NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 41, 2024
www.incda-fundulea.ro; doi.org/10.59665/rar4108 First Online: December, 2023. DII 2067-5720 RAR 2024-32

Analysis of the Application of Modern Technologies in Agriculture in Three Balkan Countries and the Impact on Biodiversity

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ABSTRACT

In this study, an in-depth analysis of the application of modern technologies in agriculture in three Balkan countries - Serbia, Bosnia and Herzegovina and Montenegro were conducted and its potential impact on the biodiversity of these regions is examined. Agriculture, as a main activity in these countries, brings challenges and opportunities due to the need to increase food production while preserving natural ecosystems.

The first part of the study analyzes available data on the use of modern technologies in agriculture. Special attention is given to technologies such as precision agriculture, the use of drones, sensors and software solutions to control the crop production process.

The second part of the research is devoted to the analysis of the impact of these technologies on biodiversity. Changes in land use, pesticide application, and water resource management are used to examine how digital transformation affects local ecosystems and biodiversity. Possible positive and negative impacts will be compared, taking into account the protection of wildlife, insects and plants.

Based on the analysis, possible strategies for the sustainable use of technologies in agriculture will be explored to minimize negative impacts on biodiversity.

Keywords: modern technologies, agriculture, economy, biodiversity, Balkan.

INTRODUCTION

In the era of the fourth industrial revolution (Industry 4.0), adaptations of new technologies such as drones, GPS, remote sensing, and IOT are important for use in agriculture (FAO, 2018). In 2050, it is estimated that there will be 9.7 billion people on the planet, so it will be of great importance for countries to have a developed food security system, which is highlighted in the Sustainable Development Goals (Shariff et al., 2022). Increasing production, reducing costs, reducing the number of labourers, reducing high dependence on foreign labour, reducing dependence on food imports, and increasing resources could be achieved by adapting various techniques in modern agriculture (Mladenović, 2016).

Intensive and extensive agricultural systems managed with improved varieties of different crop populations are a widespread reality in many Mediterranean countries. However, in inland and less intensively managed rural areas, old plant varieties have survived modern farming systems and preserved a unique genetic heritage. These plant species represent a unique genetic resource; their conservation and genetic maintenance through agamic propagation is now promoted by agricultural development and innovation agencies. Each tree represents a center for biodiversity conservation in agroecosystems: its spatial arrangement and temporal stability guarantee ecological niches and microhabitats suitable for members of the flora and fauna important for biodiversity conservation (Palli et al., 2023).

Modern agriculture is rapidly increasing its productivity, but it is also paying a high price for the excessive consumption of natural resources and the use of energy that is not environmentally sustainable (Gascoigne et al., 2017). To build a sustainable agricultural future, Western Balkan countries must address key challenges such as pollution, climate change, and threats to biodiversity. Adopting sustainable technologies

Received 1 October 2023; accepted 2 November 2023.

for precision agriculture in the region will optimize the use of inputs and increase productivity. Promoting smart agriculture based on the ongoing debate on the future design of the national agricultural policy with policy alignment and the use of EU funds to support farmers is necessary for the region (Vasa et al., 2018).

The Balkan countries - Serbia, Bosnia and Herzegovina, and Montenegro - are facing the challenges of sustainability in agricultural production while striving to take advantage of modern technologies. While digitalization offers undeniable benefits, the question is how to balance this revolution with the need to preserve biodiversity and the harmony of natural ecosystems (Marković et al., 2018). Sustainable agriculture fundamentally aims to achieve economic success with minimal negative impact on the environment. Technological innovations promise to facilitate this balance, but also to provoke thought (Petrović et al., 2019) The key questions that arise are how modern tools such as precision agriculture, Internet of Things (IoT) devices, and automation can be used to maximize productivity with a minimal environmental footprint (Jovanović et al., 2020).

