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In search of digitalisation in the wine industry in Bulgaria through the lens of precision agriculture Case study

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Abstract

This article is dedicated to implementing precision agriculture in the viticulture and wine sector. It is widely accepted that, at the EU level, agriculture is viewed as a way of life that has multiple socio-economic and environmental functions requiring sustainable management. In this context, for countries like Bulgaria, precision agriculture is regarded as a generally applicable management tool, regardless of the specialization and location of wine-growing enterprises. The introduction of technologies and systems for sustainable agriculture is a complex and dynamic process for wine producers that must be managed, raising significant legal and socio-ethical issues. These issues particularly relate to the conditions for protecting sustainable agricultural food production, the terms under which data regarding owners are collected and processed, and the role of individual farmers within this system. The main objective is to assess the degree of digitization of the wine sector in Bulgaria and the possibilities for applying precision agriculture in the industry. The specific characteristics of the wine sector have been identified, along with relevant analyses, conclusions, assessments, and recommendations for its digitization and precision farming. The authors use statistical methods (regression and correlation analysis) and a sociological survey. The authors prove the relationship between digitalization and competitiveness of the wine companies in Bulgaria.

Keywords: Bulgaria, Competitiveness, Digitalization, Precision agriculture, Wine enterprises management, Wine industry.

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1. Introduction

In the new conditions for agricultural development, especially its modernization, issues related to digitization and process precision in the agricultural sector remain on the agenda. Countries such as Bulgaria, Romania, Slovakia, Poland, and others that are members of the European Union have the opportunity to develop the digitization process through European Union programs and instruments. In practice, this is because within the European Union, programs related to agriculture have made significant progress, and the framework for their development is encouraging. This gives us reason to believe, based on our experience, that EU countries with developed agriculture can work to increase their precision and digitization. Within the European Union (EU), precision agriculture and digitization are seen as a new fundamental step towards achieving new development and effective management. It is accepted that digitization can cope with the growing pressure on ecosystems caused by agriculture. The gradual implementation of precision agriculture should not replace the need to continue designing and implementing measures to protect and promote biodiversity. From an environmental point of view, it is clear that precision farming can indirectly influence the shaping of land parcels and landscapes. The design and implementation of measures to protect and promote biodiversity, particularly through the integration of agroecological principles into different farming systems, will need to be continued or even improved due to the side effects of precision agriculture. It should be noted that, in addition to the benefits of applying artificial intelligence, several obstacles hinder its application in the wine sector. Working with databases and artificial intelligence requires specific knowledge and skills on the part of owners. This necessitates training to acquire this knowledge. Digital technologies also require specialized equipment to be installed on the farm. This equipment is expensive and requires large initial investments that owners must make to implement the digital management approach in their businesses. Another significant barrier is that access to certain databases is paid, which increases the fixed costs of managing a vineyard. Precision farming requires extensive knowledge and adds complexity to farmers' decision-making processes due to the large amount of information that needs to be processed. Data quickly accumulates into overly large and complex sets that cannot be analyzed without software and do not create value on their own. The large amount of information available to owners, collected through various precision farming techniques, may require additional advice and guidance on how this information is incorporated into actual management plans. The data must still be standardized to generate useful information for farm decisions. Within the rural development pillar of the Common Agricultural Policy (CAP), a measure for advisory services is already in place for possible uptake by Member States. During the introduction of cross-compliance (2005-2007), support for advice in the sector helped wine producers understand the requirements to comply with the new EU rules. Provided that it is programmed within the rural development programming of the Member States, support for advice to wine-producing enterprises is available in the Member States, and any agricultural holding may access it voluntarily.

2. Materials and Methods

The study's main objective is to assess the degree of digitization in the Bulgarian wine sector and explore the potential for applying precision agriculture within the industry. To achieve this goal, methods such as analytical, descriptive, and theoretical analysis, sociological research, statistical techniques (including correlation and regression analysis), and expert opinions were employed.

To substantiate the main objective, a specific methodological approach has been developed and adapted. Its application is based on the following steps:

- Development of a methodology for identifying the main barriers to the accelerated digitization of business processes in wine-growing and wine-producing enterprises. This process includes the use of surveys and focus groups to gather detailed information on the challenges and constraints in sectoral digitization.
- Developing a method for analyzing and assessing the demand and supply of digital technologies to increase the competitiveness of wine-growing and wine-producing enterprises. For this purpose, statistical data and surveys among the main suppliers and users of digital solutions are used.
- Defining an approach for analyzing and assessing the competitiveness of wine-growing and wine-producing enterprises that have already implemented digital technologies in their management.
- Developing a methodology for analyzing and assessing the impact of digitization on the competitiveness of wine-growing and wine-producing enterprises.
- Creating a strategic approach for the digitization of the wine sector through the use of SWOT analysis and focus groups. These will be used to identify an effective strategy that considers the unique characteristics and needs of enterprises in the sector.
- Identification of mechanisms for engaging stakeholders to accelerate the digitization process in the wine sector.

To collect objective information characterizing the state of the object and subject of the study, a questionnaire was developed. This questionnaire includes questions aimed at obtaining information on:

- Territorial distribution of wine-growing enterprises;
- Additional sectors developing in wine-growing enterprises;
- Economic size of enterprises;
- Membership in associations;
- Age of the owner/entrepreneur;
- Type of education of the owner/entrepreneur;
- Experience in the wine-growing and wine-making business;
- Participation in projects under any of the measures of the Rural Development Program (RDP);

- The role of the wine-growing and wine-making business in generating income for the owner;
- Digital services used by owners;
- Assessment of the benefits of using digital services;
- Preferred sources of information on digital services available on the market;
- Location of the digital service provider;
- Barriers limiting access to digital services;
- Access to digital services.

The total number of respondents is 197 (business owners or managers). They were selected using the random selection principle. The questionnaire was completed on-site, with the personal participation of the doctoral student conducting the interview.

Regression analysis aims to determine the effects of digitization on the competitiveness of wine-growing enterprises. The method seeks to answer the question, "To what extent is there a statistically significant relationship between the costs incurred for the digitization of vineyard and winery management (these costs are perceived as a factor indicator) and the level of competitiveness achieved as a result." The following performance indicators are used to assess the effects of the degree of digitization of the management of the wine-growing enterprise: (1) return on investment; (2) gross profit; (3) sales revenue; (4) gross margin; (5) return on sales; and (6) market share. All these indicators have been validated and can be considered reliable for assessing the level of competitiveness achieved. Six links between the indicators characterizing the cause factor and the result factor are tested, as follows:

- Relationship between the costs of implementing precision technologies and the return on investment;
- Relationship between the costs of implementing precision technologies and gross profit;
- Relationship between the costs of implementing precision technologies and sales revenue;
- Relationship between the costs of implementing precision technologies and the gross margin;
- Relationship between the costs of implementing precision technologies and the profitability of sales;
- Relationship between the costs of implementing precision technologies and market share.

3. Results and Discussion

In Bulgaria, systems for digitizing production and business processes in wine-growing and wine-making enterprises are available, which can be grouped into three segments: equipment and software for data generation, equipment and software for data analysis, and equipment and software for performing precise agrotechnical measures on the farm. By combining the above equipment and integrating different software platforms, the following highly efficient precision farming technologies can be applied by owners in Bulgaria: controlled traffic of agricultural machinery. Also, satellite navigation, control of production processes, and mapping of fields in the vineyard. Application of geographic information systems for synthesizing information necessary for farm management purposes. Monitoring of vine crops and mapping, and management of variable characteristics. Development of wireless systems of sensors and sensors, on-board sensors, and "smart" equipment, and radio frequency identification. Risks to privacy and personal data protection may also arise in connection with the conditions under which data processing takes place. This is due to the continuous development of databases and their interconnection, which may lead to uncontrolled access by third parties who may take advantage of this to the detriment of the principle of personal privacy. Viticultural data, insofar as it constitutes personal data, may give rise to interference with the right to respect for private life guaranteed by Article 8 of the Council of Europe Convention on Human Rights and Article 7 of the Charter of Fundamental Rights of the European Union [1, 2]. This is because access to such data may violate the right to anonymity and privacy guaranteed to all persons in the EU and may therefore only be permitted under specific conditions and safeguards.

