Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 2, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

IMPLEMENTING PRECISION AGRICULTURE TECHNOLOGIES IN SOUTH-MUNTENIA REGION: ECONOMIC BENEFITS AND OPERATIONAL CHALLENGES

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Abstract

Precision agriculture can be considered a revolution in modern farming, relying on data and advanced technologies aimed at optimizing production and efficiently utilizing resources. This approach enhances yields and reduces losses, thereby ensuring the sustainability and competitiveness of the agricultural sector. In a global context profoundly impacted by climate change, population growth, and increasing economic demands, precision agriculture plays a critical role in adapting farms to these new challenges while ensuring their profitability. This paper aims to asses the level of technical equipment, the degree of use and perceptions of precision agriculture technologies in eight farms with various surfaces in South-Muntenia region. The research is based on a questionnaire applied on these farms. The collected data were analyzed descriptively, with graphical representations. The results highlight the widespread adoption of self-guidance systems, the variable rate applications, digital platforms and soil sensors. The identified benefits include reduced production costs, increased efficiency and improved production quality while the main barriers are high costs, lack of training and technological complexity. The overall conclusion highlights the potential of precision agriculture to support farm performance and competitiveness, with support policies and professional training needed for widespread adoption.

Key words: *precision agriculture, sustainability, economic growth, agriculture profitability*

INTRODUCTION

For the global economy, agriculture is an essential sector, being responsible for producing raw materials and food necessary to feed the ever-growing population [4, 9, 22]. Currently, agriculture is facing notable challenges such as the need to increase food production to meet global demand [7], while reducing the impact on the environment [11] and conserving natural resources for future generations [21], but also with inflation and high production prices [14]. In order to meet the increasing demand, it is necessary to intensify agricultural production [15, 25], which can have negative consequences on the environment, contributing to soil degradation, water pollution and loss of biodiversity, and through various agricultural practices that have negative long-term impacts [2]. Conventional agriculture, dominant for the last hundred years, is an intensive system that uses modern technologies such as mechanized irrigation, agricultural machinery, and chemical inputs which, lead to high production costs [26] to ensure the productivity needed for global demand [19, 20], but unfortunately, this system contributes to the depletion of natural resources and implicitly to climate change.

In this context, precision agriculture emerges as an innovative solution [12,16], based on advanced technologies, which allows the optimization of agricultural production [8] through efficient resource management, reducing the impact on the environment [5] and of course increasing productivity and profitability. It is distinguished by the fact that, unlike conventional techniques, it adapts interventions to the specifics of each land, by applying and precisely executing the works according to its potential [18]. Like many tech-driven sectors, precision agriculture has rapidly evolved and continues to develop through ongoing research and innovation [17]. Precision agriculture, with the help of technologies, offers farmers the chance to have better control over the production process to increase their profitability and reduce production risks, by enabling data-driven decision making. [3]. And some of these technologies have been adopted as standard practices in certain agricultural communities [13]. And globally, the adoption of precision agriculture is growing, as it plays an important role in addressing several challenges such as climate change, food security, and resource scarcity. Developed countries are investing heavily in research and infrastructure to support its implementation [6, 24]. Most farmers know the advantages and disadvantages that these technologies bring. Many farmers admit that it is not easy to implement and use these technologies due to the high investment costs and the lack of the necessary skills of operators to use and understand how they work [23].

Therefore, to be successful in implementing these solutions, active participation and a positive attitude of both the farmer and the entire staff are needed [10].

In this context, the purpose of this research is to assess the current state of adoption, usage, and perceptions of precision agriculture technologies among farms in the South-Muntenia region, with a focus on identifying the key benefits and barriers to their implementation.

MATERIALS AND METHODS

To analyze the degree of use and perceptions of precision agriculture technologies, a structured questionnaire, consisting of 14 questions, was developed and applied to a sample of 8 agricultural holdings in the South-Muntenia region. The selected farms are specialized in cereal cultivation and use, in one form or another, precision agriculture systems. The size of the holdings varies between 64 ha and 1,600 ha, which provides a diversified overview of the implementation of these technologies depending on the production capacity. The inclusion of a smaller farm was justified by the interest in capturing various perspectives on the access and applicability of the technologies, depending on the available resources.