Biodiversity, the foundation of healthy agriculture, requires special attention. On the one hand, technology can ensure more efficient production; on the other hand, it can threaten the balance of natural ecosystems (Šarković et al., 2016). The introduction of modern technologies should go hand in hand with strategies to protect and restore biodiversity. Local species, such as autochthonous plants and animals, should be promoted through technologically assisted breeding methods (Stevanović et al., 2021). The environmental impact of increasing food demand will depend on the direction in which global agriculture evolves (Rockström et al., 2017). Preserving global biodiversity and minimizing agriculture's impact on global greenhouse gas emissions may depend on this path (Șerdinescu et al., 2023). A pathway that adapts and implements modern technologies to food-deficient countries improves soil fertility, ensures more efficient use of nutrients and minimizes soil degradation (Pretty et al., 2018). At the same time, it enables ecologically sustainable intensification of agriculture and long-term equitable distribution of food supplies on a global scale (Bharucha et al., 2021; Smith et al., 2022). This research focuses on a deeper analysis of the implementation of modern technologies in the agriculture of three Balkan countries. The goal is to understand how innovations, including IoT devices, automation, digitization, and precision agriculture, are shaping the agricultural landscape. In addition, the research will explore in detail the possible implications of these transformations on the biodiversity and sustainability of regional ecosystems.

MATERIAL AND METHODS

The methodology used in the preparation of this research included a combination of quantitative and qualitative methods. The quantitative aspect of the investigation was based on the collection and analysis of data on the implementation of technologies and their impact on production results. This part of the research provided numerical evidence on increasing yield capacity and reducing losses through the use of modern technologies.

The qualitative aspect of the research complemented the quantitative aspect through in-depth analyzes of the perceptions and experiences of agricultural stakeholders. Interviews with farmers, biodiversity and technology experts provided an understanding of the motivations for adopting technologies, the interaction of these technologies with natural ecosystems, and the broader social and economic impacts. This integrated approach allowed for a holistic analysis of the impact of modern technologies on agriculture, using numerical results with a contextual understanding of their application. Through this combination of quantitative and qualitative methods, the research aimed to provide relevant insights for informed decision-making and the promotion of sustainable agricultural practices.

RESULTS AND DISCUSSION

The discussion was focus on a deeper analysis of the results and their relation to the theoretical framework. It analyzed how digital transformation affects different aspects of agriculture, including productivity, resourse use and land use.

It also highlight the impact of these changes on biodiversity and natural habitat conzervation.

In Serbia, Bosnia and Herzegovina and Montenegro, technological innovation is gradually being integrated into agricultural practices to improve efficiency and maintain sustainability. Key technologies vary across countries, but some common trends are evident. Table 1 shows the results of the survey of experts responsible for the implementation of modern technologies in practise and for monitoring the results in different segments of agricultural production.

Table 1. Usage of technological innovation in region

	Serbia	Bosnia and Herzegovina	Montenegro
Technology	Precision agriculture	GPS controlled machinery	Mobile apps for crop monitoring
Use	Plot mapping, tailored crop nutrition	Precision seeding and pesticide application	Harvest management on the go
Technology	IoT sensors	Intelligent irrigation systems	Online platforms for training
Use	Monitoring soil moisture and temperature	Water management and resource conservation	Training farmers in modern techniques
Technology	Automated machnery	Satellite monitoring of crops	Connection to the market
Use	Seeding, harvesting, pesticide application	Early detection of stresses in crops	Facilitating sales and distribution
Technology	Drones	E-markets for sales	Use of biological agents
Use	Crop monitoring, pest detection	Connecting growers and buyers	Reduction in the use of chemical agents

According to the research results, precision agriculture, IoT sensors, automated machines and drones are leading in technological innovations in Serbia. As for Bosnia and Herzegovina, GPS-guided mechanization, smart irrigation systems, satellite monitoring of crop conditions, and electronic market trade are the most prominent. In agriculture, Montenegro has introduced mobile applications for crop condition monitoring, online platforms for farmer training, and market connectivity and use of biological agents. Analysis of the data presented shows that Serbia is making extensive use of precision agriculture and GIS mapping for better resource management. In Bosnia and Herzegovina, the use of IoT devices for habitat monitoring and irrigation, while in Montenegro, the focus is on automated irrigation and using IoT sensors to optimize soil moisture. Drones are ubiquitous in all countries and are used to quickly and accurately monitor crop conditions and identify potential problems.

When we analyze this data from the perspective of technological innovation, we can see that all three countries are actively adapting to modern agricultural practices. The use of precision agriculture, IoT devices, automation, and drones allows for more efficient production while reducing resources and potentially increasing yields. Data also shows that these technologies can have positive impacts on agricultural sustainability. Precise use of mineral fertilizer and water reduces negative environmental footprints, while automation can reduce resource losses. However, it is important that these advances are properly managed to maintain the balance of natural ecosystems and biodiversity. Figure 1 illustrates the distribution of technological innovations in agriculture in all three mentioned countries.