Another important aspect is strengthening the wine-growing and wine-producing industry's adequate response to the environment. Creating new value along the chain (new business models) [3-5]. Increasing the profitability of activities, encouraging innovation, and marketing activities, as well as promoting technology transfer and the valuation of new knowledge. Digitalization and artificial intelligence can make a significant contribution to solving these problems. Through the Internet of Things and database management, owners can access objective data and algorithms that enable them to optimize production processes in wine-growing enterprises [6]. The potential benefits of using digital technologies in agriculture can contribute to increasing crop yields and animal productivity, optimizing input processes and labor, all of which increase competitiveness [7]. Another important aspect of productivity is achieving economies of scale. Here, too, the digitization of information flows from data characterizing technological processes can help formulate optimal solutions for economies of scale. There is a clear trend towards the widespread use of artificial intelligence in production quality management in high-tech companies. Production quality is monitored using databases and intelligent systems. Digitization is one of the main tools for implementing total quality management, which is a prerequisite for achieving economic competitiveness. By digitizing data, it is easy to standardize production, thereby realizing economies of scale and achieving quality parameters in production [8].

In the field of precision farming, any information related to location plays a key role. Regular monitoring through sensor networks is necessary to gather evidence and data on the impact of the Common Agricultural Policy (CAP) on the pressure that agriculture exerts on the ecology and social development of rural areas in Member States. Given the significant need for geographical data for the management of EU agricultural policy, geospatial information has become a determining factor in the implementation of this policy, which includes the establishment and maintenance of an Integrated Administration and Control System (IACS) within the Union. According to the legal requirements of the CAP, each

Member State has established an Integrated Administration and Control System (IACS), including a system for the identification of agricultural parcels, known as the Land Parcel Identification System (LPIS), as a spatial component [9]. Using computerized techniques to establish a system for identifying agricultural parcels is a legal obligation laid down in Council Regulation 73/2009. By locating, identifying, and quantifying agricultural land eligible for EU support through very detailed geospatial data, the IACS has become the most important system for the management and control of payments to farmers made by Member States in application of the Common Agricultural Policy. The LPIS is a system based on maps or land register documents, or other cartographic references, using computerized Geographic Information Systems (GIS) [10]. This system registers all agricultural parcels in the Member States that are considered eligible for annual area-based subsidy payments under the CAP. The system is used for cross-checks during administrative control procedures and as a basis for on-the-spot checks by the paying agency. These checks aim to verify that vineyard owners have complied with the set of cross-compliance rules introduced in 2005. To control the application of the CAP for cross-compliance and greening, several additional types of data are collected together with the geospatial information, as regulated by a set of provisions. These include, for example, requirements relating to the environment, health, soil, animal welfare, food safety, climate change, water protection policies, etc., as well as standards for good agricultural and environmental conditions. Precision farming can offer a comprehensive view of CAP requirements from a legal and informational perspective. This can improve the effective implementation of the Common Agricultural Policy by collecting georeferenced data on soil characteristics, meteorological indices, and crop conditions at the level of individual land parcels. Given that the 2003, 2007, and 2013 reforms of the Common Agricultural Policy have led to significant changes in the data required by wine producers when submitting applications for financial support, precision farming and its potential for standardization could have a positive effect on the way owners apply for direct payments by simplifying control and verification procedures [11]. The information recorded and produced within the framework of data management and precision farming activities can be used to facilitate various administrative and control procedures of the LPIS and IACS that focus on verifying eligibility conditions. Beyond the challenge of collecting comprehensive and accurate data focused on wine-growing enterprises and creating high-quality data sets, standardization, knowledge integration, and interoperability of data exchange in agriculture represent additional barriers to the formation of a harmonized approach to the design of common rules and implementation practices. The interconnection of information systems implies the possibility of linking information systems. This solution requires technical compatibility between systems, as well as strict safeguards for personal data protection and access control rules. There are different levels of interoperability affecting data, such as technical (the use of data management systems that allow connection to other systems), semantic (use of metadata and knowledge organization systems for describing and organizing data, based on existing standards), and legal (use of appropriate licenses that allow data exchange between different systems and providers). Operational interoperability, seen as more than just the interconnection of ICT systems, entails certain risks relating to the possible breach of data protection principles, in particular the principle of access restriction. Most of the spatial data in question is now subject to a process of pan-European standardization and harmonization triggered by the INSPIRE Directive. In addition to its inherent capacity to collect data and substantiate specific parameters, precision farming could contribute to the harmonization of standards, the consolidation of databases, and the simplification of the current system, thereby giving impetus to a system capable of modernizing the CAP. Precision farming could become an important factor in standardizing and harmonizing data, which could facilitate data exchange in practice and lead to a less bureaucratic CAP. It can also help to facilitate the development of uniform requirements for parameters such as reference parcel, land cover type, agricultural restriction, aid application for farmers, agricultural parcel, farmer sketch, and crop code. Closely linked to the need for standardization and harmonization of data exchange and format, precision farming could also support the declaration document for wine producers, as the geographical accuracy of the maps of agricultural parcels must be sufficient to enable owners to use them for submitting their applications for digital payments. The introduction of precision agriculture could pave the way for Member States to implement digitization programs regarding the relationship between the government and wine producers, to obtain a “single farm file” including integrated and synchronized crop data management. Precision farming could make agriculture more transparent and improve the traceability of agricultural products.

The increasing adoption of precision farming presents additional challenges for established agricultural advisory services. Vine and wine producers need to receive personalized, targeted advice based on the information and data they hold and provide to their advisors. To facilitate this, open-source environmental data, geographical information, and satellite imagery should also be made available to advisory schemes, enabling a balanced dissemination of information without bias or conflicts of interest.

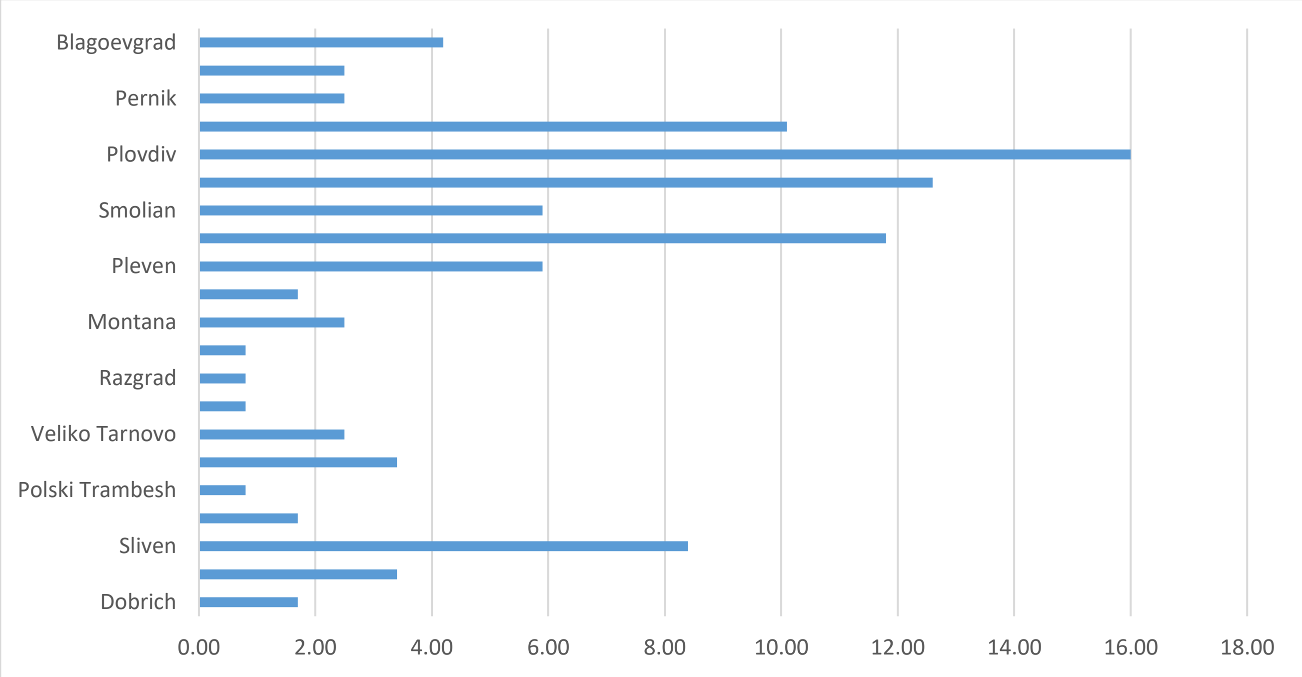

Figure 1.
Territorial distribution of the surveyed enterprises.
Source: data from a survey of 197 enterprises, 2022.

