma", where it leverages existing functionalities – such as the precision agriculture database provided by other "Ifarma" modules, including "PreFer" (Karydas et al., 2023).

Recently, numerous platforms and technologies for farm management have emerged. Some of the notable options include Climate FieldView, Granular's Farm Management Software (FMS), Farmers Edge, Agworld, Taranis, Trimble, Sentera, Topcon Agriculture, and Raven Industries provide automation solutions, such as guidance and steering systems (Karydas et al., 2023). Additional platforms – listed for comprehensive context – include: FarmWorks, 365FarmNet, Ifarma, FARMnet, Kilo, Fieldtouch, WIDHOC, FARMA, Afimilk, and Mark Online are available (Tummers et al., 2019).

Other solutions supporting farm management include SIG AGRO, (Baseca et al., 2019) and "AgroDSS" (Rupnik et al., 2019). Development of the last mentioned tool was undertaken within the AgroIT project – cofinanced by the European Union under the Information and Communication Technologies Policy Support Programme (CIP-ICT PSP). The "Geofolia" application - developed and deployed in Romania (Geofolia – Program de management agricol - ISAGRI, 2025) – provides farmers with a decision-support dashboard that integrates geospatial layers, crop-management modules, and compliance reporting tools („Software pentru managementul fermei Archives", 2025). Another platform, called "AGRIMI", supports farm decision-making (Geofolia – Agricultural Management Program - ISAGRI, 2025). Furthermore, "Crop360" is another application that facilitates farm management through artificial intelligence and has become one of the most popular tools in Romanian agriculture (Markovits, 2023).

Free, open-source farm-management tools – designed for farmers and available on the market – are identified as a promising means of enhancing sustainability; these tools include information-technology (IT) solutions such as LiteFarm, farmOS, ekilibre, Farm-Simulator (Tribki, 2017/2025), GENMON (SolangeD, 2016/2024), and myCrop (Apostolakis, 2013/2024). Among these, the LiteFarm program deserves special attention. The LiteFarm application – developed by an interdisciplinary team of scientists, researchers, farmers, designers, and software specialists – is highlighted for its comprehensive feature set and its role in facilitating data-driven decision-making. The team – formed at the University of British Columbia (UBC) – has established a data-sharing framework whereby anonymized farm records collected through the platform are utilized for scientific research.

A free option available for small farms in Poland is "eDWIN" (Internet Platform for Advice and Decision Support in Integrated Crop Management), which includes the "Virtual Farm" e-service. One of the features of "Virtual Farm" is its ability to assist farmers in deciding when, where, and how much to apply crop protection products. "FarmSmart" provides a similar solution but is entirely commercial. Other commercially available farm management programs on the Polish market include "xFarm", "eAgronom", "Agroasystent", and "RolnikON" (Dmowski et al., 2024). Notably, "xFarm" offers some basic functions for free, while "eAgronom" provides only a limited free trial period.

"FarmPortal" is widely adopted on small family farms with low automation requirements, as well as on medium- and large-scale operations where full resource control, production optimization, and automation are required. The CropX platform – positioned as a data-aggregation hub – ingests soil analyses and real-time weather telemetry, transforms these streams into actionable insights, and delivers a unified dashboard view of field conditions, thereby supporting proactive crop-health monitoring. These platforms rely on cloud connectivity, Internet of Things (IoT) sensors, and artificial intelligence (AI) to enable real-time monitoring and optimization of agronomic workflows. Across a dataset of representative

holdings, average yield gains of 1.75%, energy-cost reductions of $17-32 per hectare, and irrigation-water savings of 8% have been documented (Saiz-Rubio et al., 2020).

An analysis of 38 articles conducted by Tummers et al. (2019) shows that FMIS offer features such as financial management (found in 17 cases), reporting (14 cases), and data collection (13 cases), which support effective operational decision-making on farms. Mobile and web-based modules – particularly important for young farmers – enable remote monitoring of fields, crops, and resources, thereby aligning with their digital lifestyle. Additional key features include resource and equipment management, as well as operational planning, which help reduce production costs. Less experienced young farmers benefit from simple, mobile FMIS that lower the barrier to entry and reduce costs.

Automated decision-support systems are becoming increasingly important for managing agricultural irrigation, especially in the context of climate change. A notable system developed in Spain uses continuous soil measurements alongside climate data to accurately predict crop water needs. This research aims to demonstrate, within the context of accelerating climate change, the efficacy of an automated decision-support system (ADSS) for irrigation management – a framework that fuses real-time soil-moisture measurements with long-term climate records – thereby enabling data-driven, climate-adaptive water allocation (Navarro-Hellín et al., 2016). Although this conceptual solution has been applied to citrus-tree cultivation, work is underway to adapt the system to other crops. A solution that is already operational and supports farmers' decisions is "IRRINET", an online irrigation system developed in the Emilia-Romagna region (Giusti, Marsili-Libelli, 2015).

"LandCaRe DSS" is an interactive, model-based platform developed in Germany—designed to assess the impact of climate change on agriculture and land management and to analyze potential adaptation strategies at regional and local scales (Wenkel et al., 2013). The primary goal of "LandCaRe DSS" is to provide information on the complex, long-term effects of climate change and to explore possible management options for adaptation by addressing "what-if" scenarios.

An illustrative application of DSS technology is documented in Israeli research on pesticide management in greenhouse cultivation, where, in 2015, greenhouses managed by the DSS received approximately 67% fewer pesticides than control greenhouses (Nestel et al., 2019). A similar initiative, focused on integrated pest management (IPM), was implemented in Italy (Aiello et al., 2018).

SCADA (Supervisory Control And Data Acquisition) denotes a class of industrial control architecture that employs hardware and software to enable organizations to monitor, manage, and control processes, machines, and facilities, both locally and at remote locations. Spanish researchers employed Gensym Corporation's G2 (a model-based, real-time decision-support platform) and SCADA in combination with the LabVIEW (Laboratory Virtual Instrument Engineering Workbench) tool to implement an agriculture-focused decision-support system. The resulting integrated platform – operating in real time – provides producers with

decision-support alerts, delivers additional climate-control data to greenhouse systems, and offers a suite of solutions for issues arising during automatic monitoring of environmental parameters throughout the growth period (Cañadas et al., 2017). As of 2017, the platform remained in the prototype stage.

According to the accepted definitions, "FMIS with DSS components" (Table 1) refers to farm management information systems that include analytical/decision-support elements, and a DSS (in the strict sense) is a system whose primary function is to generate decision recommendations based on models, data, and rules. The FMIS/DSS combination best suited for small farms is presented in Table 1.

Table 1.
FMIS with DSS and the "OneSoil" component designed for small farms

System name	Production planning	Analisys of the costs	Support for operational decisions	Data integration	Paid program	Free period	Free features	Interface languages	Producer
FarmPortal	✓	✓	✓	◐	not	demo	FMIS Basic	PL	Digital Crops
Greenfield	◐	◐	◐	◐	Partly	Free-mium	Poetry	IN	Greenfield Technologies
Harvest Profit	◐	✓	◐	–	not	trial	limit analysis	IN	Bushel / Harvest Profit
OneSoil	◐	–	✓	✓	NO	constant	satellite maps	PL, EN, RU	OneSoil AI
eAgronomist	✓	✓	✓	◐	not	trial	Poetry	PL, EN, inside	eAgronom OÜ
LiteFarm	◐	◐	◐	◐	NO	constant	full	IN, IS	LiteFarm (UBC)
xFarm	✓	◐	✓	✓	Partly	Fre-emium	FMIS	PL, EN, IT	xFarm Technologies

Symbols in the table: ✓– function explicitly declared, ◐ – intermediate/supporting function, – no declaration.

Source: The data collected was analyzed in a Python environment using ChatGPT code. Due to its length, the prompt will be made available by the author upon submitting a query.

The environmental burden is reduced through a decision-support system for herbicide-spraying planning and nozzle-size selection (Sampurno et al., 2014). Scientific research is advancing faster than practical application: complex FMIS concepts are emerging, but office software and basic planning tools still dominate on farms.

Generally, farm management information systems (FMIS) can be categorized as (Fountas et al., 2015):

- "Basic systems" – focused primarily on finances and reports,
- "sales-oriented systems" – strong in sales, inventory, and finances,
- "site-specific systems", geared toward precision agriculture,
- "complete systems", offering the broadest set of functions, including quality management, best-practice frameworks, and, often, precision modules.

In recent years, farm-management systems – including Farm Management Software (FMS) and Farm Management Information Systems (FMIS) – have been gaining importance in the agricultural sector; however, the advisory needs of young farmers in this context remain poorly researched. Much research focuses on precision agriculture technologies and their adoption by

producers, which may suggest the presence of a research gap regarding the specific advisory needs of young farmers regarding FMS and DSS.

5. Training needs of young farmers

A research gap is also evident in understanding the impact of education on the adoption of new technologies, and many studies suggest that educated farmers are more likely to adopt new technologies, meaning that access to education regarding FMS and DSS could significantly increase their practical application (Santiago, Roxas, 2015) The development of tailored training programs, therefore, is proposed as a strategic measure to facilitate technological adaptation by young farmers operating within a rapidly evolving technological environment.

