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THE IMPACT OF PRECISION AGRICULTURE ON THE SUSTAINABILITY OF AGRICULTURAL PRODUCTION

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ABSTRACT

Precision agriculture represents a modern approach to managing agricultural resources that utilizes advanced technologies, all with the goal of optimizing production and reducing negative environmental impacts. With the continuous development of technology, more and more farmers are recognizing the advantages of integrating advanced tools such as GPS systems, drones, sensors, and satellite technologies into their daily practices. The application of precision agriculture in agricultural production allows more efficient use of resources such as water, fertilizers, and pesticides, thereby reducing their consumption and minimizing the negative impact on the ecosystem. Additionally, this technology enables more detailed monitoring of crop health, identification of diseases and pests, as well as the precise application of agrochemicals, improving the quality and yield of products. Agricultural production, as a sector involved in food production, animal feed, and raw materials for industry, faces challenges such as climate change, the reduction of arable land, and the need for greater production efficiency. Precision agriculture is the response to these challenges, as it allows farmers to work with greater precision, increasing productivity and reducing costs. Through the application of these technologies, agricultural production becomes more sustainable, resilient to climate change, and capable of meeting the growing demands of the global food market.

Keywords: *agriculture, precision agriculture, agricultural production, sensors, sustainable.*

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INTRODUCTION

Many previous studies suggest that the world population will reach nearly 10 billion by 2050 (more than a 10% increase compared to the current population), which will simultaneously increase the global demand for food (Bošković et al., 2024; Jocković et al., 2023). In addition to this very important factor, climate change is emerging as a constant problem in production. Extreme weather events and changes in precipitation significantly affect crop yields and water availability.

Energy prices, the import and export of agricultural products, as well as market conditions, can affect the profitability and sustainability of production (Mihailović et al., 2024; Novaković, 2019). The quantity and quality of land, irrigation water, and access to essential inputs such as seeds, fertilizers, and pesticides play a key role in agricultural production. For this reason, we believe that the application of digitalization in agriculture would reduce the costs of fertilizers, pesticides, water, fuel, and other inputs (Grujić Vučkovski & Subić, 2024). Political decisions, together with agricultural policies, can significantly impact the production and export of agricultural products.

Changes in the age structure of the population, mainly in rural areas, and migration to urban environments can greatly alter the course of agricultural production. This primarily refers to the computer literacy of the population remaining in rural areas, i.e., elderly households, where the level of their computer (digital) literacy is taken into account (Grujić Vučkovski & Subić, 2024).

On the other hand, the expansion of urban areas can lead to a reduction in the available arable land and the creation of competition for land, which may decrease the capacity for agricultural production.

The global market conditions also pose challenges to agricultural production, as competition in the production and distribution of agricultural products from other countries affects domestic production (Dukmenić, 2019).

When it comes to Serbia, agricultural production is very important for the Serbian economy, as the agricultural sector generates a surplus in foreign trade exchange with other countries (Grujić et al., 2021; Grujić Vučkovski & Subić, 2024). The state of agricultural production in Serbia faces numerous challenges that have various direct impacts on its development, competitiveness, and sustainability. A noticeable decline in livestock production, reduced efficiency per hectare, a weak strategic approach, and the disappearance of small farms represent the main obstacles to the progress of this sector.

The biggest problem is noticeable in livestock farming, which is why this example is considered. A nearly halved livestock population in Serbia was observed during the last decade of the 20th century. The significant decline in livestock production continued as a result of several factors, including a lack of modernization, insufficient support for farmers, and unfavorable climate changes. Based on the agricultural census conducted in 2022, a decrease in the number of farms engaged in livestock farming was recorded, with 6 out of 10 farms involved in livestock farming, compared to 2018, when the situation was better (8 out of 10 farms). Table 1 shows the percentage decrease in livestock breeding.

Table 1. Livestock Population

Population	Number	Percentage decrease compared to the 2018 survey
Cattle population	725,408	17.7%
Pig population	2.263,705	30.7%
Sheep population	1.702,682	5.4%
Goat population	149,558	31.5%
Bee population	22.022,439	5.0%

Source: Popis poljoprivrede, 2023.