In principle, vine and wine advisory services in Member States can play a special role in supporting precision farming by providing support and advice to vine and wine producers on precision farming technologies and methods as an independent body not linked to commercial companies. Given that precision farming is currently almost entirely based on the private sector offering devices, products, and services to larger owners who can afford them, public service advice is usually very limited. An addendum to see what the need for digitization and programmatic agriculture is, companies from typical agricultural municipalities, which are described in Figure 1 were surveyed. The data presented above shows that the largest share of the surveyed enterprises is from the Plovdiv region – 16%, the Pazardzhik region – 12.6%, the Kardzhali region – 11.8%, and the Sofia region – 10.1%.

The production specialization of the surveyed enterprises is shown in Figure 2. The data indicate that in the surveyed group of enterprises, in addition to viticulture and winemaking, the cultivation of grain and essential oil crops is also developing, accounting for 28.2% of the total number of surveyed entities. These are followed by those engaged in livestock farming, representing 17.6% of the surveyed enterprises. Wine-growing enterprises that also specialize in vegetables account for a significant share of the surveyed enterprises – 13.9%. The development of precision agriculture presents several significant challenges that require a strategic approach to ensure a smooth transition.

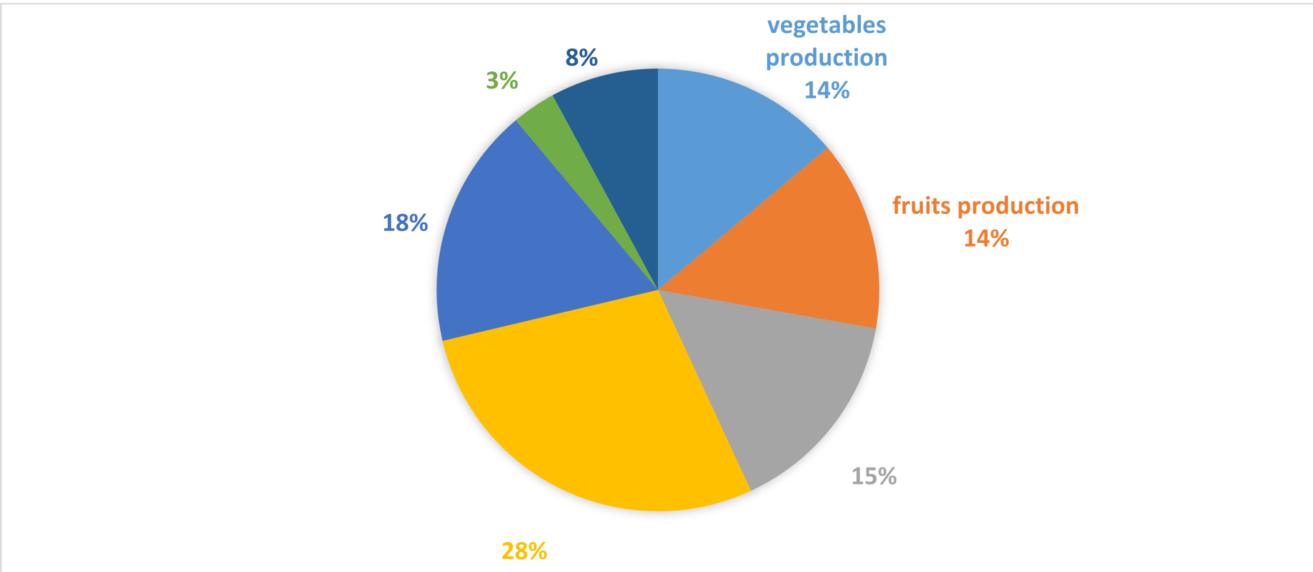

Figure 2.
Additional sectors of the surveyed wine-growing enterprises.
Source: data from a survey of 197 enterprises conducted in 2022.

The next criterion used to identify wine-growing enterprises in the sample is their size. Figure 3 provides a graphical analysis of the enterprises according to this criterion. The graphical analysis of the survey data shows that small enterprises (with a size of up to EUR 8,000) predominate, accounting for 44% of the total number of enterprises surveyed. They are followed by a significant group of medium-sized enterprises (with a size of EUR 8,000 to EUR 50,000), which account for 30.1% of the total number of enterprises surveyed.

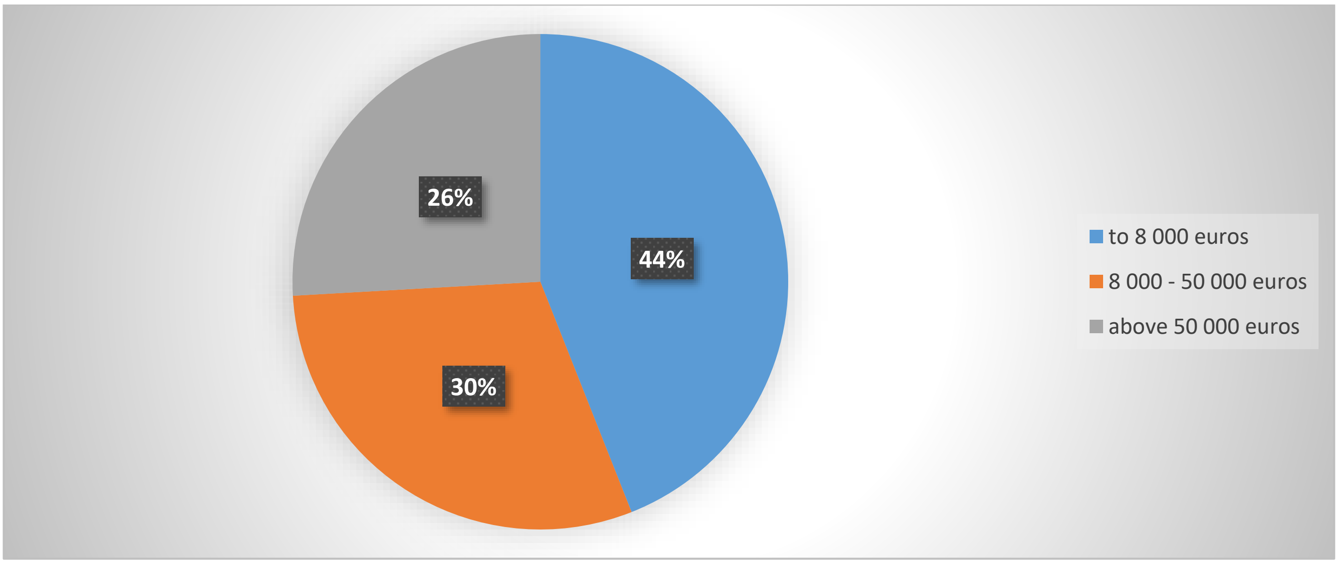

Figure 3.
Economic size of the surveyed enterprises. Source: data from a survey of 197 enterprises, 2022.