The questionnaire was administered digitally through the Microsoft Forms platform, between March 28 and April 4, 2025. This interval was chosen to coincide with the period preceding spring agricultural works, when farmers' willingness to respond is increased, and the information provided is consistent with current field activities.

Data analysis was performed using descriptive methods, using frequencies and percentages to interpret the responses. The results were graphically represented to facilitate understanding and highlight trends in the use of precision agriculture.

RESULTS AND DISCUSSIONS

In this paper, we analyzed the level of farm equipment in the South Muntenia Region, both in terms of overall agricultural machinery stock and the integration of precision agriculture systems.

In the South-Muntenia region, the evolution of the agricultural machinery fleet from 2015 to 2023 indicates not only a general modernization trend, but also the beginnings of the transition to precision agriculture. The constant increase in the number of physical agricultural tractors, from 34,123 in 2015 to 38,013 in 2023, reflects a renewal of equipment on farms, in the context where modern tractors are often equipped with GPS systems, automated control and integrated sensors, essential for precision agriculture practices. The financing of these investments was supported by Measure 4.1 of the PNRD 2014–2020 and, more recently, by intervention DR-13 of the CAP Strategic Plan 2023–2027.

According to the available information, the intensity of the non-reimbursable support granted under Sub-measure 4.1 varied between 30% and 90%, depending on the economic size of the holding and the type of beneficiary. For vegetable farms with an economic size between 8,000 and 250,000 euro SO, the support was up to 50% of the total eligible expenditure, without exceeding 350,000 euro for simple purchases (AFIR).

Another relevant indicator is the evolution of spraying and dusting machines, which recorded a decrease in 2020 followed by a recovery. This equipment is critical for variable pesticide application, based on crop health mapping — a central practice in precision agriculture. Also, seeding and cultivator equipment can be equipped with technologies that allow variable seeding based on soil analysis, which provides the premises for a more efficient use of inputs. Although the data in the table does not directly reflect the level of digitalization of equipment, the stability or growth of some key categories can be correlated with accessing European funds dedicated to innovative technologies, including additional points awarded to precision agriculture-compatible equipment in the applicant's guides. Thus, the evolution of agricultural equipment in South Muntenia over the last decade highlights a gradual process of transition towards more efficient agriculture, supported by technology and public policies oriented towards sustainability and innovation (Table 1).

Table 1. Evolution of Agricultural Machinery and Equipment in the South-Muntenia Region (2015–2023)

Category of Tractors and Agricultural Machinery	2015	2020	2021	2022	2023	Growth Rate 2015/2023 %
Physical agricultural tractors	34,123	36,336	37,292	37,802	38,013	89.77
Tractor plows	29,426	23,088	23,311	23,398	23,435	125.56
Mechanical cultivators	7,903	5,503	5,789	5,796	5,789	136.52
Mechanical seeders	17,958	13,684	13,575	13,657	13,732	130.77
Spraying and dusting machines with mechanical traction	1,751	1,423	1,527	1,746	1,774	98.70
Self-propelled combine harvesters for cereal crops	5,593	5,454	5,215	5,269	5,451	102.61
Self-propelled forage harvesters	95	142	129	140	149	63.76
Combines and machines for potato harvesting	842	976	977	984	1,012	83.20
Balers for straw and hay	2,849	2,348	2,383	2,410	2,406	118.41
Forage windrowers	254	203	199	191	191	132.98

Source: Calculation based on the number of physically registered units per category provided by National Institute of Statistics - Tempo Online, 2025 [27].

Between 2015 and 2023, the total number of farmers decreased from 882,351 to 734,653, representing a reduction of approximately 16.7%. The largest absolute decrease was recorded in the category of farmers with areas up to 10 ha, from 798,085 to 632,608 farmers, i.e. a decrease of over 165,000 people. The only category that increased in absolute terms is that of farms between 10 - 50 ha, with an increase from 64,045 to 78,540 farmers (+22.7%). The categories 50 - 150 ha and 150 - 1,000 ha also recorded increases, but more modest, of approximately 18% and 15.5%, respectively. The >1,000 ha category remained relatively constant, with a slight increase from 845 to 882 farmers (Table 2).