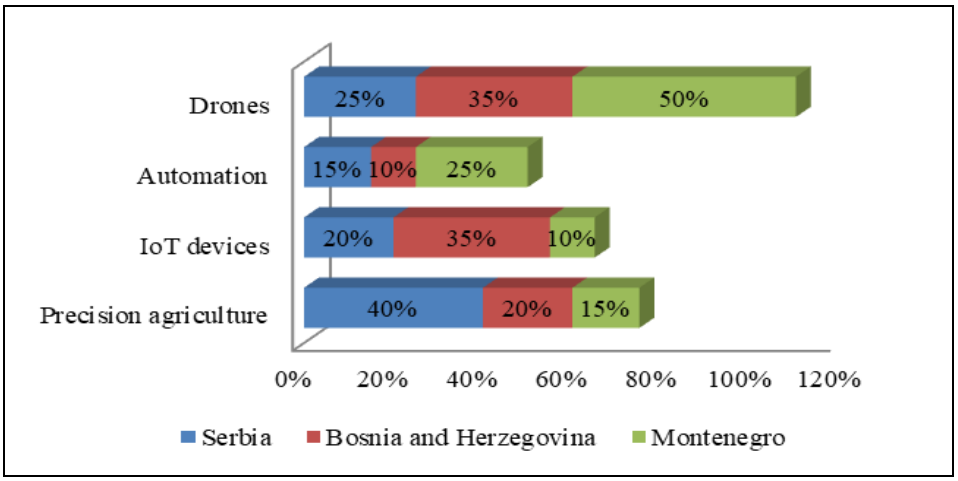

Figure 1. Distribution of technological innovations in agriculture

The introduction of modern technologies in agriculture has led to a significant increase in productivity compared to traditional methods. Changes in yields and efficiency can be seen in each country. This response provides an insight into the changes in productivity that are noticeably occurring due to the use of modern technologies. The percentage values for increasing yield capacity and reducing losses are shown in Figure 2.

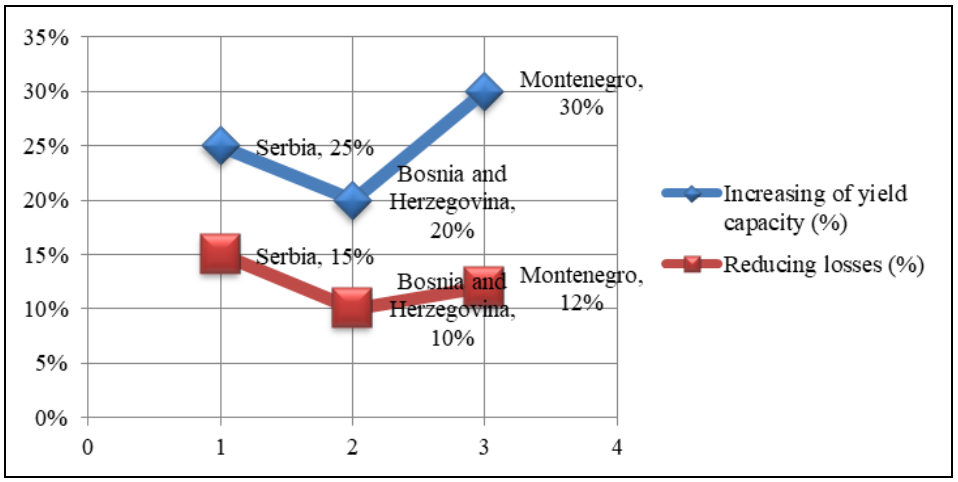

Figure 2. Impact of modern technologies on productivity

Description of increase or decrease:

1. Serbia:

- A 25% increase in yield capacity is achieved through the use of technologies such as precision agriculture and automation. These technological advances allow for optimal fertilization and irrigation, which contributes to higher crop yields.

- Better monitoring of crop condition reduces losses from pests and diseases by 15%. The use of IoT devices and drones enables rapid detection of potential problems and timely intervention;

2. Bosnia and Herzegovina:

- Technology improves yield capacity by 20% thanks to GPS-guided machinery for seeding and spraying. These machines allow a better distribution of resources and a more precise cultivation of the soil.