The next profiling criterion for the surveyed group of enterprises is their membership in various organizations. Figure 4 shows the percentage distribution of the surveyed enterprises. The data clearly indicates that wine-producing enterprises prefer to join non-governmental organizations 93.9% of them report being members of such organizations.

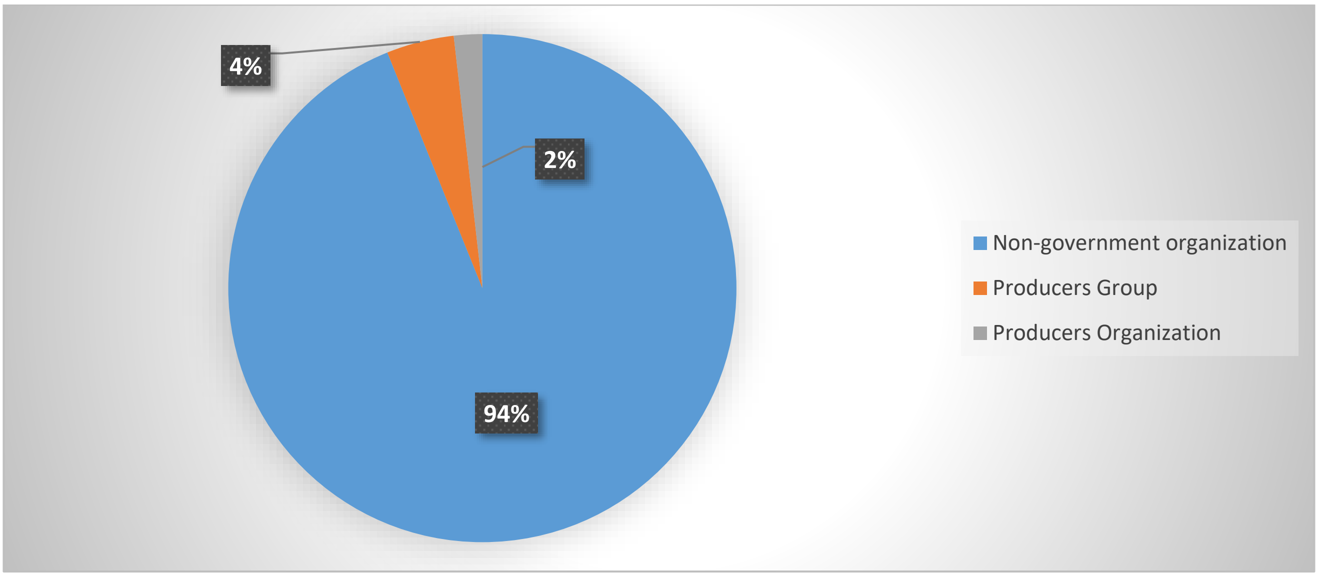

Figure 4.
Distribution of enterprises according to their membership in associations. Source: data from a survey of 197 enterprises, 2022.

At the same time, the introduction of precision agriculture may also in itself become a source of various challenges of legal or regulatory interest [12, 13]. First, from a technological point of view, some of the main challenges include compatibility issues limiting the development of technologies, low uptake of digital technologies, limited data infrastructure on farms, which are not designed for data exchange, extensive brand protection by large companies (supplier lock-in), poor compliance with software development standards and data formats, data sharing, (business models for) data management, and interconnection strategies. Common standards, connectivity, and interoperability are key issues in this area. Wireless and broadband coverage in rural areas is unstable, while sensor network standards are still being developed, and specialized agricultural software is still maturing. Beyond the diversity of the rural environment and stakeholders, rural areas, especially in Southern and Eastern Europe, tend to lag behind urban areas in broadband deployment, which is crucial for the effective use of big data for agricultural purposes. The digitization of the wine sector is a prerequisite for easier forecasting of market prices for both production resources and the final product. This enables owners to have objective information on market trends when planning the activities of their enterprises. Digital technologies have a positive impact on viticulture and wine-making activities and help reduce the pressure of crop production on the environment [14]. This is achieved by measuring the negative impact of wine production and seeking regulatory action by the state to reduce the negative impact on the environment without compromising the profitability of farms. Digital technologies have numerous advantages in the production of agricultural products with potentially high economic impact. They are believed to improve the efficiency of production operations by reducing inputs such as seeds, fertilizers, pesticides, etc., thereby minimizing the cost of production inputs. Studies are available on specific digital technologies that consistently increase net returns in vineyards [15-18]. According to Schieffer and Dillon, producers using precision agricultural technologies have the opportunity to reduce their environmental impact while improving productivity and financial results [19]. The digital transformation in agriculture is also leading to an increase in value creation agreements between producers and partners in the supply chain, who are rethinking their operations, control, and coordination of activities. A review and literature review of publications by researchers on the competitiveness of wine-growing enterprises shows that the main problems in competitiveness management are the following factors that play a role in the development of the wine-growing sector [20-23]. These are related to increasing the productivity of production factors, realizing economies of scale, and improving the quality of the products produced.

Although precision agriculture is not a separate technological field, the question arises as to whether it should be considered a separate legal category or only about the technological tools used. The challenges associated with this approach can be divided into two main categories: (1) those arising from the technologies themselves, used in precision agriculture such as drones, robots, GPS systems, and others which raise questions related to technological control, safety, civil liability, and personal data protection, and (2) challenges arising from the development of precision agriculture as an autonomous technological field. One of the main obstacles to the widespread adoption of precision agriculture is the lack of broadband infrastructure in rural areas, as well as the limited connectivity of devices tractors, computers, tablets, and smartphones that collect and process data on agricultural processes [24].

The implementation of precision farming raises some serious issues related to the compatibility between agricultural machinery and digital infrastructure [25]. There is concern among the farming community about hardware and software compatibility and the suitability of the technical systems chosen for the introduction of precision farming. The various digital technologies to be used on the farm must be compatible with the hardware devices in which the farmer has invested. Purchasing the necessary hardware is an expensive investment, and if these devices are not compatible with the software needed to solve everyday problems on the farm, the investment will be pointless. The assessment of the impact of digitalization on competitiveness is based on the results of a survey conducted among 197 agricultural enterprises whose owners have, to some extent, implemented digital technologies in the management of their activities. Of the agricultural enterprises surveyed, 75% have successfully implemented several hardware solutions and related software. Based on the field study, this is considered a high level of digitization of management activities. Of all agricultural enterprises, 33% use software for processing agricultural information as an element of digitization applicable in the daily management of the vineyard and winery, and 13% have opted for a single hardware solution (Figure 5).

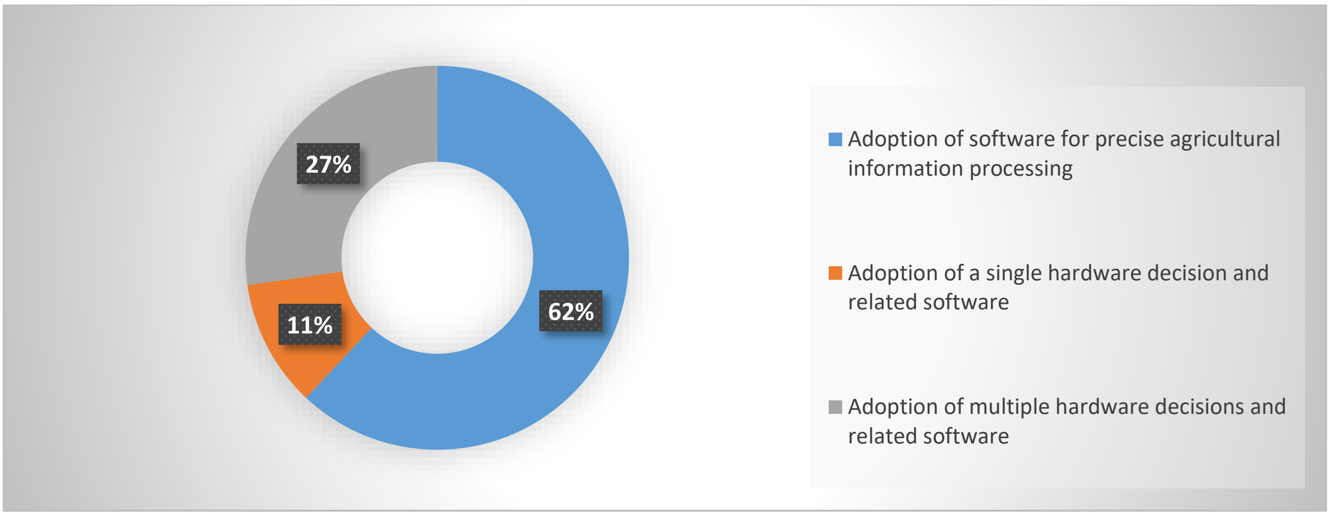

Figure 5.
Degree of digitization of management activities in the surveyed enterprises. Results from field research among 30 enterprises, 2021-2022.