Farmers' insufficient skills represent a barrier to the use of Farm Management Information Systems (FMIS), and, as demonstrated by Tummers et al. (2019), farmers often possess a low level of education, which limits their ability to fully utilize the potential of FMIS. Better education and training for farmers are widely recognized as one of the most important factors facilitating the implementation of sustainable agricultural technologies (Saiz-Rubio et al., 2020). A strong positive correlation has been documented between a farmer's participation in specialized training on digitalization and the number of technologies that are implemented. The cultivation of digital competencies through formal education and targeted training programs is therefore identified as a critical lever for overcoming adoption barriers and realizing the full potential of these digital tools (Tur et al., 2025). Operating advanced software and analyzing data requires specialized knowledge, which is often lacking among farmers.

Public and private agricultural advisory systems have long played a crucial role in transferring knowledge and technology into agricultural practices. As early as the 1970s, during the implementation of early information-technology (IT) systems such as the Canadian "Canfarm", advisory staff were key in educating farmers on the use of new tools (Thompson, 1976). The advisory role – characterized by technology selection, system integration, and data interpretation – remains essential.

Small holdings are anticipated to adopt basic digital tools gradually, whereas large-scale operations are projected to invest in advanced sensor-linked equipment, and intuition-based management, uninformed by data, is expected to decline as the dominant paradigm within professional agriculture. Information-technology (IT) systems that support management are identified as a source of opportunities, especially for the new generation of young farmers who are accustomed to digital technologies, and the offsetting of the negative effects of an aging rural population through the leveraging of innovations is documented (Saiz-Rubio et al., 2020).

However, to fully realize the potential of Agriculture 5.0, the provision of in-depth training to users is necessary; the optimal target group for such training is identified as young farmers eager to learn and apply modern technologies in agriculture (Saiz-Rubio et al., 2020).

Key Features of a Farm Management Support Program for Young Farmers (Fountas et al., 2015):

- Field-operation management – enabling the planning and recording of all tasks (sowing, fertilization, spraying, and harvesting) – facilitates compliance with subsidy requirements, environmental standards, and yield analysis.
- Finance – enables calculation of costs per hectare and per crop, comparison of technology options, and assessment of farm profitability, which is particularly important for young farmers with limited capital.
- Inventory and Inputs – the module facilitates the monitoring of fertilizers, plant protection products, fuel, and seed, thereby establishing a foundation for traceability.
- Reporting – report generation for payment agencies, inspections, and banks (e.g., for investment loans) reduces time spent on administrative tasks.

The findings underscore that, within the context of resource-constrained adoption, barriers to technology uptake among the new generation of farmers can be reduced through systemic support delivered via well-organized advisory services and targeted training programs – so that investments in human capital are accorded the same priority as investments in the technology itself, because competencies ultimately determine implementation effectiveness. Although young farmers are often more open to innovation, they also require professional support to navigate the complex world of digital agriculture.

As early as 2002, it was noted in Australia that adoption rates of farm-management information systems (FMIS) were significantly lower than expected, and that increased computer availability on farms did not automatically result in the use of computers for farm management (Hayman, Easdown, 2002).

A review of the literature indicates that the effective digital transformation of the agricultural sector requires an integrated and systemic approach. The promises of Agriculture 4.0 can only be fulfilled by creating a coherent support ecosystem that will simultaneously:

- Address the skills gap through targeted training programs and the development of professional advisory services.
- Overcome the financial barrier using available financing instruments, such as EU funds and preferential loans, which help cover high initial costs.
- Strengthen trust and infrastructure by ensuring universal access to high-speed internet and establishing a clear legal framework regarding data security and ownership.

Ultimately, the future of Polish and European agriculture depends on the ability to harmoniously combine technological progress with investments in human capital and to create an environment conducive to innovation. Only through such coordinated action can the full potential of digitalization be harnessed to build a resilient, competitive, and sustainable agricultural sector, and digital education is now regarded as being no less essential than instruction in biology, economics, or management.

6. Results – research area, area, and production directions of the surveyed farms

The surveyed farmers are drawn from twenty-four municipalities: Charsznica, Igołomia-Wawrzeńczyce, Jerzmanowice-Przeginia, Kłobuck, Koniusza, Koszyce, Krzeszowice, Limanowa, Lisia Góra, Moszczenica, Nowy Targ, Osiek, Pałecznica, Proszowice, Raciechowice, Racławice, Skała, Sułoszowa, Trzyciąż, Wieprz, Wolbrom, Woźniki, and Zator.

The highest proportion of survey participants was recorded in Proszowice County (35.0%), followed by Kraków County (16.0%), Olkusz County (13.0%), and Miechów County (8.0%). The remaining farmers were recruited from the counties of Oświęcim, Gorlice, Kłobuck, Limanowa, Lubliniec, Myślenice, Nowy Targ, Tarnów, and Wadowice.

The average farm size was recorded as 8.81 ha; the modal class – defined as the interval containing the highest frequency of observations – spanned 10-15 ha (35.0 % of the sample), indicating a predominance of smallholder operations. In second place in terms of frequency were farms up to 5 ha (32.4% of cases), and nine out of ten farms did not exceed 15 ha (91.9% of the surveyed farms).

The average lease size was recorded as 16.7 ha, a figure inflated by a single outlier farm leasing 148 ha; in the majority of cases, lease size did not exceed 80 ha (Table 2). It is worth noting that half of the farms leased no more than 20 ha of land

Two out of three farms grew wheat (73% of the surveyed farms), and more than half of the farms planted no more than 10 ha with wheat (54.1% of the farms), a distribution primarily driven by the preponderance of farms with an area of up to 10 ha.

Barley (Hordeum vulgare) was not cultivated on two out of three surveyed farms (70.3% of respondents), and the most frequently reported sown area for barley was 2 ha (16.2% of responses).

Corn (Zea mays) was cultivated more frequently than barley, although exactly half of the surveyed farms (54.1%) did not grow corn. Additionally, around 70% do not cultivate legumes, and, on one in ten farms, legume area does not exceed 2 ha. Legumes—through a symbiotic association with nodule-forming bacteria of the genus Rhizobium—fix atmospheric nitrogen, thereby acting as natural green manure and enriching the soil with this essential nutrient.

In addition, three out of four farms do not maintain cattle (75.7% of farms), and, when cattle are present, holdings most frequently report 20-30 head (8.1% of farms); swine production is even more limited—only four farms raise pigs. In contrast, four farms reported maintaining herds of 100-200 head, thereby demonstrating the concentration of swine production at a larger scale. Poultry management – characterized by low stocking densities for self-sufficiency – was recorded on seven farms, with flock sizes not exceeding 50 birds; however, one farm maintained a commercial-scale layer operation of 4500 birds, underscoring the presence of specialized poultry production within the study region. Equine holdings were limited to three farms, one of which kept a herd of 20 animals, thus indicating a marginal role for horse husbandry in the local agricultural matrix.

7. Results – gender, age, education, profession of respondents

The survey sample consisted of 5 women and 32 men, and the age structure revealed that the largest cohort—spanning 45.9% of respondents—was concentrated between 25 and 35 years; at the time of data collection, 35.0% of participants were 25 years or younger, whereas 19.1% were aged 35 to 45.

The gender distribution was predominantly male, with men representing 86.5% of the sample (32 individuals) and women constituting 13.5% (5 individuals). The largest percentage of respondents held a secondary education—technical school (45.9% of respondents). The smallest shares consisted of respondents with a high-school education (general secondary school) and a bachelor's degree (approximately 13.5% each); a master's degree was held by 27.0% of the sample.

The occupational profiles of program beneficiaries reveal that 62.2% of respondents report a primary occupation in agriculture; 5.4% combine agricultural work with business management; and 19.9% couple agricultural activities with employment in the private sector. A limited number of respondents combined agricultural labor with employment at the municipal office or in teaching roles. Approximately 8% of respondents reported employment in a private company.

These outcomes indicate that sustaining a livelihood exclusively on farm income—particularly from small, grain-dependent operations—remains challenging, a pattern attributed to persistently low commodity prices.

8. Results – farm labor engagement

The most frequently observed household configuration comprises three members—typically parents and a young farmer (29.7% of respondents)—while four-adult households were also relatively common (27.0% of respondents), and six-person households occurred least frequently (5.4% of respondents). Young farmers participating in the study maintain separate households, and multigenerational families are reported to be declining.

Most surveyed families did not include minor children (54.3% of respondents), one in four families had two children (25.7% of surveyed farmers), and one in six families had only one child (14.3% of respondents).

Most often, farm work is carried out by a single individual (37.8% of responses), followed by two or three individuals (27.0% of responses each), and having four or five individuals engaged in on-farm labor is a very rare occurrence. V. Discussion In the past, there was talk of hidden unemployment in rural areas; however, in the present sample, such a phenomenon appears unlikely to be present.

In one out of every three farms, no one works outside the farm (32.4% of respondents), whereas, in the remaining farms, one person often works outside the farm (37.8% of respondents), and less commonly, two people (21.6% of responses) or three people (8.1% of responses) do so.