The number of pigs and goats has experienced the greatest decrease, and this trend represents a direct impact on agricultural production, leading to long-term changes in food supply security. Many factors contributing to such a decrease can be mitigated by using precision agriculture technologies. The use of such systems in livestock farming allows for the measurement of physiological and production indicators for each animal individually, thereby contributing to better strategic farm management (Bewley, 2010). This process involves the selection of genetically superior breeds, using performance data that can be analyzed. This information can increase the livestock population and thus ensure stable production results.

MATERIAL AND METHODS OF WORK

This paper presents a literature review that examines the impact of various factors on agricultural production, with a focus on precision agriculture. The aim of the paper is to analyze existing studies, research, and theories related to agricultural production and to provide a comprehensive overview of the development in this field to date. The originality of the paper involves undertaking specific activities to justify the research goal and evaluate the acquired knowledge. The topic addressed is also attractive, as it is well-known how the introduction of digitalization in agricultural production is an inevitable process for market-oriented farms.

During the research, a brief overview of agricultural production in Serbia in the past period was also made, highlighting changes observed from the results of the 2023 Agricultural Census. Special attention is given to changes in the livestock sector in relation to the status of livestock recorded during the implementation of the 2018 Agricultural Holdings Structure Survey.

DISCUSSION

In the following sections of the paper, we will focus on the possibilities of applying precision agriculture and examine its significance in terms of increasing resource use efficiency, optimizing yields, reducing negative environmental impacts, assessing risks from unforeseen situations, adapting to daily climate changes, and evaluating crop conditions.

Precision agriculture utilizes various modern technologies such as satellite imagery obtained from space, GPS positioning, and sensors, which enable detailed monitoring of field conditions. By using these technologies, farmers can manage resources such as water, fertilizers, pesticides, and seeds with high precision (Marina, et al., 2024; Sanyaolu & Sadowski, 2024). This technology replaces the application of resources uniformly across the entire area with targeted application only in the parts of the land that actually

require them, allowing for interventions on precisely targeted areas (Bongiovanni & Lowenberg-DeBoer, 2004). In recent decades, with the advancement of technological solutions, the use of sensors for precise irrigation has become more widespread. Such use of sensors for accurate measurement of moisture levels helps prevent water losses and reduces water-related costs. In areas with arid climates and limited water resources, these sensors provide better conditions for agricultural production (García et al., 2020).

One of the most important goals of precision agriculture is yield optimization (Khanal et al., 2017). By using technologies such as drones, automatic spraying systems, and GPS, farmers can analyze yield variations across different parts of a field. Based on this data, they can take targeted actions, such as applying additional nutrients or pesticides only to areas of land that require them. Figure 1 shows an orthomosaic created using the DJI Mavic 3M aerial unmanned aerial vehicle (UAV). This orthomosaic of a vineyard serves as an example of how this technology can be applied. The use of UAV is much more effective on larger areas where it is difficult to monitor the entire field.

Figure 1. Ortomozaik, Source: author

The use of UAVs for collecting data on crop conditions enables easier and more accurate analysis of the current field status, such as moisture levels, plant health, and infection levels. The application of UAVs ultimately aims at precise pesticide spraying, leading to better yields (Tsouros et al., 2019; Kim et al., 2019).

Precision agriculture contributes to reducing the negative environmental impact through decreased use of pesticides and fertilizers (Marina et al., 2024). The goal is to apply these inputs only where they are necessary, thus reducing excessive contamination of soil, water, and air (Pajić et al., 2019). Additionally, the use of these technologies reduces soil erosion and enables sustainable land use. The implementation of precision irrigation and the targeted use of pesticides significantly reduces resource losses and minimizes the risk of groundwater contamination (Nikolić Roljević & Paraušić, 2019).

Precision agriculture enables better risk assessment of natural disasters, diseases, and pests through the use of sensors and meteorological data. By using this data, farmers can predict unfavorable weather conditions and respond quickly, thereby reducing the risk of production losses.

Precision agriculture helps in adapting to daily climate changes by allowing farmers to better address challenges related to weather conditions, as it provides real-time data, thus reducing dependence on weather impacts (Suciu et al., 2019). By using technologies

to monitor microclimates and specific crop needs, farmers can respond more quickly to changes in conditions, such as droughts or heavy rainfall. The use of satellite data for climate change analysis enables farmers to better prepare for changes in temperature and humidity conditions, reducing the risk of poor yields (Mendelsohn et al., 2007). This way, the number of agricultural operations is reduced, positively affecting the reduction in input consumption and gas emissions (Garg et al., 2024).