In agriculture, finding the optimal route is often an opportunity to reduce the costs of field cultivation and harvesting, as well as to achieve a multiplier effect when carrying out parallel machine processes in the vineyard. Another useful effect is the protection of the environment through lower carbon emissions into the atmosphere. To implement controlled machine traffic in viticulture and winemaking, it is necessary to invest in satellite navigation.

Global navigation satellite systems (GNSS) are a key element of precision agriculture, providing the basis for optimizing and improving production processes in vineyards [26]. The continuous development of these systems leads to increased accuracy and reliability, which improves the efficiency of agricultural activities. Navigation systems operate on the principle of triangulation, where the user's position is determined by analyzing signals from several satellites. Each satellite transmits coded signals at regular intervals, which are processed by the receiver to calculate the exact position, speed, and time. Thanks to this accuracy, detailed maps of soil parameters and vineyards can be created, facilitating the monitoring and management of agricultural activities.

Field mapping. This technology, which is mainly based on the use of satellite navigation and networks of sensors and detectors, enables precise monitoring of vineyards in terms of the availability of essential nutrients, the presence of diseases and pathogens in vine crops, soil moisture, and water resources in farm reservoirs, etc [27]. The purchase of all the equipment needed to map agricultural land requires significant investment, which not every farmer can afford. Therefore, there are many providers on the market offering this service for a subscription fee. They can create detailed maps of fields that include various parameters such as area and shape, pH levels, phosphorus content, and other slowly changing nutrients, soil texture and compaction, and weed presence.

Vineyard monitoring and mapping. This technology allows the determination of the following production parameters in the vineyard with high accuracy: the size and quality of the crop to be harvested from the field; the extent of crops affected by diseases and pests; the size of areas at risk of drought and erosion, etc. Through monitoring, owners can make economically sound decisions and reduce pressure on the environment. By mapping vineyards and production areas, farmers can take advantage of variable trait management technology [28].

Building wireless sensor systems. Ubiquitous Agriculture (U-Agri) is the next generation of precision farming. It focuses on the integration of wireless sensor networks (WSN) into various aspects of agriculture, providing low-cost and widely available sensors in vineyards [29]. These sensors collect data on climatic conditions, soil characteristics, and crop status, which are transmitted to satellites and then to ground stations and computer systems for analysis. The data obtained plays a key role in meeting agronomic requirements and supports the development of effective decision-making systems. Through communication networks such as the Internet, SMS, radio, and other technologies, wireless sensor networks provide farmers with timely and accurate information. This approach is widely used in agriculture, helping to optimize the use of pesticides, fertilizers, and water. For its successful implementation, it is necessary to build a reliable WSN infrastructure that integrates meteorological data from remote farms and provides an easily accessible web interface for farmers.

On-board sensors and "smart" equipment [30]. Sensors mounted on agricultural machinery are a key component of the precision farming information system. They provide real-time data while the machines are in motion, with the most advanced ultrasonic and optical sensors monitoring parameters such as row spacing, plant height, terrain slope, crop yield, and weed presence. Connecting these sensors to GPS and using autopilot systems allows operations to be performed with an accuracy of up to 2 cm. The operator can select the navigation pattern and monitor movement via a display in the cab, with the system reducing errors, saving time and labor, and enabling 24-hour operation when necessary.

Software solutions for precision farming [31]. A variety of software systems for managing agricultural processes include office, mobile, and wireless solutions. Stationary software platforms process spatially related data, storing the information in separate layers that can be visualized on a map. This allows farmers to analyze data on seed varieties, soil characteristics, and yields and create maps for optimized fertilization and irrigation.

In this regard, it is important to identify the main factors determining the demand for digital services among owners, as well as to identify the main barriers limiting access to them.

Figure 6 presents the results of the survey, according to which owners rely on digital services related to specialized meteorological information, navigation systems, and specialized software. These types of services are mentioned by 63.4% of respondents. In second place, 24.2% of owners say they use digital solutions for managing technological processes. The smallest share, 12.4% of respondents, prefer digital services aimed at managing managerial activities.

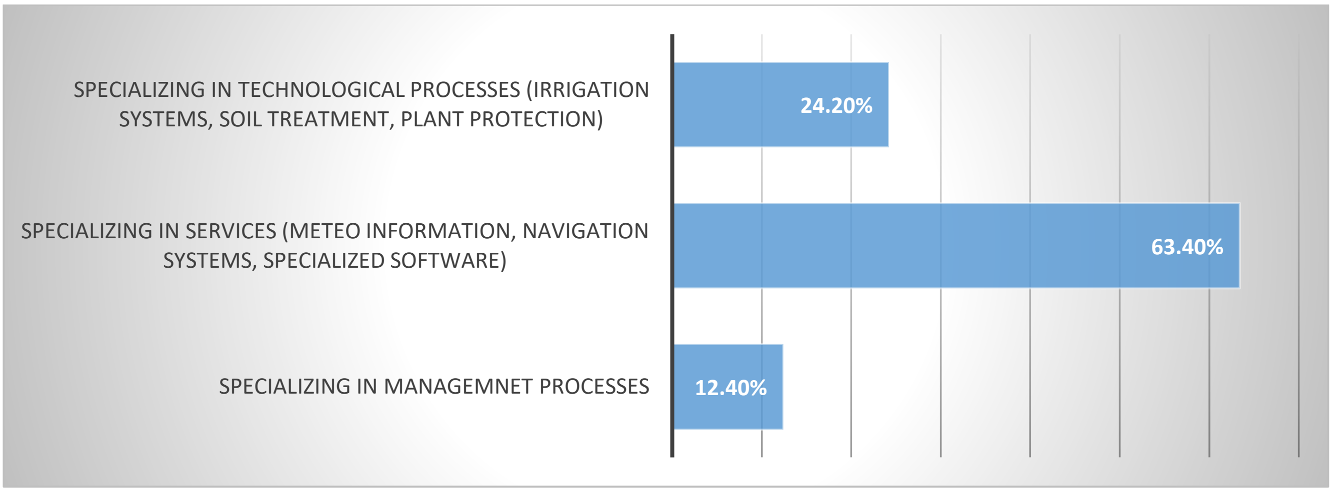

Figure 6.
Digital services are used by owners.
Source: Data from a survey of 197 respondents, 2022.

It is very interesting that, according to the survey, there is a high degree of implementation of digital solutions in vineyard management, and sales profitability increases 75% of these farmers surveyed cited this as a fact. Companies that have implemented only a single hardware solution and related software also report an increase in sales profitability 77% of the owners surveyed say that the profitability of their sales is increasing (see Figure 7).