Between 2015 and 2023, the total utilized agricultural area increased slightly, from 9,171,661 ha to 9,868,326 ha, representing an increase of approximately 7.6%. However, the analysis by area category shows a significant redistribution between types of holdings.

The area exploited by small farms (≤10 ha) decreased significantly, from 2,342,058 ha in 2015 to 1,959,408 ha in 2023, a reduction of approximately 16.3%.

In contrast, the 10–50 ha category increased by over 430,000 ha, representing an increase of 32.6%, the highest percentage increase of all categories.

Table 2. Evolution of the number of farmers by agricultural area categories (2015–2023)

Farm surface category	Number of farmers					Growth Rate %
	2015	2020	2021	2022	2023	2015/2023
<=10 ha	798,085	685,180	677,389	653,588	632,608	126.16
10 - 50 ha	64,045	77,440	77,189	78,652	78,540	81.54
50 - 150 ha	11,485	13,171	13,583	13,906	13,509	85.02
150 - 1,000 ha	7,891	8,681	8,833	9,031	9,114	86.58
> 1,000 ha	845	892	875	879	882	95.80
Total	**882,351**	**785,364**	**777,869**	**756,056**	**734,653**	**120.10**

Source: Calculation based on the number reported by APIA, 2025 [1].

Farms of 50–150 ha and 150–1,000 ha also had moderate increases in the area exploited — approximately 19.3% and 12.1%, respectively. The area worked by large farms (>1,000 ha) remained relatively stable, with a slight increase of 6.9% (Table 3).

Table 3. Evolution of utilized agricultural area by farm size categories (2015–2023)

Farm surface category	Surface					Growth Rate %
	2015	2020	2021	2022	2023	2015/2023
<=10 ha	2,342,058	2,103,592	2,054,451	2,019,664	1,959,408	119.53
10 - 50 ha	1,320,209	1,657,503	1,668,717	1,713,129	1,751,655	75.37
50 - 150 ha	996,053	1,147,735	1,177,992	1,206,185	1,188,448	83.81
150 - 1,000 ha	2,805,553	3,026,985	3,081,643	3,131,973	3,143,930	89.24
> 1,000 ha	1,707,788	1,818,035	1,778,443	1,771,096	1,824,885	93.58
Total	**9,171,661**	**9,753,849**	**9,761,247**	**9,842,047**	**9,868,326**	**92.94**

Source: Calculation based on the number reported by APIA, 2025 [1].

In the southern area of the country, agricultural farms focus mainly on cultivating cereals, benefiting from a predominantly plain relief and fertile soil, favorable to this type of crop. This region stands out as one of the most important from an agricultural point of view at the national level, both in terms of cultivated areas and in terms of productivity obtained.
The distribution of agricultural areas by legal form highlights a clear link between the type of legal organization and the size of the holding. The four Limited Liability Companies included in the sample manage significant areas, ranging from 400 ha to 1,477 ha, which indicates an increased investment capacity, an advanced level of technology and a commercial operational structure. In contrast, the other legal forms are represented by a single holding each: the Sole Proprietorship manages 750 ha, the Self-Employed Individual operates on 500 ha, and the Family Enterprise works an area of 64.01 ha. This dispersion highlights the fact that small and medium-sized farms choose simpler legal forms, characterized by flexibility, but with limited resources, while large farms prefer legal structures that allow better mobilization of capital and wider access to high-performance technologies (Figure 1).

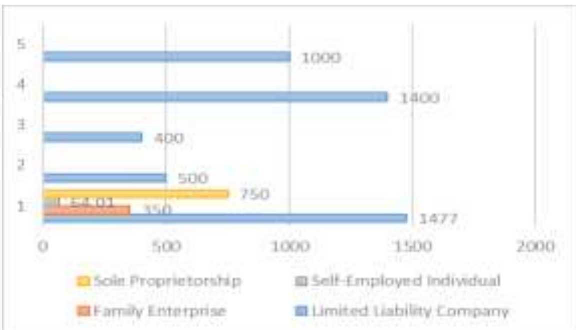

Fig. 1. Size of agricultural holdings analyzed according to legal status
Source: Own representation based on data collected, 2025.