9. Results – Young farmers' use of digital technologies

This study investigates the limited uptake of innovations among young farmers and reports that 48.6% of respondents do not employ production, technology, or management innovations, whereas only 13.5% self-identify as users of such solutions (see Figure 3). Among the limited set of adopters, the following technologies are deployed: GPS-guided sprayers with remote section control, GPS navigation, soil maps that reveal site-specific nutrient content, zero-till cultivation systems, and computer-based herd-management software – all of which are implemented at scales that remain below widespread diffusion thresholds (see Figure 3). No-till farming was practiced by two respondents, and herd-management software was employed by one.

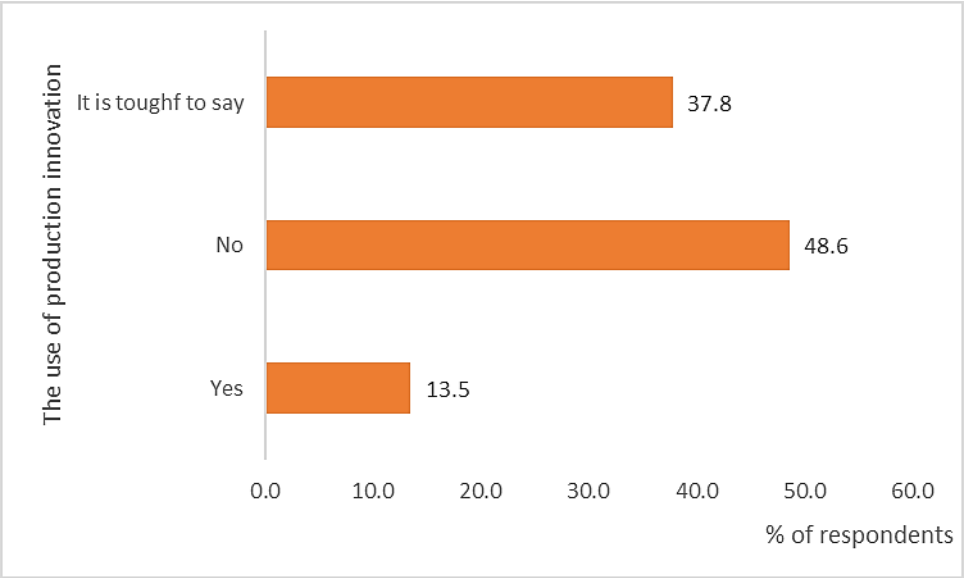


Figure 3. Structure of the answers to the question: Does your farm use production, technological, and management innovations? (%)

Source: own study, N = 37.

Six out of ten surveyed farmers use a computer to support farm management (59.5% of responses—Figure 4). This level of adoption is assessed as satisfactory, although an Excel spreadsheet alone offers significant capabilities for data analysis and decision-making, and the non-use of computers for cost or income recording is noted as anachronistic in the current technological context.

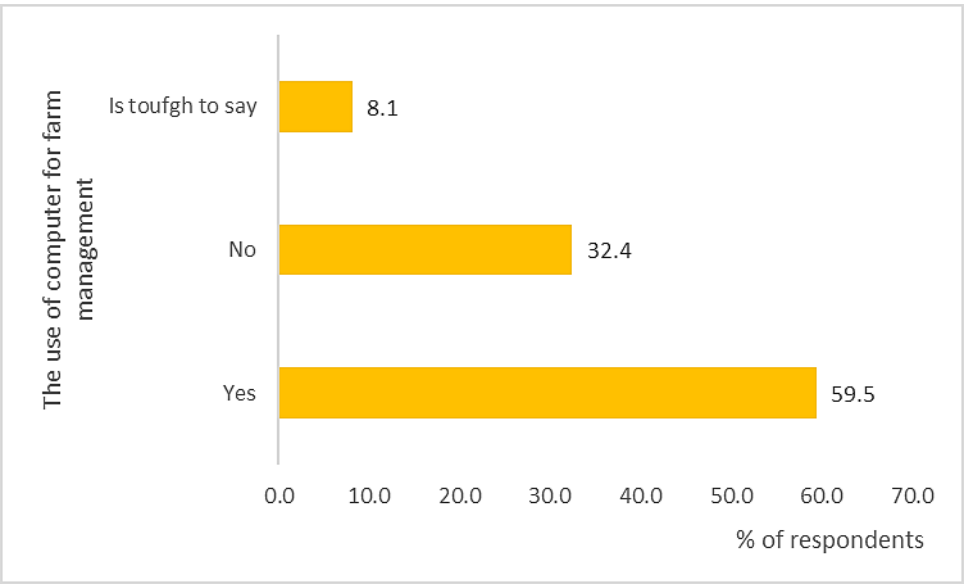


Figure 4. How many of respondents use a computer to support farm management? (%)

Source: own study, N = 37.

Younger producers, operating under intensified data-management pressures, cited specific examples of information-management support: record-keeping of farm income and expenses, animal registration and deregistration, invoice issuance, and e-commerce listing on OLX or Allegro. The machine is further leveraged for the submission of applications to the ARiMR (Agency for Restructuring and Modernization of Agriculture) for direct payments, for the management of official matters, and, in a minority of cases, for the maintenance of agrotechnical treatment records – including the application of plant protection products – within the Excel environment. In Eco-Schemes – where digital recordkeeping is a compliance prerequisite – all treatments are required to be documented, and data are most often entered manually, subsequent to field or barn operations, with only one surveyed young farmer having herd-management software installed.

Most farmers manually input data into their computers, often doing so at home after a day's work in the field or barn. Only one of the surveyed young farmers had herd management software installed on their computer.

Only a few farmers had farm-management software compatible with the GPS navigation system in their tractors, demonstrating that seamless data exchange between in-cab displays and back-office platforms remains limited. The software passively records the application rates of specific plant protection products used on a given plot of land, or the fertilizer application rates used on a given field, thereby enabling retroactive dose verification and regulatory compliance. The date of application is also recorded, and the software – interoperable with the navigation system – permits remote visualization of the entire dataset on a desktop computer.

An Excel add-in (developed by Bogusław Kiedrowski) is employed by some operators to generate a fertilization plan – computational routines calculate the required rates of nitrogen, phosphorus, potassium, and magnesium, and they indicate the need for liming.

Farmers also search for information regarding available plant protection products or new plant varieties, often using a geoportal to find geospatial information and identify agricultural plots. Additionally, farmers communicate through computers, and buyers of agricultural products often look for sales markets online. For a few of the surveyed farmers, electronic mail (email) contact with an advisor or accountant is also considered essential. Online training participation was reported by a minority of respondents.

The most frequently adopted management-support tool was identified as the Excel spreadsheet (51.4% of responses; Figure 5), which was cited as a familiar platform for record-keeping and budget-projection activities.

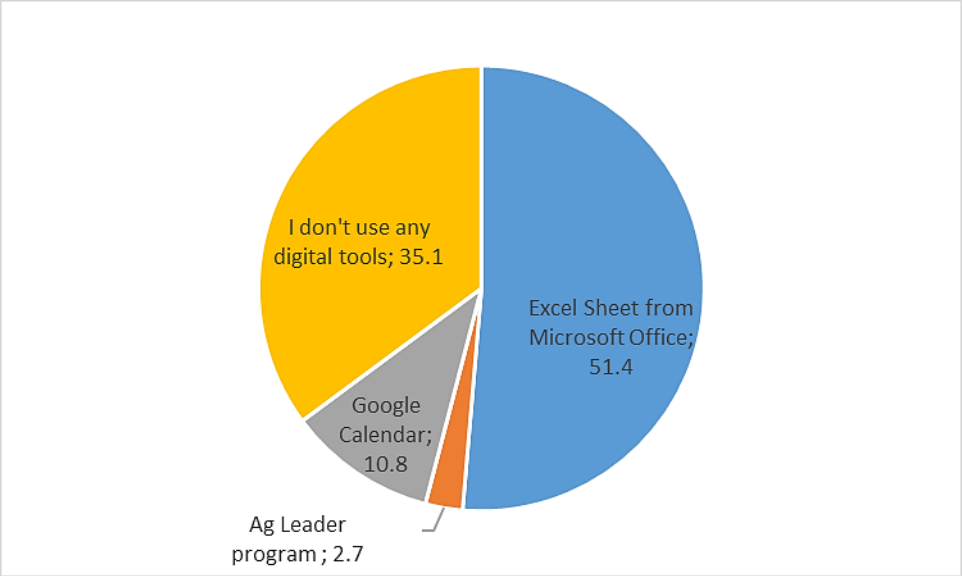


Figure 5. Structure of responses to the question "What tools do you use to support farm management?" (%)

Source: own study, N = 37.

Additional tools cited included Google Calendar for activity planning, and, in a single instance involving a young farmer, a professional farm-management software package from AG Leader – a U.S. firm specializing in precision agriculture solutions.

10. Results – Expectations of young farmers towards an IT program supporting farm management

Farmers were asked to identify management problems that could be addressed by a computer program supporting farm management. In their responses, farmers pointed to "faster implementation of agrotechnical measures and accurate cost and profit accounting". For some, it is important for the software to solve the problem of "recording the plant protection products used on a given field". Keeping records of plant protection products is important because the surveyed farmers maintain these records in paper form, which is time-consuming.