- A reduction in crop damage is achieved through the use of automatic irrigation systems and better crop monitoring. The technology enables precise metering of water and spraying, reducing losses;

3. Montenegro:

- Technology supports 30% higher yields and greater efficiency thanks to IoT sensors

that monitor soil moisture and automate irrigation. These devices enable optimal use of water and better conditions for plant growth.

- Early detection of problems reduces crop losses by 12%. Using drones to monitor and map demage allows for quick intervention and minimizes the impact of damaging factors.

Technological advances can significantly transform rural areas by increasing productivity and efficiency while reducing resource use. However, little is known about the barriers to farmer adoption of such technologies, particularly in developing countries such as the Balkans. As shown in Table 2, seven categories of factors were identified, which include sixteen barriers that have a significant impact on the adoption of modern technologies in agriculture.

Table 2. List of factors influencing the introduction of modern technologies in agriculture

Category	Impending factor	Relevance
Impacts on local ecosystems and biodiversity	Reduction in areas of natural habitats	Increased demand for cropland can lead to loss of natural habitats.
	Changes in land use	Some sectors are mooving to more intensive production, which affects the distribution of land.
	Increased use of pesticides	Use of technology requires frequent application of pesticides, which can impact on animal species.
	Impacts on insect populations	Changes in pesticide use can have serious consequences for insects and pollinators.
Technical	Rural infrastructure	Lack of stable internet in rural areas
	Sustainability	Concern for long-term maintenance and recycling of technological equipment.
Social	Training	Lack of trained personnel for effective technology management.
	Income diversification	Technology is enabling more diverse sources of income, such as agritourism and online sales.
	Reduction in workforce	Automatisation can lead to a reduction in the need for labor.
	New skills	Need for technological skills creates new opportunities for training and employment.
Behavioural	Attitude to adopt	Some see technology as an opportunity for sustainability and efficiency, while others express concern about the potential negative impacts.
Operational	Access to data	Lack of reliable weather and crop data.
Economic challenges	Financial challenges	High cost of acquiring and maintaining technologies.
Implementation	Subsidies	Government financial support for technology acquisition facilitates access.
	Regulations	Regulations can encourage or restrict the adoption of technologies.
	Sustainability initiatives	Legislative frameworks can encourage the adoption of technologies that support biodiversity.

As technology evolves, some perceived barriers may become obsolete over time. Therefore, identifying relevant obstacles, taking into account all factors, can lead to timely interventions. For the aforementioned reason, it is necessary to conduct similar

analyzes for other developing countries, and the aforementioned studies should be periodically reviewed in light of technological advances. This may lead to new strategies to improve the adoption of new technologies in developing countries. Table 3 shows how technologies such as precision agriculture, IoT devices and automation are used to efficiently use resources such as water, pesticides and fertilizers. Strategies for reducing resource use are presented, focusing on examples from each country.

Table 3. Optimization of resource use

Resource	Serbia	Bosnia and Herzegovina	Montenegro
Water	Precise irrigation reduces water use.	Intelligent irrigation systems optimize water use.	Automation of irrigation reduces water losses.
Pesticides	Precise application reduces pesticide use.	Precise application of pesticides with GPS guided machinery.	Use of drones for precise application of pesticides reduces costs and negative impacts.
Fertilizer	Adapted crop nutrition reduces fertilizers use.	Precise application of fertilizers using GPS technology.	Automated machinery reduce the loss of fertilizer and the harmful effect on the environment.

The application of technologies such as GPS-guided machinery and the use of drones allow precise application of pesticides and mineral fertilizers. Automated machinery additionally helps to reduce the loss of fertilizers and pesticides and prevent harmful effects on the environment. Table 4 analyzes the main challenges to the adoption of modern technologies in agriculture in each of the countries mentioned. Barriers such as financial costs, lack of trained personnel, and infrastructure problems are presented with specific examples from each country.

Table 4. Challenges in the application of modern technologies

Challenge	Serbia	Bosnia and Herzegovina	Montenegro
Financial costs	High cost of acquiring and training to use modern technologies.	Lack of funds to invest in technologies.	Lack of financial resources to implement technologies.
Lack of knowledge	Need for training for effective use of technologies.	Lack of professional to provide technical support.	Need for training for farmers in the use of technologies.
Infrastructure	No stable internet in rural areas.	Weak infrastructure makes connectivity difficult.	Limited internet access in rural areas.