The structure of farms in this area varies depending on the size of the exploited areas, directly influencing the degree of mechanization and technical equipment. Thus, the machinery park of the analyzed farms includes between 3 and 10 agricultural equipment, reflecting a moderate diversity in operational capacity.

Regarding the adoption of modern technologies, the implementation of precision agriculture systems presents a variable chronology. The period of use of these technologies among the surveyed farms varies between 2 and 17 years, which suggests a different degree of digital maturity and integration of innovations into agricultural processes. This temporal differentiation indicates both a growing interest in optimizing agricultural activities and an evolutionary dynamic in terms of access to technologies and specialized know-how.

In the context of the intensification of extreme climatic phenomena in recent years, farmers are facing a significant reduction in optimal working windows. This situation requires rigorous optimization of agricultural activities to respond efficiently to favorable moments from an agrotechnical point of view. The implementation of precision agriculture systems directly contributes to increasing farm productivity, with percentages ranging from 10% to 40%, facilitating the rapid completion of essential agricultural work.

Empirical data indicate that the adoption of these technologies allows for the reduction of production costs by percentages ranging from 10% to 40%, depending on the degree of implementation of digital technologies and the level of mechanization of each agricultural holding. Investments in precision agriculture are in a significant range, with values ranging from 6,000 to 100,000 euros, depending on the size of the farm (number of hectares worked) and the complexity of the implemented systems.

In addition to the economic benefits, the use of precision agriculture technologies has a positive impact on the quality of agricultural production, especially on cereals, which can thus reach higher quality standards and can be more efficiently exploited on the market. These technologies also contribute to environmental protection, providing farmers with a better understanding of land variability, including in terms of productive potential and the presence of diseases or pests.

Advanced technologies also allow for the precise and efficient application of phytosanitary treatments and other inputs at the optimal times, leading to the rational use of resources and reducing the impact on the environment.

In the South-Muntenia region, the most frequently used precision agriculture system is the self-guidance system, considered the basic technology in most farms. It allows for saving input and fuel, while also contributing to increasing productivity. Around 50% of farmers use crop monitoring systems based on satellite imagery, which provide a comprehensive view of crops and allow for early identification of large-scale problems. In addition, 37.5% of respondents use soil sensors and weather stations to monitor soil and climate conditions, indicating a growing interest in sustainable natural resource management. Drones are used by around 25% of farmers, a low percentage probably due to the high costs and complex technical requirements associated with their operation.

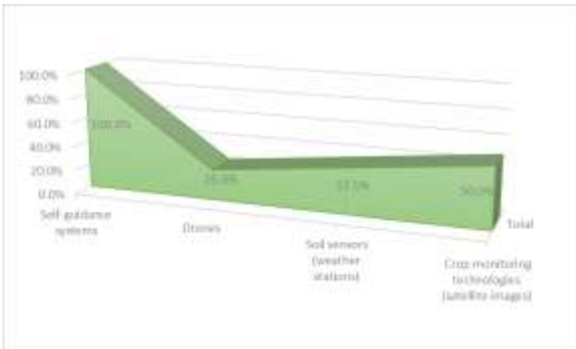

Fig. 2. Types of precision farming systems used in South-Muntenia region
Source: Own representation based on data collected, 2025.

Self-guidance technology is widely adopted by all farmers interviewed, due to its versatility and applicability in all stages of agricultural work carried out in the field. It is an essential component of modern precision farming systems, facilitating significant resource savings and increasing operational efficiency.

Section control technology is used by approximately 62.5% of farmers. It allows for cost reduction by avoiding overlaps in the application of inputs and seeds, thus

Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 25, Issue 2, 2025
PRINT ISSN 2284-7995, E-ISSN 2285-3952

contributing to a more rational use of resources.

Variable rate application, used by 50% of farmers, gives them the opportunity to adjust the dosage of inputs according to soil heterogeneity and the productive potential of different areas within the soils, thus optimizing the yield and sustainability of the farm.