For livestock farmers, it would be important for the software to allow, for example, "calving planning" and a "dry-off schedule". Crop-production specialists, in turn, highlighted the need for modules that would automate fieldwork logging, calculate fertilizer application rates for a given field, determine spraying dates, and enable "analysis of crop-production data". Additional stakeholders emphasized decision-support capabilities – formulated as response-condition pairs (e.g., "At a given temperature, can a plant protection product be applied?" or "Can this product be mixed with another product?") – that are intended to reduce application errors and associated environmental risks.

One farmer, using Ag Leader's software on a daily basis, highlighted its advantages: "The problem is that you don't remember which variety was sown, or how and what you applied. We have everything recorded. We open the field map and everything is recorded there".

Most farmers (62.2% of responses – Figure 6) indicated a preference for a desktop version, although a browser-based solution – accessible on mobile phones, desktop computers, or laptops – was identified as potentially more resilient in field conditions.

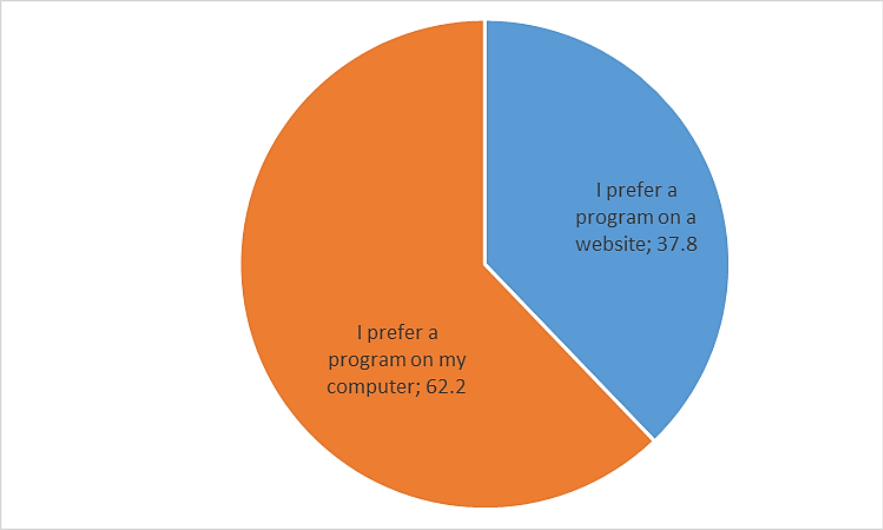


Figure 6. Structure of the answer to the question "Should the farm management support program be in the browser or locally on your computer?" (%)

Source: own study, N = 37.

According to the vast majority of farmers, a program designed to support farm management should include a map on which agricultural plots can be marked (Figure 7).

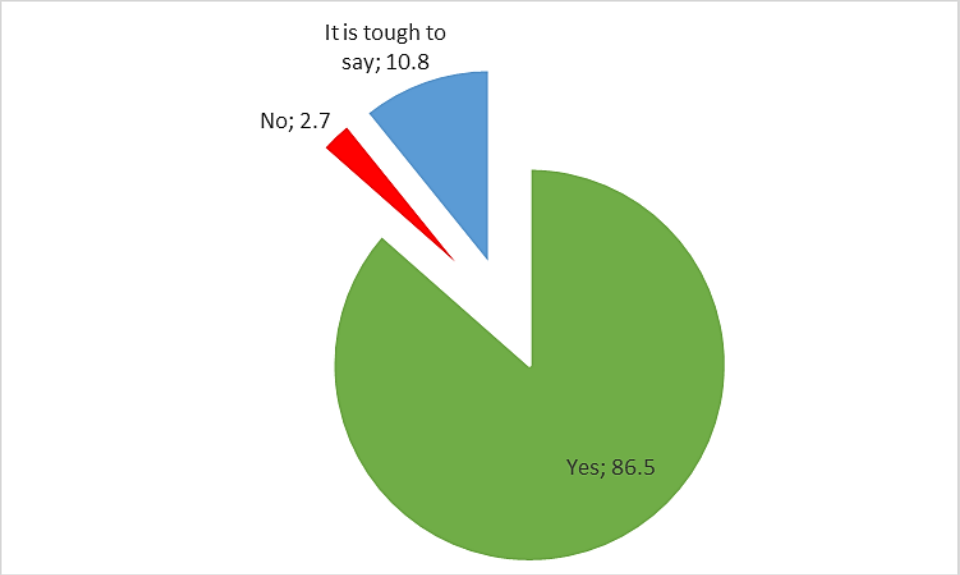
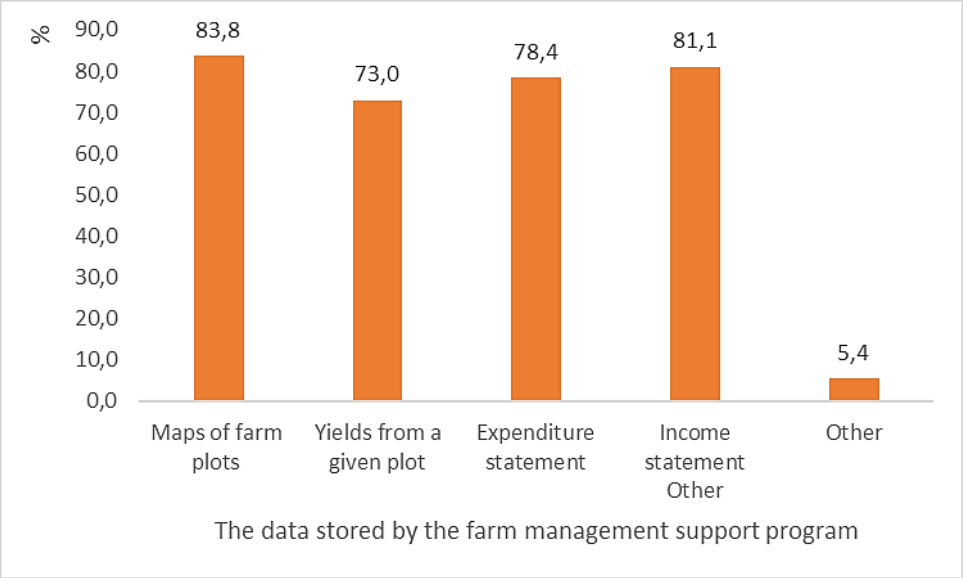


Figure 7. Structure of farmers' responses to the question: "Should the farm management support program include a map to mark your agricultural plots?" (%)

Source: own study, N = 37.

The young farmers surveyed were asked: “What farm data should a program designed to support farm management store?” The highest response frequency was recorded for the storage of farm-plot maps (83.8%); the next most frequently cited item was a revenue summary (81.15%); and the lowest frequency pertained to the storage of plot-level yield data (73%).

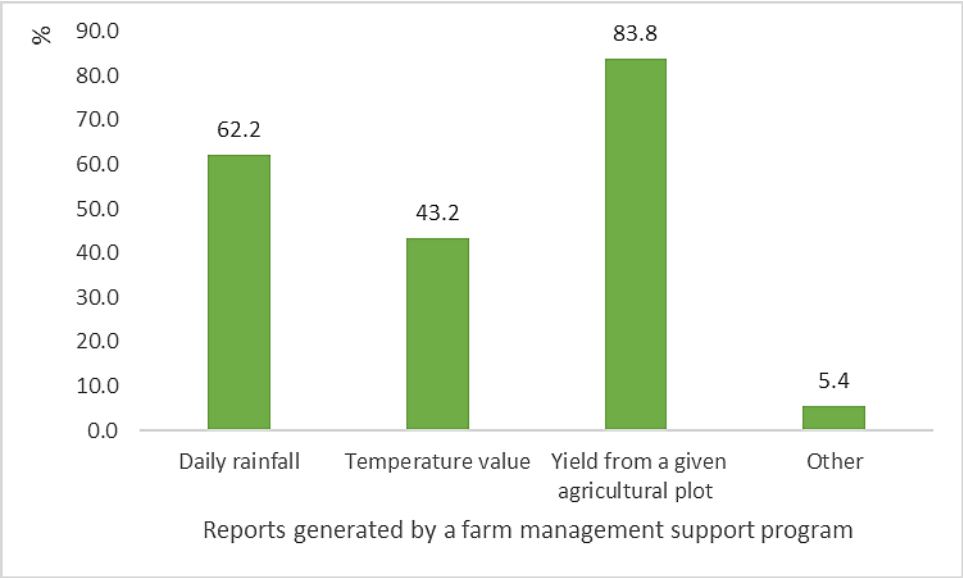


Other answers no mentioned in the figure 8: income statement, treatment dates, plant protection products used, most necessary items for everyone.

Figure 8. Structure of the answer to the question: "What farm data should the farm management support program store?" (multiple answers could be selected; %).

Source: own study, N = 37.

In response to the question “What reports should a farm-management support program generate?” (Figure 9), yield reports for individual farm plots were cited most frequently (83.8% of responses), precipitation summaries were mentioned less often (62.2%), and temperature records were cited least frequently (43.2%); additional requests included a financial report and a precipitation–yield correlation analysis. Daily precipitation was mentioned less frequently (62.2% of responses), and temperature was mentioned least frequently (43.2% of responses); a small proportion of respondents cited additional desired reports, such as a financial report or a report correlating precipitation with crop yields.