In Serbia, high financial costa are a major challenge for farmers. Acquiring and training in the use of certain technologies can be expensive, making access to these advanced tools difficult. Lack of knowledge about the proper use of the technology also makes it difficult to use effectively. Bosnia and Herzegovina faces similar financial and technical challenges. In Montenegro, limited infrastructure, especially in rural areas, poses a challenge to the successful application of modern technologies. Ristić (2018) notes that sustainable development of agriculture is one of the most important tasks of modern society. According to the author, this requires modern education, with an innovative approach and greater investment in research and development of modern technologies, and at the same time, it also requires appropriate policy in this area. Sustainable agriculture conserves resources such as soil, water, and biodiversity, protects the environment, and meets the needs of current and future generations (Koyuncu et al., 2023). Table 5 shows the research results on the impact of digital transformation of agriculture on local ecosystems and biodiversity in Serbia, Bosnia and Herzegovina, and Montenegro. Shown are changes in habitats, pesticide use, and diversification, with a focus on impacts on nature.

Table 5. Impact of digital transformation on biodiversity

Influence	Serbia	Bosnia and Herzegovina	Montenegro
Habitat changes	Urbanization reduces the area of natural habitats.	Intensive agriculture reduces natural habitats.	Land use changes affect habitats.
Pesticides use	Use of pesticides can negatively impact on insects.	Pesticides use can endanger pollinators.	Pesticide monitoring with IoT devices reduces harmful impacts.
Diversification	The need to diversify crops to maintain diversity.	Crop diversification helps maintain biodiversity.	Diversification of crops and habitats promotes biodiversity.

In Serbia, increasing urbanization is having an unfavorable impact on natural habitats. Development of urban areas reduces the area of available natural habitats, which can lead to a loss of diversity of plant and animal species. In Bosnia and Herzegovina, intensive agricultural practices can also affect natural habitats. Excessive use of pesticides can disrupt ecosystem balance and negatively impact populations of pollinators and other beneficial insects. Montenegro is facing with land use changes that have dramatic impacts on habitats and biodiversity. The need to expand agricultural land or change land use can seriously disrupt natural ecosystems. Table 6 shows the analysis of farmers' attitudes towards the use of technologies and their impact on biodiversity, as well as the need for additional training. Different attitudes and training needs are presented for each of the countries mentioned.

Table 6. Farmer attitudes and training needs

Aspect	Serbia	Bosnia and Herzegovina	Montenegro
Attitudes	They vacillate between enthusiasm and concern.	Farmers are interested, but they are looking for support.	There is interest, but also need for training and support.
Need for training	Training for proper use of technologies is needed.	Lack of professional support for effective use of technologies.	Needed education on benefits and challenges.

In all three countries, especially in Bosnia and Herzegovina and Montenegro, the lack of professional support for the efficient use of technologies is a major challenge. Farmers express the need for additional training to understand the benefits and challenges of the digital transformation of agriculture. The importance of education in the process of technology adoption in agriculture is key and underscores the need for support and training to ensure proper use of technologies and maximum benefits for farmers. Table 7 shows how government policies and regulatory frameworks influence the adoption and implementation of modern technologies in agriculture.

Table 7. Impact of policy and regulation on the adoption of technologies

Aspect	Serbia	Bosnia and Herzegovina	Montenegro
Government initiatives	Subsidies for the purchase of technologies.	Incentives for the use of technologies.	Support through subsidies and education.
Regulations	Regulations can support or limit adoption.	Lack of clear regulations for technology.	Need for flexible regulations.

Government initiatives and regulatory challenges in each of the countries mentioned are presented. Policies and regulations are important in shaping the conditions for successful adoption and application of modern technologies in agriculture. Government initiatives, subsidies, and regulations play a key role in helping farmers realize the benefits that technology can bring. Rodino et al. (2023) reached similar conclusions in their research on the challenges of digitizing agriculture in Romania. They note that digital technologies are advancing rapidly and bringing changes

to all parts of the value chain, from agricultural production to the end consumer. The adoption of these technologies will improve efficiency, create new jobs, generate new sources of income and save resources. Table 8 presents an analysis of the impact of modern technology in agriculture on the socioeconomic aspects of rural communities.