Other 50% of farmers use farm management platforms, digital tools that allow them to systematically document and analyze agricultural activities. These platforms facilitate data-driven decision-making, contributing to improved decision-making and planning of activities.

Regarding the use of prescription maps, only 37.5% of respondents use these advanced tools, which are based on data combining productivity maps, satellite images or agrochemical soil analyses. This relatively low rate of use can be explained by the complexity of the process of developing and integrating these maps into agricultural management systems.

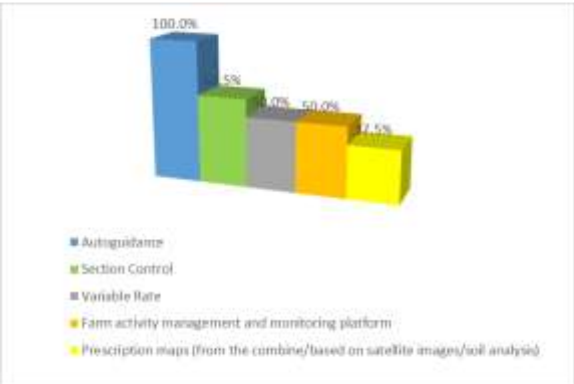

Fig. 3. Types of technologies used in the South-Muntenia selected farms
Source: Own representation based on the data collected, 2025.

The self-guidance system is one of the most widespread and fundamental technologies used in precision agriculture, due to its versatility and wide applicability to most mechanized agricultural works. This technology is compatible with tractors, combines and treatment equipment (sprayers), bringing significant benefits in terms of operational efficiency, cost reduction and optimization of input use.

Within the farms analyzed, a 100% adoption rate of self-guidance systems on tractors is noted. This underlines the importance of technology in performing basic agricultural works, such as soil preparation, sowing or fertilizer application. Self-guidance contributes to increasing the precision of the works, eliminating overlaps, reducing fuel consumption and idle times, which directly leads to increased productivity.

In contrast, the extension of these systems to other machines is lower. Only 62.5% of the farms use self-guidance on combines and sprayers as well. On combines, this technology helps maintain an optimal harvesting trajectory, which minimizes losses and allows operators to focus on harvesting quality parameters and efficient operation of the machine. In the case of sprayers, self-guidance is essential for the uniform application of plant protection products, avoiding overdoses and omissions, and thus contributing to reducing the impact on the environment and protecting crops.

The comparative benefits of using the self-guidance system are thus differentiated, depending on the type of machine: for tractors, the emphasis is on overall efficiency and reducing resource consumption; for combines, on optimizing the harvesting process; and for sprayers, on treatment precision and environmental protection. These advantages justify the growing interest of farmers in extending the use of this technology to all farm equipment.

The implementation of precision agriculture systems generates a series of significant benefits for farmers, reflected in the improvement of the economic and productive performance of agricultural holdings.

According to the data collected, 87.5% of farmers believe that these technologies contribute directly to reducing production costs, by optimizing the consumption of inputs and the efficient management of available resources.

Fig. 4. Distribution of guidance system usage by agricultural machinery type
Source: Own representation based on data collected, 2025.

This is possible thanks to the precise application of fertilizers, pesticides and other treatments according to the specific needs of each cultivated area, avoiding waste and overdoses.

Also, 62.5% of farmers state that the use of precision agriculture systems has led to an improvement in the quality of agricultural production and to obtaining higher yields. This increase in productivity is attributed to the ability of these systems to provide precise and real-time information, which allows for informed agronomic decisions to be made and adapted to the pedoclimatic and biological conditions of each soil.

Therefore, precision agriculture not only supports better resource management, but also plays an essential role in increasing the competitiveness and sustainability of agricultural activities.