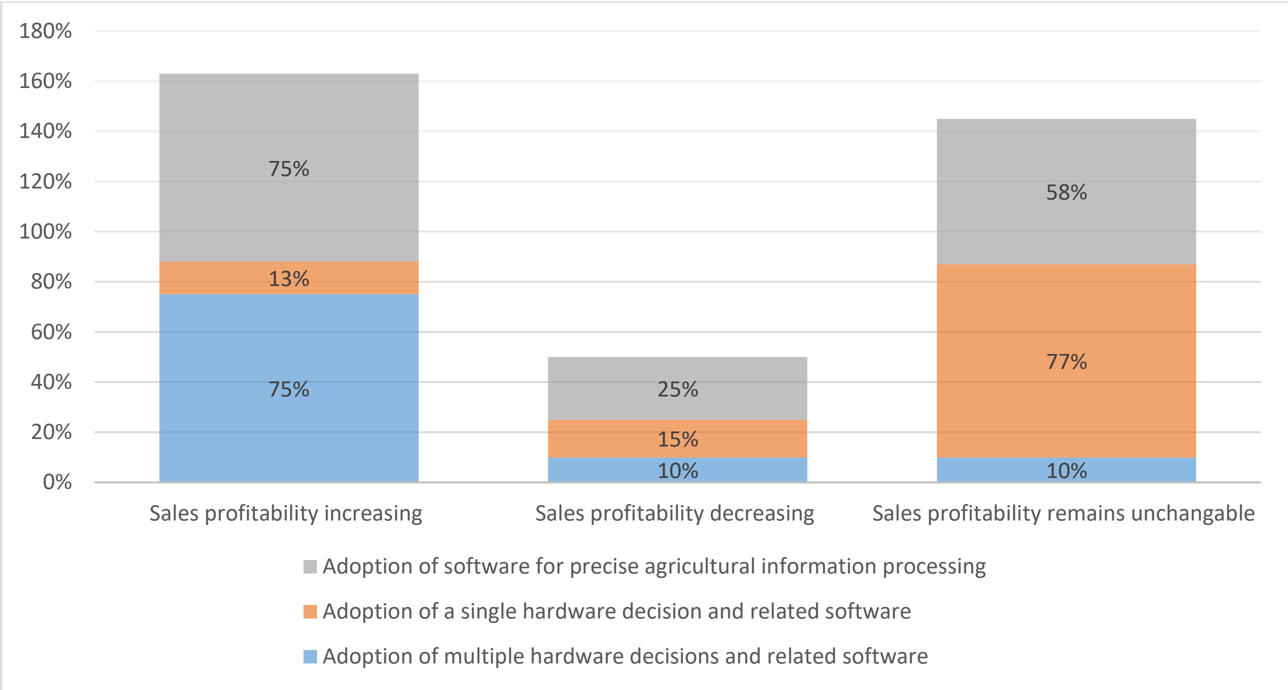

Figure 7.
Impact of digitalization on sales profitability in wine-growing enterprises.

The introduction of new products is boldly implemented by owners who assess the extent to which the digital solutions used affect the competitiveness of their agricultural enterprises. However, we must bear in mind that competitiveness is assessed using indicators such as sales profitability, return on investment, and gross margin, while digitalization itself helps to improve the management of the agricultural process on farms.

The regression analysis aims to establish the extent to which there is a statistically significant relationship between the costs incurred for the digitization of vineyard and winery management (these costs are considered a factor indicator) and the level of competitiveness achieved as a result. The following performance indicators are used to assess the effects of the degree of digitization of the management of the wine-growing and wine-making enterprise: (1) return on investment; (2) gross profit; (3) sales revenue; (4) gross margin; (5) return on sales; and (6) market share [32]. All these indicators have been validated and can be considered reliable for assessing the level of competitiveness achieved. Six links between the indicators characterizing the cause factor and the result factor are tested as follows:

- Relationship between the costs of introducing precision technologies and the return on investment;
- Relationship between the costs of introducing precision technologies and gross profit;
- Relationship between the costs of introducing precision technologies and sales revenue;
- Relationship between the costs of implementing precision technologies and the gross margin;
- Relationship between the costs of implementing precision technologies and the profitability of sales;
- Relationship between the costs of implementing precision technologies and the market share.

Table 1.
Results of regression analysis assessing the interaction between the degree of digitization and the level of competitiveness of wine-growing and wine-producing enterprises.

Statistical measures	Investment returns	Gross Benefit	Sales Revenue	Gross margin	Profitability of sales	Market share
Correlation coefficient Multiple R	0.174	0.935	0.095	0.304	0.776	0.095
Definition coefficient R square	0.030	0.875	0.0091	0.093	0.603	0.009
Adjusted R Square	-0.004	0.871	-0.0261	0.060	0.589	-0.026
Correlation degree	Weak	Very strong	Very weak	Moderate	Strong	Very weak
Correlation type	Reverse	Direct	Reverse	Reverse	Direct	Reverse
Regression coefficient $б_0$	0.788	18805.9	6208280.2	620901.2	0.034	3.44
Regression coefficient $б_1$	-1.797	0.05	-0.0431	-1.4313	00000.5	-2.4

Table 1 presents the results of testing the relationship between the degree of digitization and the level of competitiveness achieved by wine-growing and wine-producing enterprises [33]. The regression analysis indicates that the costs associated with introducing precision technologies have a positive (there is a direct relationship between the factors studied) impact on gross profit and return on sales [34]. There is a strong degree of dependence between these two relationships, with determination coefficients of -0.875 and 0.603, respectively.

Precision technology costs negatively impact the return on investment, sales revenue, gross margin, and market share of vineyards and wineries. Figure 8 shows the relationship between the costs of implementing precision technologies in the wine industry and the return on investment [34]. The regression equation is graphically represented by a linear relationship. This relationship indicates an inverse correlation between the factors (indicators) studied. As the costs of implementing precision technologies increase, the return on investment decreases, assuming all other factors remain constant. This inverse relationship can be explained by the fact that precision technologies require higher total investment costs in viticulture and wine production, which negatively impact the return on investment in the short term. A longer period is necessary to recover the investments made in digitization. Most of the surveyed enterprises have recently invested in the application of precision technologies, and it will take time for these investments to become profitable.

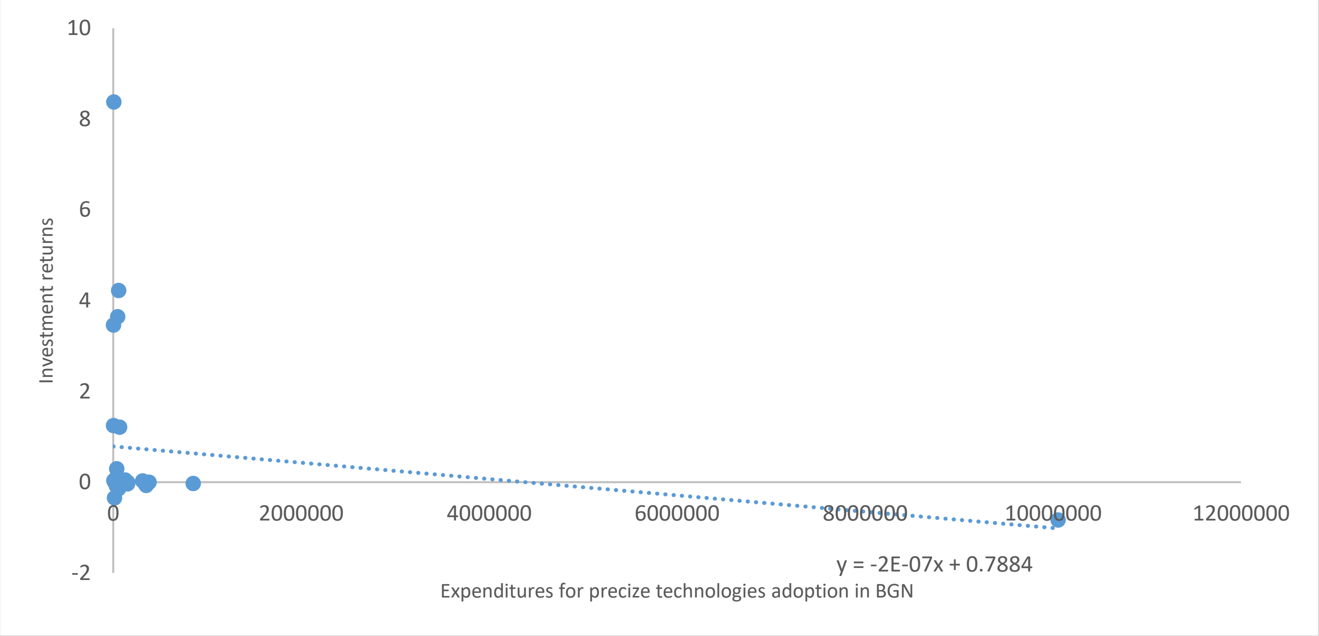

Figure 8.
The interaction between the costs of implementing precision technologies and the return on investment.