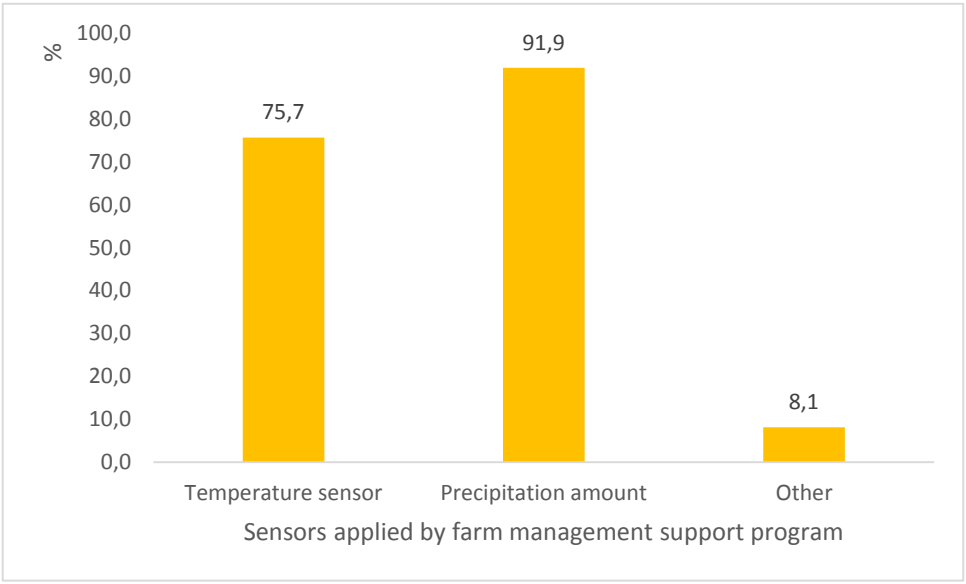


Other responses included: financial report, report on the correlation between rainfall and crop yield.

Figure 9. Structure of the answers to the question: "What reports should a farm management support program generate?" (multiple answers were possible, %).

Source: own study, N = 37.

In addition, the need for direct integration with environmental sensors was emphasized, with data collection from a rainfall sensor (91.9% of responses—Figure 10) and a temperature sensor (75.7% of responses) identified as essential components of the decision-support architecture. Additional requirements, cited by a smaller subset of respondents, included direct integration with the nearest weather station, wind-speed measurement, and Global Positioning System (GPS) navigation interfaces for agricultural machinery.



Other: operate the nearest weather station nearby, measure wind speed, and connect to GPS.

Figure 10. Share of responses to the question: "Should the program support any sensors, e.g., temperature, rainfall?" (%)

Source: own study, N = 37.

Based on the collected responses, it can be concluded that farmers expect a farm-management software program to primarily offer analytical and computational functionalities that will enable more effective planning and assessment of the profitability of agricultural production. The respondents' comments can be grouped into several main themes (Table 2).

Table 2.
Synthesis of farmers' needs and proposed software functionalities for small farms

Category	Farmers' expectations	Functional specification
Maps	Spatial visualization of the farm and marking agricultural plots.	Mapping and Geolocation Module: Interactive maps allowing for defining plot boundaries, storing, and displaying spatial farm data.
Revenue summaries	Accurate cost and profit accounting, and assessing the profitability of various crops.	Financial and Analytical Module: Automated record-keeping of income and expenses, calculation of profit per hectare or crop, break-even point determination, and financial report generation.
Yield data	Storing plot-level yield data for efficiency analysis.	Yield Recording and Reporting Module: Recording harvest quantities assigned to specific plots and automatically generating yield reports for individual farm plots.
Plant protection records	Faster implementation of agrotechnical measures, replacing time-consuming paper records, and avoiding application errors (e.g., due to temperature or improper mixing).	Decision Support and Digital Field Diary: Automated recording of applied products, conditional alerts based on response-condition pairs (e.g., temperature warnings or substance mixing prohibitions), and monitoring maximum permissible rates.
Fertilizer rates	Calculating optimal fertilizer application rates based on crop type, expected yield, and soil test results.	Fertilization Calculator: Nutrient-balance calculation, automatic adjustment to crop requirements, and automatic conversion of fertilizer quantities to the specific field area.
Animal-production deadlines	Scheduling and tracking key events in the livestock life cycle.	Herd Scheduling Module: Calendar and notification system enabling calving planning and setting dry-off schedules.
Weather data	Understanding the impact of weather conditions on crop yield and planning field operations based on weather data.	Environmental Integration Module: Direct integration with environmental sensors (temperature, rainfall) or nearby weather stations, suggesting spraying dates based on weather, and analyzing the correlation between precipitation and crop yields.

Source: own elaboration based on empirical research.

The most frequently mentioned expectations include: the capacity to calculate profit per hectare or per crop; the analysis of production costs (inputs, fuel, labor, etc.); the balancing of income and expenses; the determination of the break-even point and the profitability of various crops; and the automated record-keeping of income and expenses. A substantial proportion of respondents indicated that these calculations are currently executed in spreadsheet applications (e.g., Excel), thereby signifying the need for a simplified, intuitive software module that integrates the aforementioned functions.

The second key area involves functions supporting decisions regarding fertilization and plant protection, including calculating optimal fertilizer rates based on crop type, soil test results, and expected yield. For young farmers, monitoring maximum permissible rates of fertilizers and plant protection products is also important. The software is expected to suggest spraying dates, taking weather conditions (temperature, precipitation, risk of fungal diseases) into account. Nutrient-balance calculation and their automatic adjustment to crop requirements

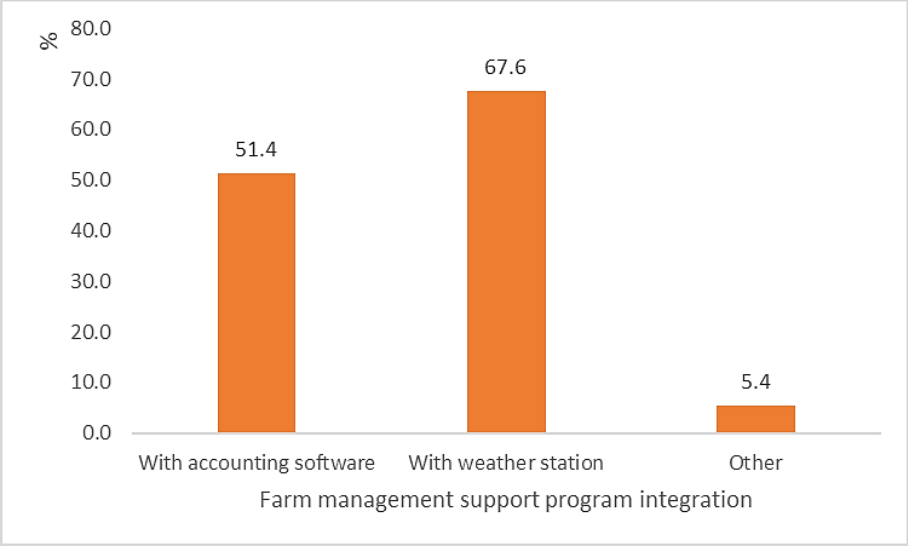
were also cited as essential modules. Automatic conversion of fertilizer or plant-protection-product quantities to field area, thereby eliminating manual calculation, was identified as a critical back-end function.

The integration of environmental data – including average daily temperature and average seasonal precipitation – was identified as essential, because it enables the quantification of feedback loops among fertilization, weather conditions, and crop yield, thereby supporting retrospective efficiency analysis across successive growing seasons.

The need to expand the program's functionality to include the following components is highlighted: inventory management (e.g., grain quantities in silos, breakdown by type), land and crop records, and production planning capabilities (e.g., crop rotation, eligibility for payments under eco-schemes such as "Carbon Farming").

Several respondents indicated that the platform should be comprehensive and integrated—so that it provides everything a farmer might require – and that it should operate intuitively and automatically once foundational data are submitted, thereby supporting widespread adoption.

Young farmers were asked: "Should a program designed to support farm management integrate with anything?" The most frequently cited integration points were weather-station data (67.6% of responses; Figure 11) and accounting-software interfaces (51.4% of responses); additional mentions included SatAgro maps and Global Positioning System (GPS) navigation tools.



Other: with SatAgro maps, with GPS navigation.

Figure 11. Share of responses to the question: "Should the farm management support program be integrated with anything?"; (%)

Source: own study, N = 37.

Nearly half of farmers would be willing to pay no more than 200 PLN per year for a farm-management support program (45.9% of responses—Figure 12), indicating that this group of farmers likely does not fully realize the benefits of this solution and therefore values it so lowly. Between 200 and 400 PLN per year was indicated by 16.2% of respondents, whereas the 400-600 PLN bracket was cited by 8.1% of respondents.