Table 8. Impact on socioeconomic aspects

Aspect	Serbia	Bosnia and Herzegovina	Montenegro
Income diversification	Technology allows for more diverse income sources.	Introduction of agritourism and online sales.	Income diversification through new business models.
Employment	Automation may reduce need for lobour.	Possible decrease in employment due to automation.	New employment in sectors such as IT to support technology.

The changes in income diversification, employment, and economic dynamics in each of the mentioned countries are presented. The application of modern technologies enables farmers to develop more diverse sources of income. This is achieved through more efficient production, higher quality products, and the possibility of placement in different markets. Similar conclusions were reached by Bularda et al. (2023). Modern technologies not only contribute to income diversification through more efficient agricultural production, but also support the development of agritourism and online sales. The technology support sector, like the IT sector, can create new employment. Table 9 shows examples of best practices and pilot projects that have already been implemented with the goal of conserving agricultural biodiversity.

Table 9. Best practices and pilot projects for biodiversity

Projects	Serbia	Bosnia and Herzegovina	Montenegro
Eco-seed systems	Introduction of eco-seed systems.	Introduction of agroecological plans.	Smart irrigation systems that save water.
Use of drones	Recording of crops and detection of problems.	Monitoring the condition of crops using drones.	Use of drones for damage mapping.
Habitat conservation	Natural habitats conservation initiatives.	Intra-agricultural wildlife corridors.	Creation of green corridors.

Specific initiatives for habitat conservation and technology use in each of the countries mentioned are presented. Best practices and pilot projects show that it is possible to achieve sustainable agriculture that balances the needs of productivity and conservation of natural resources. Bularda et al. (2023) concluded that modern agricultural practices use advanced technologies and data analytics to optimize crop production and reduce waste. This includes the use of sensors and other devices to monitor and collect data on soil moisture, plant health, and weather conditions, which are then used to make decisions about irrigation, fertilization, and pest control. Table 10 provides key recommendations for harmonizing agricultural modernization and biodiversity conservation in Serbia, Bosnia and Herzegovina and Montenegro.

Table 10. Key recommendations for harmonization of modernization and biodiversity

Recommendations	Serbia	Bosnia and Herzegovina	Montenegro
Education	Education in sustainable practices.	Education on technologies and their impacts.	Education about the benefits and challenges of technologies.
Incentives	Incentivize technologies that support sustainability.	Financial support for the purchase of technologies.	Support through grants and education.
Local collaboration	Collaboration between farmers and government agencies.	Platforms for sharing experiences and information.	Cooperation networks between sectors.

Guidelines for education, support, and cooperation are presented to achieve a balance between technical progress and conservation. These recommendations point out that education, incentive support, and increased local collaboration play a key role to achieving a balance between the modernization of agriculture and the preservation of biodiversity.

Obtained results of the analysis

An SWAT analysis was conducted that highlights common strengths and weaknesses as internal indicators, on the one hand, and opportunities and threats as external factors, on the other, in the application of modern technologies in agriculture for three Balkan countries: Serbia, Bosnia and Herzegovina, and Montenegro (Figure 3).