Figure 9 shows the relationship between the costs of implementing precision technologies in viticulture and the gross profit of the farm. The regression equation is graphically represented by a linear relationship. The regression coefficient for this relationship indicates that there is a directly proportional relationship between the factors (indicators) studied. As the costs of implementing precision technologies increase, gross profit increases, all other factors being equal.

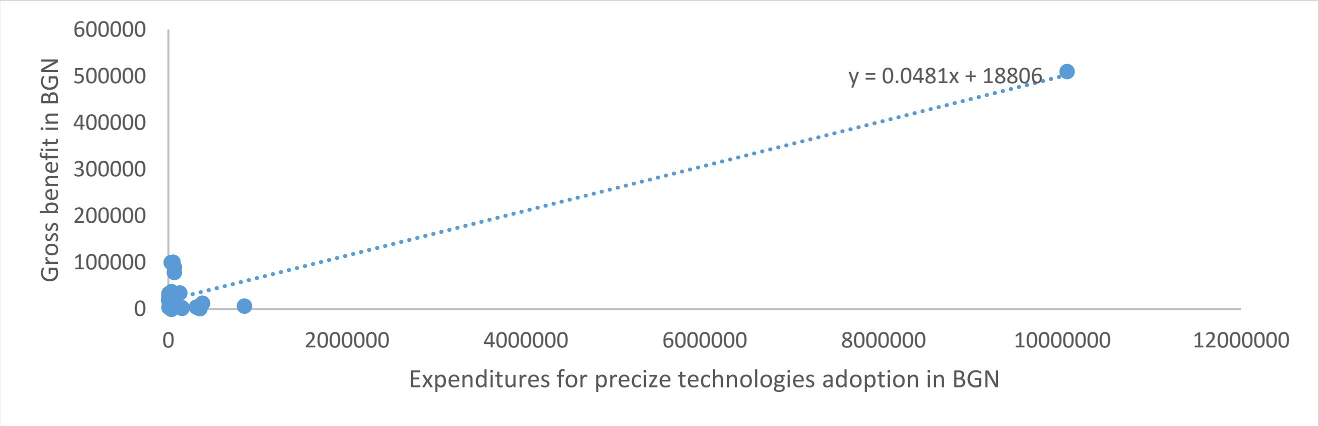

Figure 9.
The interaction between the costs of introducing precision technologies and gross profit.

Figure 10 shows the relationship between the costs of introducing precision technologies in viticulture and wine production and the farm's sales revenue. The regression equation is graphically represented by a linear relationship. The regression coefficient for this relationship indicates an inverse proportional relationship between the factors (indicators) studied. As the costs of implementing precision technologies increase, sales revenue decreases, all other factors being equal.

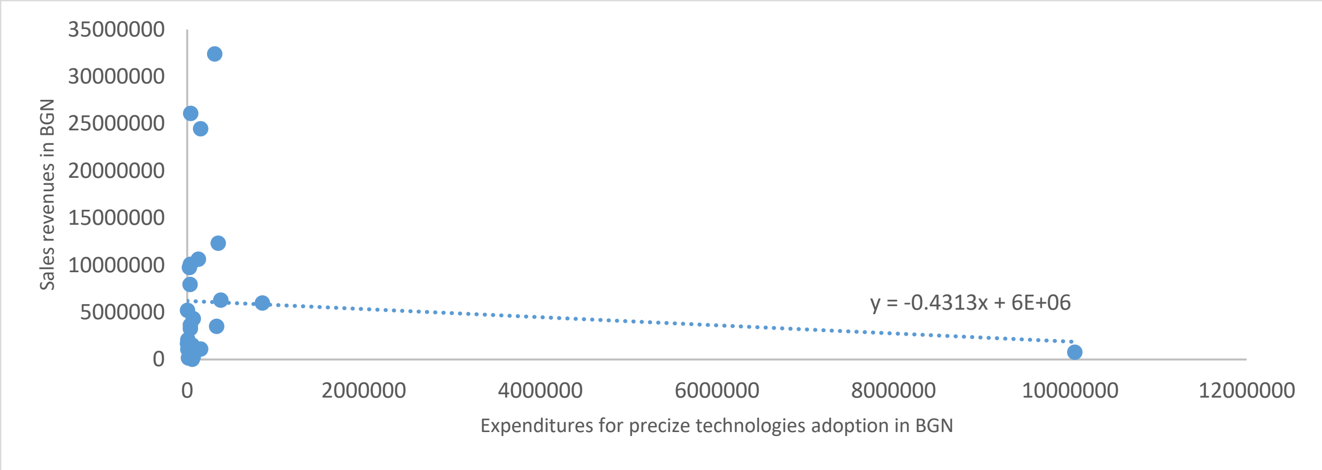

Figure 10.
The interaction between the costs of introducing precision technologies and sales revenue.

Figure 11 shows the relationship between the costs of introducing precision technologies in the vineyard and winery and the gross margin of the farm. The regression equation is graphically represented by a linear relationship. The regression coefficient for this relationship indicates an inverse relationship between the factors (indicators) studied. As the costs of implementing precision technologies increase, the gross margin decreases, all other factors being equal.

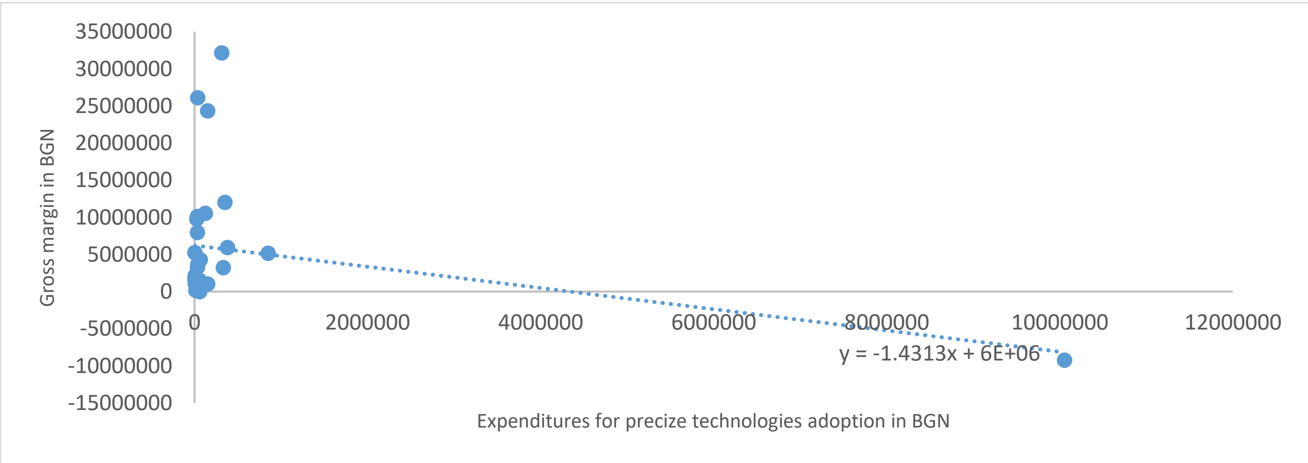

Figure 11.
The interaction between the costs of implementing precision technologies and sales revenue.