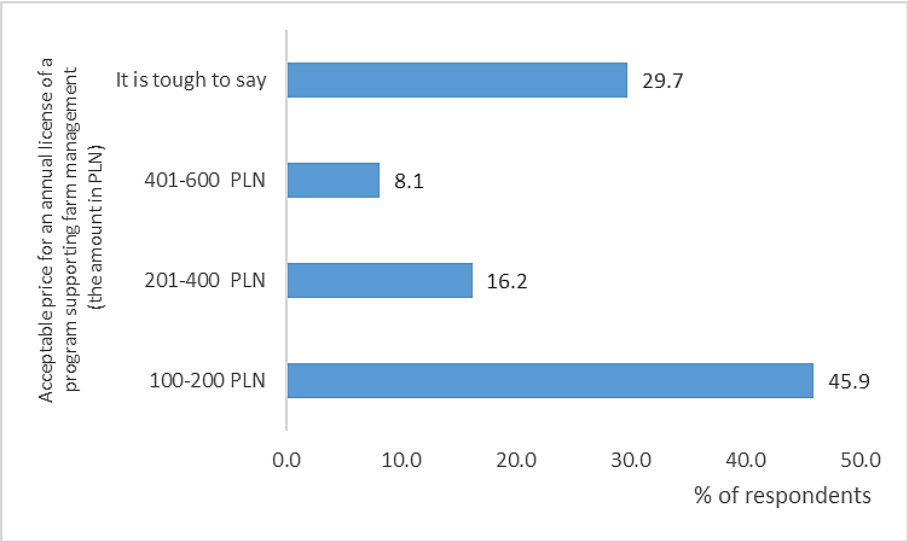


Figure 12. Structure of answers to the question: "What is the acceptable price for an annual license of a program supporting farm management?" (%)

Source: own study, N = 37.

Only 29.7% of young farmers indicated a need for additional farm-management training (Figure 13), underscoring the urgency of targeted extension interventions. One in five young farmers (21.6%) explicitly indicated no such need, whereas nearly half (48.6%) remained undecided, underscoring the ongoing uncertainty regarding the urgency of management training (Figure 13).

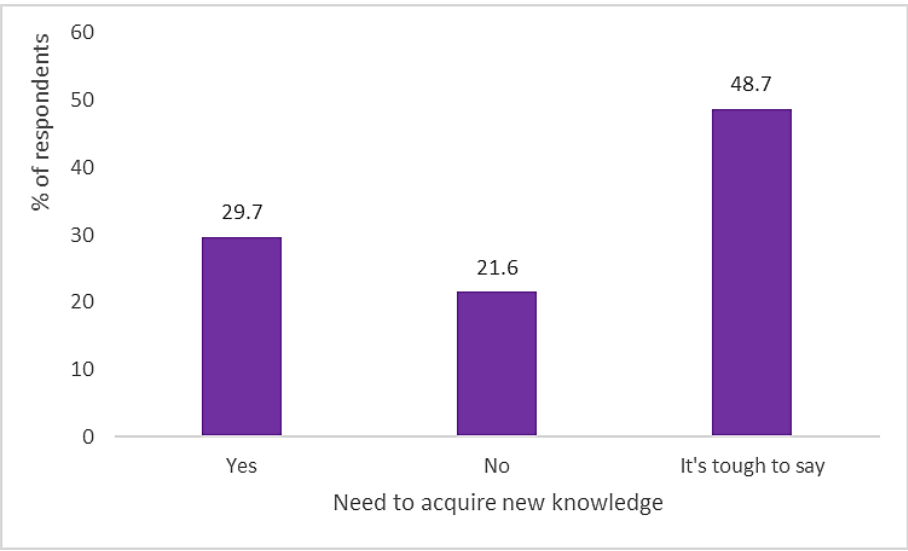


Figure 13. Structure of responses to the question: "Do you feel you need to expand your knowledge of farm management?" (%)

Source: own study, N = 37.

Young farmers were asked to what extent they would like to expand their knowledge. In their responses, they indicated a desire to expand their knowledge regarding crop production, and less frequently regarding livestock production. With regard to crop production, young farmers expect training in the following areas:

- new plant protection products (active ingredients),
- organic plant protection,
- the use of cover crops (instead of fertilizers),
- no-till farming,
- new fertilizers,
- new cereal varietiesEcological plant protection.

In the area of animal production, a need to deepen knowledge of modern veterinary medicines and other issues related to animal husbandry has been highlighted by farmers operating under varying climatic and regulatory pressures. In addition, farmers reported a need to acquire knowledge in the areas of production management and marketing management. They see the main challenges in expanding their knowledge of sales and agricultural economics. In this context, they expressed interest in participating in training under a program supporting farm management.

The "Young Farmer" program – of which the respondents were beneficiaries – requires farmers to participate in training, and under current requirements, a young farmer must have an advisor; farmers stated that they learn primarily from the Internet and most often receive advice from those selling plant protection products.

11. Discussion and conclusions

In crop production, 27.5% of all innovations were related to the modernization of agricultural machinery (Olszańska, Szymańska, 2014). In 95% of the surveyed young farmers' farms, many capital expenditures were financed from European Union (EU) aid funds (Olszańska, Szymańska, 2014). The situation is similar among the farmers surveyed in the present study, who are beneficiaries of the "Young Farmer" program; thus, each of them received investment funds from EU sources. Unfortunately, the acquisition of a tractor or other agricultural machinery does not automatically entail a transition to digital agriculture, including in management; small farms, while incurring the expense of purchasing better agricultural equipment, do not expand their equipment options to include digital solutions enabling automated operation using GPS or the collection of digital data while the machine is in operation.

Survey research conducted in 2024 on a sample of 106 farms shows that the larger the farm, the more frequently it uses management software (Dmowski et al., 2024). The results obtained in this study confirmed this trend and indicate that small farms are foregoing IT solutions because their cost would exceed the benefits they could bring (Da et al., 2025; Dmowski et al., 2024). However, it was not mentioned that there exist information-technology (IT) tools that carry no direct licensing costs beyond the investment required for farmer training. Therefore,

digital education – delivered through regional Agricultural Advisory Centers (AACs) – should be identified as a strategic priority, particularly for small-scale farmers.

Although digital farm-management support technologies are becoming increasingly widespread in agriculture, young farmers' advisory needs regarding FMS, FMIS, and DSS remain unmet. There is a significant gap in research aimed at understanding these needs, which may hinder the adoption of digital management support in agricultural practices. Young farmers require enhanced educational pathways and streamlined information access regarding these systems so that they can fully realize the potential of modern **agriculture**. Results reported indicate that, in a 2021 Swiss survey (Ammann et al., 2022), 43.0% of 109 agricultural students had received no instruction on digital technologies – either during basic training or in farm-management courses – a proportion that, when extrapolated to Polish classrooms, is anticipated to remain comparable or slightly lower. Regarding FMIS, 51% of students indicated that they had never heard of FMIS during their agricultural training (Ammann et al., 2022). It appears that these percentages would be the same among Polish students or – more likely – even slightly lower.

The implementation and use of Farm Management Software (FMS) are, unfortunately, not significant factors in the optimization of agricultural practices among the young farmers surveyed. Although studies indicate that younger users are more inclined to use digital tools and technologies in agricultural activities than their older counterparts (Chuang et al., 2020; Citra Irawan et al., 2023; Figurek et al., 2023; Nurlaela et al., 2022; Rooij, 2006), this pattern holds for owners of large farms; however, the ICT proficiency of young farmers from small farms is reported to be limited, a factor that discourages their engagement in more advanced farming methods. Meanwhile, the integration of interactive technology and data-analysis workflows into cropping systems is projected to raise precision, yield, and profitability for smallholders, to facilitate climate-change preparedness, and to limit adverse environmental externalities (Trendov et al., 2019).

An analysis of survey results from young farmers who utilized EU funds supporting the launch of agricultural operations indicates that, despite owning a computer, four out of ten farmers do not use it in connection with running their farm. In the study region (Małopolskie Province, Poland), where farm sizes are small, this barrier to innovation adoption is particularly pronounced. An analysis of the global literature on information technology (IT) systems for farm management support indicates dynamic growth in their number and quality, and the emergence of nonproprietary decision-support tools that could be localized for smallholders (Trendov et al., 2019). However, during the literature review, non-commercial software programs supporting economic decision-making were identified, and it is recommended that these tools be translated into Polish and promoted among small farm owners. Expanding the knowledge of young farmers is crucial for encouraging even small farms to begin using IT systems for farm management.