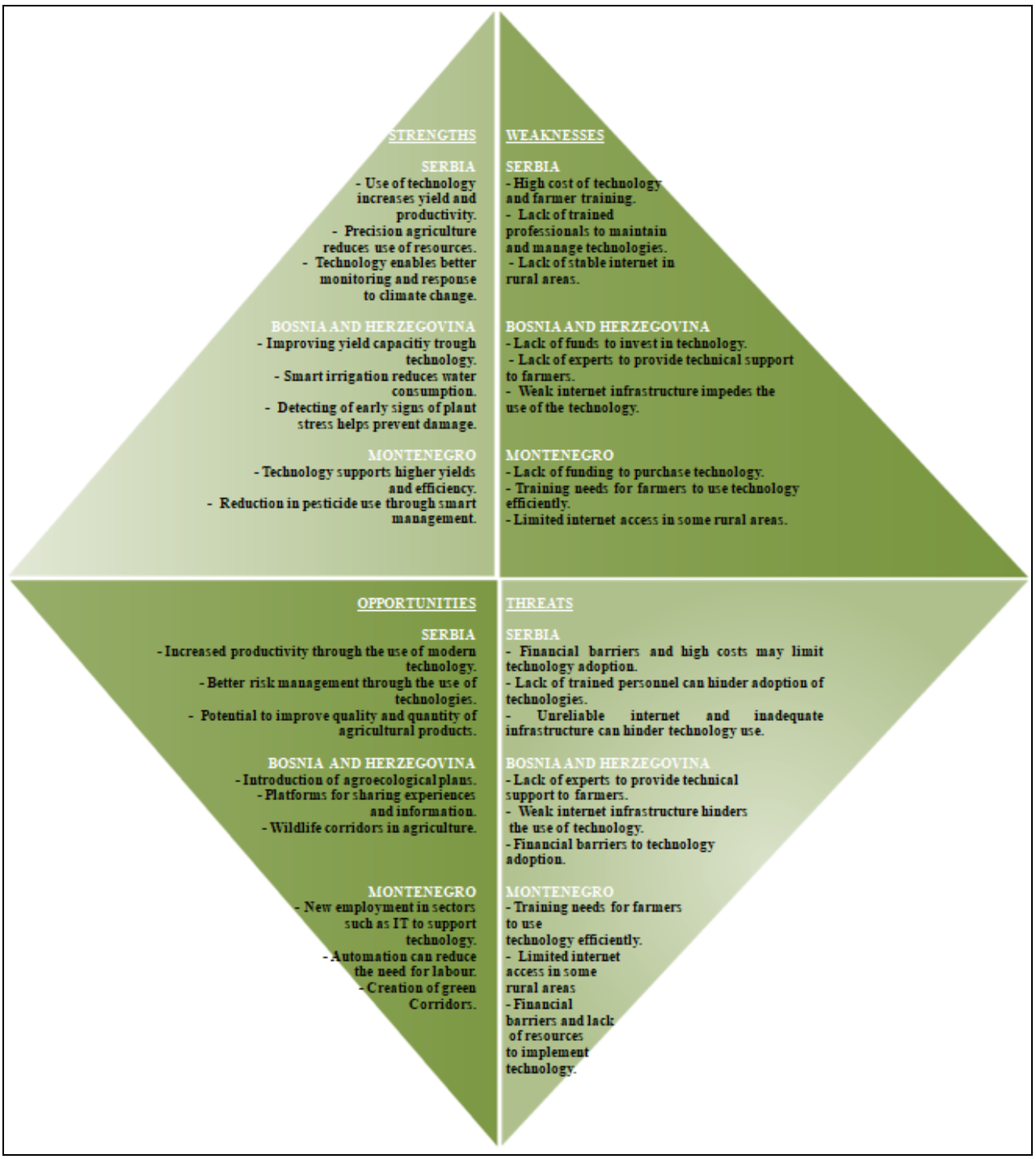

Figure 3. SWAT analysis of the application of modern technologies in agriculture for three Balkan Countries

CONCLUSIONS

Based on a comprehensive analysis, the conclusions highlight the potential of technology to transform agriculture, but also the need for balance to preserve biodiversity. Key guidelines for supporting actions are identified, including training and empowering farmers to take advantage of digitalization with minimal negative impact on natural ecosystems. In addition, the conclusions identify perspectives for further research, including a deeper understanding of socioeconomic dynamics and inclusive initiatives for sustainable agriculture.

The concept of sustainable agriculture plays a key role in solving environmental problems and meeting human needs for food and resources. Sustainable agriculture is based on the efficient use of resources, the protection of biodiversity, and the balance of ecosystems. The European Union (EU) recognizes the importance of this concept through the European Green Deal and the Common Agricultural Policy (CAP), which focus on biodiversity protection, natural resource management, and rural support.

As an integral part of agriculture, biodiversity plays a key role in ensuring a healthy environment and high-quality food. The EU Biodiversity Strategy to 2030 sets ambitious targets for the protection and restoration of natural ecosystems. Biodiversity conservation is critical for maintaining ecosystem services and adapting to climate change. Under the ZPP and Rural Development Program, some countries are working to conserve and revitalize ancient plant and animal species, which promotes local biodiversity and the preservation of traditional farming practices.