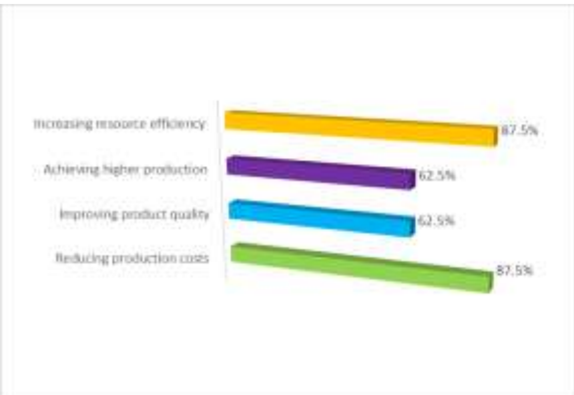

Fig. 5. Farmer-reported advantages of precision agriculture implementation
Source: Own representation based on data collected, 2025.

Although precision agriculture systems bring numerous benefits in terms of economic efficiency and sustainability of agricultural activities, farmers face several significant challenges in the process of adopting and implementing these technologies.

The main obstacle identified by 63% of farmers is the high initial cost of investments required for the acquisition and installation of specific equipment and software. This financial barrier is particularly restrictive for small and medium-sized farms, which have limited resources for such capital investments.

At the same time, half of farmers (50%) emphasize the need to participate in specialized training programs to be able to use these systems effectively. The lack of adequate training can lead to underutilization of available functionalities or inefficient implementations that do not bring the expected results.

The technical complexity of these systems is another impediment noted by 38% of respondents, who consider that the interfaces and operations involved are not intuitive and may require a high level of digital knowledge. This may discourage wider adoption, especially among farmers who are inexperienced in using information technologies.

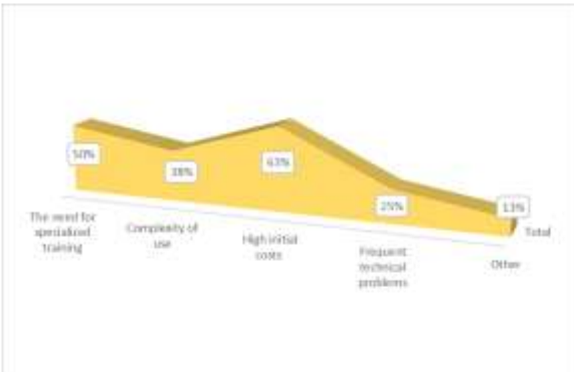

Fig. 6. Main challenges faced in the adoption of precision agriculture systems
Source: Own representation based on data collected, 2025

Also, 25% of farmers reported frequent technical malfunctions in the operation of equipment, which affects the reliability of the systems and generates downtime or additional costs for maintenance and repairs.

These constraints highlight the need for financial support policies, the development of professional training infrastructure and a simplification of technological interfaces, to facilitate the widespread and efficient integration of precision agriculture within farms.

CONCLUSIONS

The study conducted in the eight agricultural holdings in the South-Muntenia region highlights a consolidated trend of adopting precision agriculture technologies, with a full implementation of self-guidance systems on tractors. This technology is perceived by farmers as indispensable, due to its versatility and applicability in all types of mechanized farm work. In contrast, the extension of self-guidance to combines and herbicide machines is limited, which indicates significant potential for development in this direction.

Between 2013 and 2023, the South-Muntenia region recorded different growth rates for agricultural machinery categories, reflecting modernization trends and priorities in the agricultural sector. The highest growth was recorded for mechanical cultivators (131.47%), followed by forage harvesters (129.32%) and mechanical seeders (127.86%), reflecting an increased interest in streamlining soil preparation and sowing.

Among the major benefits reported by farmers are the reduction of production costs, increased efficiency in resource use, improved quality of agricultural production and higher yields. These aspects underline the essential role of precision agriculture in streamlining agricultural processes and ensuring the long-term sustainability of farms.

However, the implementation process is accompanied by several significant challenges. These include high initial investment costs, the need for specialized staff training, the complexity of using the systems and the frequency of technical malfunctions. These difficulties highlight the need for tailored support measures, both financially and in terms of farmer training, to facilitate a wider and more efficient adoption of digital technologies in agriculture. In conclusion, precision agriculture is emerging as a transformative factor in the modernization of the agricultural sector, contributing to increased competitiveness and the transition towards a sustainable agricultural model adapted to current challenges.

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