Based on the empirical findings, the development of Farm Management Information Systems (FMIS) targeted at small-scale and young farmers must prioritize a streamlined, low-cost approach rather than overly complex Agriculture 4.0 suites. To ensure adoption, IT developers should focus on the following concrete design specifications:

- The system must be highly affordable, as nearly half of the surveyed farmers (45.9%) expect the annual license fee to not exceed 200 PLN. The architecture should be a hybrid model that primarily functions locally but has basic cloud synchronization, avoiding complex IoT dependencies unless requested.
- While mobile browser-based solutions are seen as potentially resilient in field conditions, the clear preference among respondents (62.2%) is for a desktop-based application. Because most farmers manually input data on their computers at home after completing a day's work in the field or barn, robust offline desktop functionality is a mandatory requirement rather than an optional feature.
- A minimum viable product must include the following core modules: mapping (spatial visualization tools, as 83.8% of farmers cited farm-plot maps as the most crucial data to store), financial & yield analytics (modules capable of balancing income and expenses, calculating profit per hectare, and determining break-even points, which are currently the most heavily requested analytical features), environmental integration (direct integration with basic environmental sensors or nearby weather stations to inform agrotechnical decisions).
- Since 51.4% of farmers currently rely on Microsoft Excel for farm management, any new software must mimic its intuitive nature while eliminating the need for manual calculations. The system must operate intuitively and automatically once foundational baseline data (such as plot sizes and crop types) are submitted, significantly reducing the time currently spent on paper-based record-keeping.
- A critical value-add for developers is integrating compliance reporting. Farmers heavily rely on computers to submit applications to the Agency for Restructuring and Modernization of Agriculture (ARiMR) for direct payments. Software must automatically generate treatment records and compliance reports required for EU subsidies and "Eco-Schemes" (e.g., Carbon Farming), which currently force farmers into tedious manual data entry.

Developers must recognize that providing software is insufficient without onboarding. Insufficient skills remain a major barrier to FMIS adoption. While only 29.7% of young farmers explicitly stated a need for training, 48.6% remained undecided, indicating a hidden need for digital education. IT developers should partner with agricultural advisory services to build integrated training modules or accessible tutorials directly into the FMS ecosystem.

12.Limitations and future research

The study, which included only 37 participants, serves as an initial step for more extensive research. Therefore, the results should not be applied to the entire population of young farmers. It would be advisable to conduct similar studies involving a larger group of young farmers. To address the limitations of this research, it would be beneficial for the author to enhance their understanding of the GDPR (General Data Protection Regulation) or consult a lawyer specializing in this area. A well-structured cover letter could effectively address the concerns of the Agency for Restructuring and Modernization of Agriculture regarding the sharing of young farmers' personal data for research purposes.

Currently, there is a research gap concerning the extent to which Polish educational and advisory institutions provide students, including farmers, with updated information about digital technologies that support farm management.

Acknowledgements

The project “Greater Potential of Management and Quality Sciences through Better Utilization of the Capital of the Polish Countryside” (acronym: URK Management), co-financed from the state budget under the Minister of Science’s program titled “Regional Initiative of Excellence”, grant amount: PLN 6,187,000.00; total project value: PLN 6,187,000.00; agreement no.: RID/SP/0039/2024/01. “Funded by a subsidy from the Ministry of Science and Higher Education for the Hugo Kołłątaj University of Agriculture in Krakow for the year 2026”.

References

1. Abbasi, R., Martinez, P., Ahmad, R. (2022). The digitization of agricultural industry – a systematic literature review on agriculture 4.0. *Smart Agricultural Technology, 2*, 100042. https://doi.org/10.1016/j.atech.2022.100042
2. *AEF Online—About the AEF*. Retrieved from: https://www.aef-online.org/about-us/about-the-aef.html#/About, 28.12.2025.
3. Aiello, G., Giovino, I., Vallone, M., Catania, P., Argento, A. (2018). A decision support system based on multisensor data fusion for sustainable greenhouse management. *Journal of Cleaner Production, 172*, 4057-4065. https://doi.org/10.1016/j.jclepro.2017.02.197

4. Ammann, J., Walter, A., El Benni, N. (2022). Adoption and perception of farm management information systems by future Swiss farm managers -An online study. *Journal of Rural Studies, 89*. https://doi.org/10.1016/j.jrurstud.2021.12.008
5. Apostolakis, N. (2024). *Nickapos/myCrop [Java]*. https://github.com/nickapos/myCrop (Original work published 2013).
6. Baseca, C.C., Sendra, S., Lloret, J., Tomas, J., Baseca, C.C., Sendra, S., Lloret, J., Tomas, J. (2019). A Smart Decision System for Digital Farming. *Agronomy, 9(5).* https://doi.org/10.3390/agronomy9050216
7. Cañadas, J., Sánchez-Molina, J.A., Rodríguez, F., del Águila, I.M. (2017). Improving automatic climate control with decision support techniques to minimize disease effects in greenhouse tomatoes. *Information Processing in Agriculture, 4(1),* 50-63. https://doi.org/10.1016/j.inpa.2016.12.002
8. Carrer, M.J., Filho, H., Batalha, M. (2017). Factors influencing the adoption of Farm Management Information Systems (FMIS) by Brazilian citrus farmers. *Comput. Electron. Agric., 138,* 11-19. https://doi.org/10.1016/j.compag.2017.04.004
9. Chuang, J.-H., Wang, J.-H., Liang, C. (2020). Implementation of Internet of Things depends on intention: Young farmers' willingness to accept innovative technology. *International Food and Agribusiness Management Review, 23(2),* 253-266. https://doi.org/10.22434/IFAMR2019.0121
10. Citra Irawan, N., Irham, I., Mulyo, J.H., Suryantini, A. (2023). Unleashing the Power of Digital Farming: Local Young Farmers' Perspectives on Sustainable Value Creation. *AGRARIS: Journal of Agribusiness and Rural Development Research, 9(2),* 316-333. https://doi.org/10.18196/agraris.v9i2.239
11. Da, A., Eo, A., Es, F., Eu, H., & So, H. (2025). A Systematic Review of Management Science Integration in Farm Decision Tools: Advancing Theory for Agricultural Problem-Solving. International Journal of Multidisciplinary Research and Growth Evaluation. https://doi.org/10.54660/.ijmrge.2025.6.4.656-664
12. De Souza Filho, H.M., De Mello Brandão Vinholis, M., Carrer, M.J., Mozambani, C.I. (2023). Adoption of farm management information systems (FMIS): The case of Brazilian sugarcane farmers. *Information Development, 41,* 1131-1145. https://doi.org/10.1177/02666669231177864
13. *Digital Farming: what does it really mean?* Retrieved from: https://www.cema-agri.org/images/publications/position-papers/CEMA_Digital_Farming_-_Agriculture_4.0__13_02_2017_0.pdf, 28.12.2025.
14. Dmowski, K., Bartyna, W., Stępniak, M. (2024). Analysis of Information Technology Adoption in Polish Agriculture. *Studia Informatica. System and Information Technology, 31(2),* 103-115. https://doi.org/10.34739/si.2024.31.08

15. Figurek, A., Morphi, K., Thrassou, A., Figurek, A., Morphi, K., Thrassou, A. (2023). A Sustainable Risk Management Model and Instruments for Young Farmers in EU Agriculture. *Sustainability, 16(1).* https://doi.org/10.3390/su16010283
16. Fountas, S., Carli, G., Sørensen, C.G., Tsiropoulos, Z., Cavalaris, C., Vatsanidou, A., Liakos, B., Canavari, M., Wiebensohn, J., Tisserye, B. (2015). Farm management information systems: Current situation and future perspectives. *Computers and Electronics in Agriculture, 115*, 40-50. https://doi.org/10.1016/j.compag.2015.05.011
17. Gacek, A., Misiąg, J., Misiąg, W., Palimąka, K., Pomianek, T., Rodzinka, J. (2025). *Program przebudowy wsi i rolnictwa w kierunku zmian strukturalnych i zasad zrównoważonego rozwoju*. Wyższa Szkoła Informatyki i Zarządzania z siedzibą w Rzeszowie. https://ksiegarnia.wsiz.pl/strona-glowna/137-program-przebudowy-wsi-i-rolnictwa-w-kierunku-zmian-strukturalnych-i-zasad-zrownowazonego-rozwoju.html
18. *Geofolia – Program de management agricol—ISAGRI*. Retrieved from: https://www.isagri.ro/software/geofolia-program-de-management-agricol-isagri, 28.12.2025.
19. Giusti, E., Marsili-Libelli, S. (2015). A Fuzzy Decision Support System for irrigation and water conservation in agriculture. *Environmental Modelling & Software, 63*, 73-86. https://doi.org/10.1016/j.envsoft.2014.09.020
20. Hayman, P.T., Easdown, W.J. (2002). An ecology of a DSS: Reflections on managing wheat crops in the northeastern Australian grains region with WHEATMAN. *Agricultural Systems, 74(1),* 57-77. https://doi.org/10.1016/S0308-521X(02)00018-5
21. *Ile kosztuje wdrożenie rolnictwa precyzyjnego w gospodarstwie?* Retrieved from: https://e-ursus.pl/ile-kosztuje-wdrozenie-rolnictwa-precyzyjnego-w-gospodarstwie.htm, 21.03.2025.
22. Karydas, C., Chatziantoniou, M., Tremma, O., Milios, A., Stamkopoulos, K., Vassiliadis, V., Mourelatos, S., Karydas, C., Chatziantoniou, M., Tremma, O., Milios, A., Stamkopoulos, K., Vassiliadis, V., Mourelatos, S. (2023). Profitability Assessment of Precision Agriculture Applications—A Step Forward in Farm Management. *Applied Sciences, 13(17).* https://doi.org/10.3390/app13179640
23. Kielbasa, B., Puchala, J. (2015). Innowacyjność młodych rolników i ich postawy wobec zmian na przykładzie gospodarstw rolnych położonych w regionie rozdrobnionego rolnictwa. *Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu, 17(1).* https://bibliotekanauki.pl/articles/863726
24. Lewis, T. (1998). Evolution of farm management information systems. *Computers and Electronics in Agriculture, 19(3),* 233-248. https://doi.org/10.1016/S0168-1699(97)00040-9
25. Licciardo, F., Henke, R., Piras, F., Zanetti, B. (2024). The Setting-Up Measure to Support Generational Renewal in Agriculture: The Italian Experience. *World (2673-4060), 5(4),* 1130-1147 (181946719). https://doi.org/10.3390/world5040057