Sensors applied for crop health analysis allow farmers to quickly detect diseases, pests, or nutritional deficiencies. These technologies enable timely intervention, reducing the need for heavy chemical protection and improving crop quality. The use of UAVs with multispectral cameras can precisely identify parts of the crop affected by diseases, allowing for timely intervention with targeted pesticide application (Mulla, 2013).

Additionally, precision agriculture enables farmers to use large amounts of data to make decisions based on concrete and precise analyses (Pande & Moharir, 2023). This data includes information about soil, climate conditions, crop health, and many other factors, allowing for better production planning. The authors Lopresti et al. (2015) developed a model that can predict yields up to 30 days before the harvest. Figure 2 shows a visual representation of the connection between precision agriculture and sustainable agricultural production.

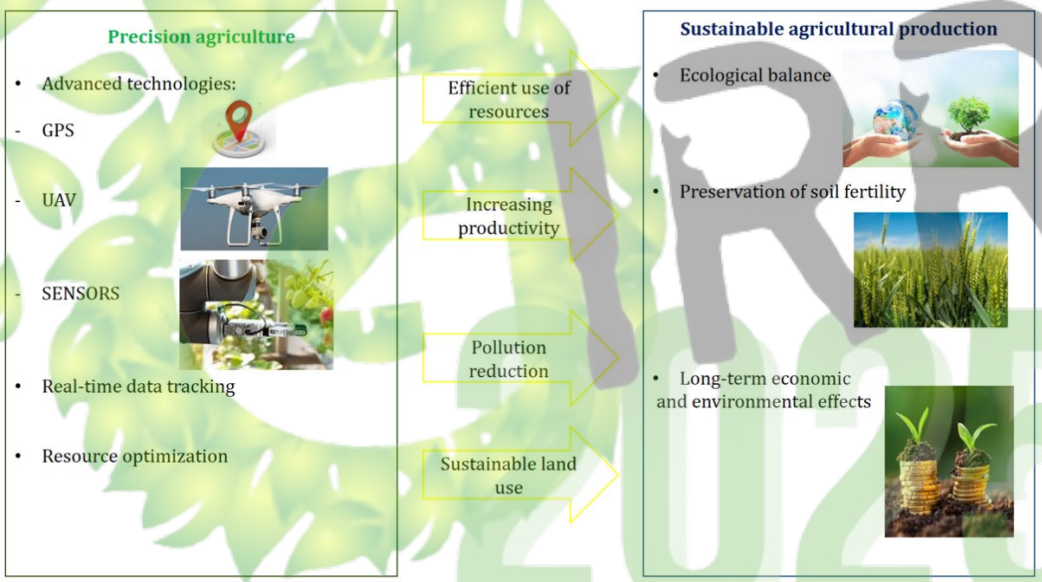

Figure 2 The connection between precision agriculture and agricultural production., Source: author

CONCLUSIONS

The direct connection between precision agriculture and agricultural production clearly shows that this approach is crucial for the future of sustainable agriculture. Precision agriculture contributes to a significant increase in resource use efficiency, enabling farmers to reduce the consumption of all resources, thereby directly lowering costs and increasing profitability. Additionally, yield optimization allows for better utilization of available resources, achieving higher yields with lower energy and material consumption.

One of the key aspects is the reduction of negative environmental impacts, as precision agriculture enables the application of resources only where they are truly needed, reducing soil and water pollution. Given the increasingly frequent climate changes, precision agriculture allows for quick adaptation to changing conditions, providing various types of technologies for monitoring and predicting changes throughout all stages of growth and development of different crops.

Precision agriculture represents a key step in modernizing agricultural production, as it not only improves efficiency but also provides solutions to challenges such as climate change, reduced input use, and the need for higher yields.

Precision agriculture also yields positive results in addressing the issue of digital literacy within the population by organizing workshops, training sessions, and similar initiatives.

In general, through the application of these technologies, agriculture becomes more sustainable, resilient, and capable of meeting the growing global food demand. The implementation of precision agriculture offers more benefits than drawbacks, making it essential for agricultural producers to define their goals during the execution of agricultural production processes.

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