Figure 12 shows the relationship between the costs of implementing precision technologies in viticulture and the profitability of sales (as an absolute value) of the farm. The regression equation is graphically represented by a linear relationship. The regression coefficient for this relationship indicates that there is a directly proportional relationship between the factors (indicators) studied. As the costs of implementing precision technologies increase, the profitability of sales increases, all other factors being equal.

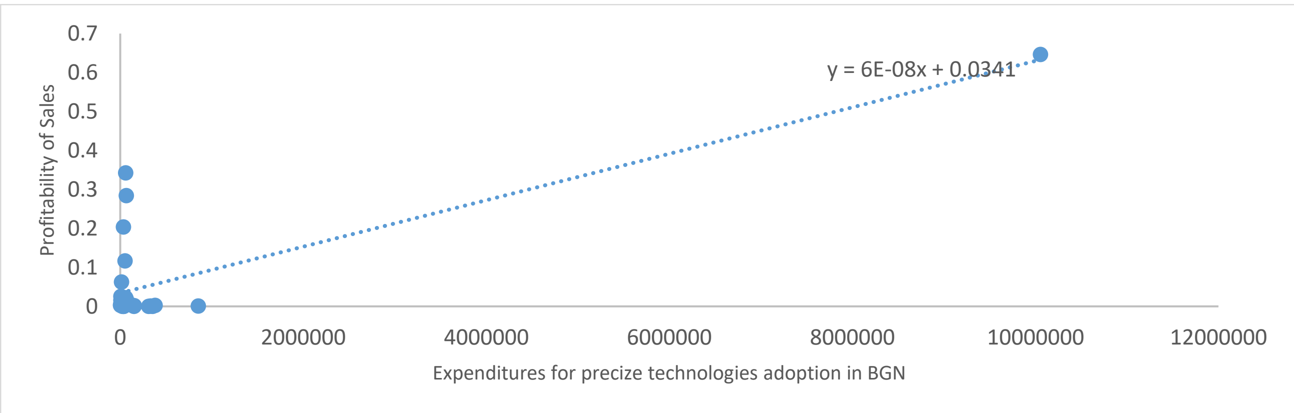

Figure 12.
The interaction between the costs of introducing precision technologies and the profitability of sales.

Figure 13 shows the relationship between the costs of introducing precision technologies in the vineyard and winery and the market share of the farm. The regression equation is graphically represented by a linear relationship. The regression coefficient in this relationship indicates an inverse proportional relationship between the factors (indicators) studied. As the costs of implementing precision technologies increase, the market share decreases, all other factors being equal.

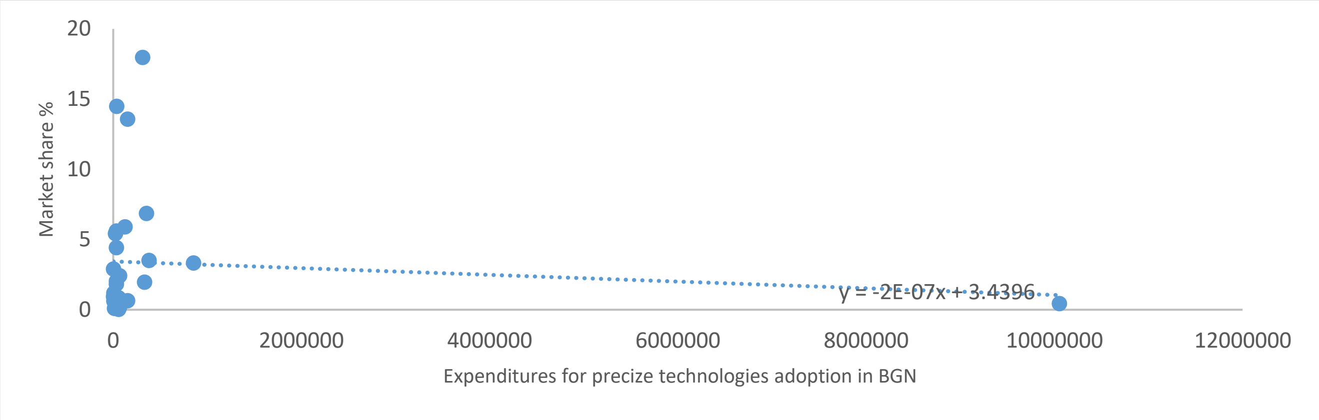

Figure 13.
The interaction between the costs of implementing precision technologies and market share.

4. Discussion

The accelerated adoption of digital technologies in agricultural practices, particularly among small- and medium-sized winemaking enterprises, will lead to more efficient grape and grape product production while reducing environmental impact. However, research shows that introducing new technologies to these enterprises faces serious challenges. High machinery costs, inadequate infrastructure, and limited knowledge are among the main barriers the wine sector must overcome. Entrepreneurs are identifying various ways to digitize their activities. According to them, this process can be achieved through:

- Encouraging cooperation between producers.
- Creating digital centers with available consultants;
- Controlling the use of agricultural land, such as pastures and meadows.
- Providing digital centers that offer direct access to services and a choice of consultants.

The effectiveness of digitization in the sector depends on the conditions created for its implementation. Information gathering and analysis processes play a key role in wine-growing and wine-producing enterprises. Without these processes, entrepreneurs cannot control the achievement of their goals. Additionally, successfully implementing digital technologies requires skillful management of the changes that occur within the enterprise in response to the dynamic business environment.

Change management is a critical issue in managing a wine-growing enterprise and can be addressed through digitization. Without change initiatives and effective management of the process, enterprises cannot be successful or flexible in response to changes in the business environment. Flexibility is one of the main internal characteristics of competitiveness; maintaining this flexibility is essential for developing the enterprise's competitiveness.

5. Conclusions

Wine-growing enterprises have primarily succeeded in digitizing their accounting and supply chain activities. They have partially succeeded in digitizing some critical technological phases of the production process, such as irrigation and vineyard monitoring, as well as control and monitoring of the distillation process.

The challenges associated with the application of precision agriculture in the sector can be divided into two broad areas: (1) those inherent in the technological tools used in precision agriculture (drones, robots, GPS, etc.), raising issues of technological control, human safety, civil liability, and privacy, and (2) those that arise with the development of precision agriculture as an autonomous technological field.

The lack of broadband infrastructure in rural areas and connectivity with devices (e.g., to a tractor, computer, tablet, or smartphone that records what is happening, or a device for satellite photography privacy issues) providing access to and ownership of data is one of the main problems for the accelerated introduction of the precision agriculture approach in the sector.

The implementation of precision farming in the sector also raises some serious issues related to the compatibility between agricultural machinery and digital infrastructure. There is concern among the business community about hardware and software compatibility and the appropriateness of the technical systems chosen for the introduction of precision agriculture. The various digital technologies to be used in the enterprise must be compatible with the hardware devices in which the entrepreneur has invested. Purchasing the necessary hardware devices is an expensive investment, and if these devices are not compatible with the software needed to solve everyday problems on farms, this will render the investment meaningless.

The results of the survey indicate that with a high degree of implementation of digital solutions in the management of wine-growing enterprises, the profitability of sales increases –75% of the wine-growing producers surveyed indicate this as a fact. Companies that have implemented only a single hardware solution and related software also report an increase in sales profitability – 77% of the owners surveyed state that the profitability of their sales has increased.

The effects of digitalization on the return on investment as a whole are also assessed positively by the owners. Owners who have implemented a large number of hardware solutions and related software believe that this decision has had a critical effect on the return on investment in their wine-growing and wine-making business – 50% of them state that the return has increased. A significant proportion of owners (60% of those surveyed) who own businesses where the implementation of a single hardware and related software solution has led to an increase in return on investment.

As a result of the statistical survey, it can be summarized that digitization impacts the competitiveness of wine-growing and wine-making enterprises in terms of gross profit growth and return on sales. Digitalization, expressed through the level of costs for its implementation in wine-growing enterprises, has a systematic negative impact on return on investment, sales revenue, and gross margin.

The Conclusions section is mandatory. In Review manuscripts, it should be replaced by Concluding Remarks.

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