26. Markovits, P.S. (2023). Digitally Enabled Decission Making in Big Crop Farms: Inspiration for a Balanced Decision Making Metaphorical Model. *Proceedings of the International Conference on Business Excellence, 17(1),* 1240-1250. https://doi.org/10.2478/picbe-2023-0111
27. Munthali, E., Munthali, K., Mikeka, C., Kunyenje, G. (2022). Effectiveness of Using Digital Technologies and Digital Labour in Farm Management towards Shaping Precision Farming to Achieve Food Security: A Malawian Perspective. *Mediterranean Journal of Basic and Applied Sciences, 6(2),* 28-35. https://doi.org/10.46382/MJBAS.2022.6204
28. Munz, J., Gindele, N., Doluschitz, R. (2020). Exploring the characteristics and utilisation of Farm Management Information Systems (FMIS) in Germany. *Comput. Electron. Agric., 170*, 105246. https://doi.org/10.1016/j.compag.2020.105246
29. *Naukowcy z SGH opracowali Indeks Cyfryzacji Przedsiębiorstw (ICP).* Retrieved from: https://naukawpolsce.pl/aktualnosci/news%2C102722%2Cnaukowcy-z-sgh-opracowali-indeks-cyfryzacji-przedsiebiorstw-icp.html, 12.12.2025.
30. Navarro-Hellín, H., Martínez-del-Rincon, J., Domingo-Miguel, R., Soto-Valles, F., Torres-Sánchez, R. (2016). A decision support system for managing irrigation in agriculture. *Computers and Electronics in Agriculture, 124*, 121-131. https://doi.org/10.1016/j.compag.2016.04.003
31. Nestel, D., Cohen, Y., Shaked, B., Alchanatis, V., Nemny-Lavy, E., Miranda, M.A., Sciarretta, A., Papadopoulos, N.T., Nestel, D., Cohen, Y., Shaked, B., Alchanatis, V., Nemny-Lavy, E., Miranda, M.A., Sciarretta, A., Papadopoulos, N.T. (2019). An Integrated Decision Support System for Environmentally-Friendly Management of the Ethiopian Fruit Fly in Greenhouse Crops. *Agronomy, 9(8).* https://doi.org/10.3390/agronomy9080459
32. Nikkilä, R., Seilonen, I., Koskinen, K. (2010). Software architecture for farm management information systems in precision agriculture. *Computers and Electronics in Agriculture, Special issue on Information and Communication Technologies in Bio and Earth Sciences, 70(2)*, 328-336. https://doi.org/10.1016/j.compag.2009.08.013
33. Nurlaela, S., Bihrajihant Raya, A., Hariadi, S.S. (2022). Information Technology Utilization Of Young Educated Farmers In Agricultural Entrepreneurship. *Agro Ekonomi, 33(1),* 11. https://doi.org/10.22146/ae.64524
34. Olszańska, A., Szymańska, J. (eds.) (2014). *Agrobiznes 2014: Rozwój agrobiznesu w okresie 10 lat przynależności Polski do Unii Europejskiej*. Wydawnictwo Uniwersytetu Ekonomicznego.
35. *Rolnictwo precyzyjne w Polsce*. Retrieved from: https://www.pfpk.org.pl/wp-content/uploads/2023/11/Rolnictwo-Precyzyjne-w-Polsce-pl.pdf, 25.08.2021.
36. Ronzhin, A., Figurek, A., Surovtsev, V., Dibirova, K. (2025). Digital Transformation and Precision Farming as Catalysts of Rural Development. *Land, 14(7).* https://doi.org/10.3390/land14071464

37. Rooij, S.J.G. de. (2006). Young farmers in Europe: Opting for innovations. *LEISA India, 6(2)*, pp. 24-26. Retrieved from: https://edepot.wur.nl/33737, 5.12.2025.
38. Ropek, D. (2025). Ekonomiczne i społeczne uwarunkowania wdrażania Rolnictwa cyfrowego, precyzyjnego i systemów Wspomagania decyzji w gospodarstwach rolnych. In: *Ekonomia i zarządzanie – wybrane zagadnienia* (pp. 297-315). Homini.
39. Rupnik, R., Kukar, M., Vračar, P., Košir, D., Pevec, D., Bosnić, Z. (2019). AgroDSS: A decision support system for agriculture and farming. *Computers and Electronics in Agriculture, 161*, 260-271. https://doi.org/10.1016/j.compag.2018.04.001
40. Saiz-Rubio, V., Rovira-Más, F., Saiz-Rubio, V., Rovira-Más, F. (2020). From Smart Farming towards Agriculture 5.0: A Review on Crop Data Management. *Agronomy, 10(2).* https://doi.org/10.3390/agronomy10020207
41. Sampurno, R., Seminar, K., Suharnoto, Y. (2014). Weed Control Decision Support System Based on Precision Agriculture Approach. *TELKOMNIKA (Telecommunication Computing Electronics and Control), 12,* 475. https://doi.org/10.12928/TELKOMNIKA.v12i2.1982
42. Santiago, A., Roxas, F. (2015). Reviving Farming Interest in the Philippines Through Agricultural Entrepreneurship Education. *Journal of Agriculture, Food Systems, and Community Development,* 1-13. https://doi.org/10.5304/jafscd.2015.054.016
43. *Software pentru managementul fermei Archives*. Retrieved from: https://nik-ro.com/agricultura-inteligenta/software-pentru-managementul-fermei/, 28.12.20125.
44. Solange, D. (2024). *SolangeD/GENMON [PHP]*. https://github.com/SolangeD/GENMON (Original work published 2016).
45. Thompson, S.C. (1976). Canfarm—A farm management information system. *Agricultural Administration, 3(3),* 181-192. https://doi.org/10.1016/0309-586X(76)90013-3
46. Trendov, N.M., Varas, S., Zeng, M. (2019). *Digital technologies in agriculture and rural areas: Status report.* Food and Agriculture Organization of the United Nations.
47. Tummers, J., Kassahun, A., Tekinerdogan, B. (2019). Obstacles and features of Farm Management Information Systems: A systematic literature review. *Computers and Electronics in Agriculture, 157,* 189-204. https://doi.org/10.1016/j.compag.2018.12.044
48. Tur, C.J., Ciaian, P., Antonioli, F., Fellmann, T., Rocciola, F., Ierardi, I., Crimeni, R., Anastasiou, E. (2025). *The state of digitalisation in EU agriculture.* JRC Publications Repository. https://doi.org/10.2760/4688498
49. Verleye, G., De Marez, L. (2005). Diffusion of innovations: Successful adoption needs more effective soft-DSS driven targeting. *Journal of Targeting, Measurement & Analysis for Marketing, 13(2)*, 140-155. (16002840). https://doi.org/10.1057/palgrave.jt.5740139
50. W br. 5,9 proc. przedsiębiorstw deklarowało wykorzystanie technologii AI. *Nauka w Polsce.* Retrieved from: https://naukawpolsce.pl/aktualnosci/news%2C105878%2Cgus-w-br-59-proc-przedsiebiorstw-deklarowalo-wykorzystanie-technologii-ai, 12.12.2025.
51. Wenkel, K.-O., Berg, M., Mirschel, W., Wieland, R., Nendel, C., Köstner, B. (2013). LandCaRe DSS – An interactive decision support system for climate change impact

assessment and the analysis of potential agricultural land use adaptation strategies. *Journal of Environmental Management, Integrated land-use and regional resource management – A cross-disciplinary dialogue on future perspectives for a sustainable development of regional resources, 127*, S168-S183. https://doi.org/10.1016/j.jenvman.2013.02.051

52. Wrzecińska, M., Czerniawska-Piątkowska, E., Kowalewska, I., Kowalczyk, A., Mylostyvyi, R., Stefaniak, W. (2023). Agriculture in the face of new digitization technologies. *Ukrainian Black Sea Region Agrarian Science, 3(27), Artykuł 27(3).* https://doi.org/10.56407/bs.agrarian/3.2023.09
53. *Zaawansowane Rozwiązania Zarządzania Stadem*. Retrieved from: https://www.afimilk.com/pl/, 23.12.2025.
54. Zhang, F., Zhang, W., Luo, X., Zhang, Z., Lu, Y., Wang, B., Zhang, F., Zhang, W., Luo, X., Zhang, Z., Lu, Y., Wang, B. (2022). Developing an IoT-Enabled Cloud Management Platform for Agricultural Machinery Equipped with Automatic Navigation Systems. *Agriculture, 12(2)*. https://doi.org/10.3390/agriculture12020310