Innovation plays a key role in the development of sustainable agriculture. Technological modernization enables more efficient and economical practices. In Poland, for example, there are research centres such as the Institute of Soil Science and Plant Breeding (IUNG) and the Institute of Technology and Life Sciences (ITP) that develop innovative solutions for agriculture. However, despite the great research potential, investment in science remains limited.

Achieving sustainable agriculture requires a holistic approach that includes biodiversity protection, the application of innovation, and government and society support. By implementing policies such as the European Green Deal and CAP, the EU and countries such as Poland are creating a framework for sustainable agriculture that balances food production and conservation. This approach will help create sustainable agricultural systems that can meet the challenges of the future.

From the conclusions, several recommendations for the promotion and enhancement of agricultural biodiversity emerge for all three Balkan countries mentioned above (Figure 4).

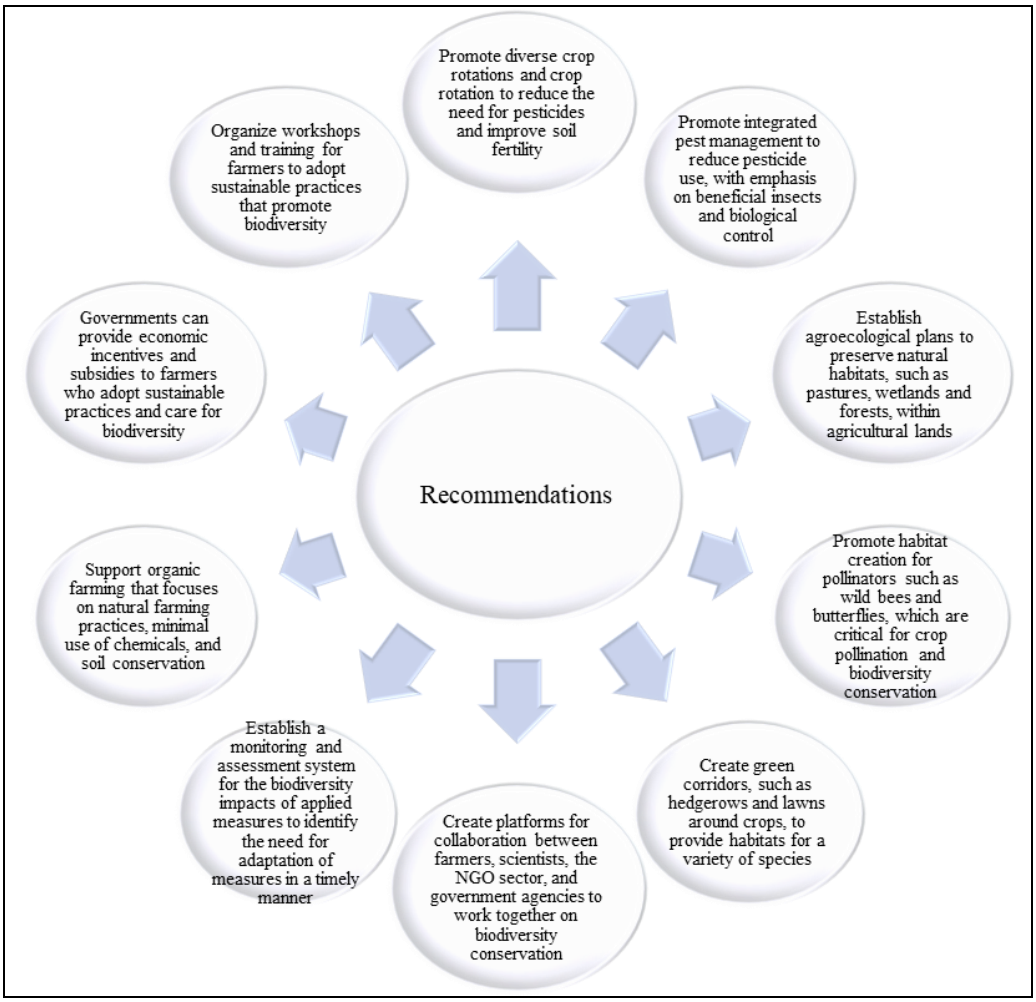

Figure 4. Recommendations for the promotion and enhancement of agricultural biodiversity

These recommendations aim to promote sustainable agricultural practices that support biodiversity and the balance of natural ecosystems.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Contract No. 451-03-47/2023-01/200088.

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