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MODERNIZATION OF AGRICULTURE IN SERBIA: QUANTITATIVE ASSESSMENT OF IMPACTS ON RURAL DEVELOPMENT AND ENVIRONMENTAL CHALLENGES IN THE CONTEXT OF EU INTEGRATION

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Abstract. The modernisation of agriculture is a crucial factor in promoting rural development, while at the same time triggering various environmental and demographic changes. This paper provides a comparative quantitative assessment of the introduction of modern technologies in Serbian agriculture compared to EU practises, focussing on productivity, demographic trends and environmental indicators. while over 80% of farms in the EU use modern technologies such as GPS navigation, drones and automated systems, the adoption rate in Serbia is significantly lower - only 15% of farms use GPS, 5% drones and 10% automated systems. The data show that average wheat and maize yields in the EU are around 6.0 tonnes/ha and 8.0 tonnes/ha respectively, while in Serbia they remain at 4.5 tonnes/ha and 6.5 tonnes/ha. The cost-benefit analysis illustrates the differences in production efficiency and access to resources. Environmental indicators such as CO_2 emissions and pesticide use show that the environmental impact is higher in Serbia. The results emphasise the need for targeted investment, improved education and alignment with EU agricultural policy to promote sustainable rural revitalisation and technological progress.

Keywords: modern technology, rural development, environmental indicators, technological gap, sustainable agriculture

1. Introduction

Agriculture is the fundamental branch of the Serbian economy, which provides a significant contribution to the gross domestic product (GDP) and employs a large part of the rural population. However, agriculture faces numerous challenges that hinder its sustainable development, including deagrarianization, depopulation of rural areas and environmental degradation. The decrease in the number of the working population in rural areas, especially among young people, is a serious problem because it leads to a decrease in production and a decrease in competitiveness on the global market. Also, intensive agricultural production without adequate ecological practices results in soil degradation,

reduction of biodiversity and pollution of water resources. (Stojanović & Radosavljević, 2021 ; Stojanović & Miljković, 2021).

In this context, the process of harmonization with European Union policies (Common Agricultural Policy - CAP) represents a key opportunity for Serbia (Jovanović & Petrović, 2020) . Adaptation to European standards not only opens up opportunities to improve competitiveness on the EU market, but also enables the application of new technologies and ecological practices that can improve productivity and long-term sustainability of agricultural production (Binswanger-Mkhize & McCalla, 2018). The emphasis in the modernization of agriculture is on the integration of modern technologies, such as precision agriculture, drones, automation and digital tools, which enable better resource management, reducing the impact on the environment and increasing efficiency (Marković & Kovačević, 2023). In this process, it is crucial to establish a balance between economic development and protection of natural resources, in order to ensure the sustainability of agricultural production and the quality of life in rural communities. This approach can become the basis for long-term development that not only increases the competitiveness of the agricultural sector, but also contributes to the preservation of the environment and the revitalization of rural areas.

2. Materials and Methods

The paper relies on the analysis of available literature, legislative documents, as well as studies from Serbia and the EU. Comparative analysis considers the successful practices of countries such as Ireland, Spain and Switzerland, while special attention is paid to the application of technologies such as precision agriculture and organic production. The methodology includes a qualitative analysis of the impact of modernization on rural development and environmental factors.

3. Results and Discussion

3.1 Impact of modernization on rural development

Modernization of agriculture through the introduction of modern technologies has a direct impact on increasing the productivity and competitiveness of agricultural production. According to the FAO (Food and Agriculture Organization) report, by introducing technologies such as precision farming systems, farmers can increase yields by 10-20% while reducing the use of water, pesticides and other resources, making production more sustainable (FAO, 2021). In Serbia, which is in the phase of modernization of agriculture, the application of mechanization such as tractors, harvesters and smart irrigation systems significantly reduces the dependence on human labor, while increasing efficiency and reducing costs (Popović & Živanović, 2020) . Data show that in the period from 2010 to 2020, investments in agricultural machinery in Serbia increased by 15%, while innovations in digitization, such as applications for monitoring climate and crop health, became available to smaller farmers as well. Ireland is an example of successfully inte-

grating agriculture with non-agricultural sectors, especially through the development of green technologies and tourism (O'Connor & O'Neill, 2020). According to European Commission data, Irish rural regions have increased their gross domestic product by 40% since 2000 thanks to the diversification of economic activities, including renewable energy sources, agricultural tourism and manufacturing. This approach enabled the sustainable development of rural areas, reducing emigration and encouraging job growth.

Recent field research conducted in 250 farms in central and southern Serbia in 2024 shows that advanced technologies such as sensors and automation are only used to a limited extent. Only 12% of farmers report using sensors for crop monitoring, while 18% use some kind of automation, e.g. in irrigation or livestock feeding systems (Tab. 1).

Table 1. Survey results from agricultural holdings in Serbia (N=250)

Question / Indicator	Response Options	% of Respodents
Do you use crop monitoring sensors on your farm?	Yes	12%
	No	88%
Do you use any type of automation (e.g. irrigation, feeding systems)?	Yes	18%
	No	82%
What is the main barrier to technology adoption?	High equipment cost	54%
	Lack of technical knowledge	28%
	Poor internet/ infrastructure	12%
	No perceived benefit	6%
Would you consider using smart technologies in the next 5 years?	Yes	64%
	No	36%
Do you believe automation improves productivity?	Yes	71%
	No/Not sure	29%

Source: Authors

Main barriers cited were the high cost of initial equipment (54%), lack of technical knowledge (28%) and inadequate digital infrastructure (12%). Nevertheless, a promising 64% of respondents expressed interest in adopting smart technologies within the next five years, and more than 70% believe that such tools can improve productivity.

3.2 Deagrarianization and demographic trends

Deagrarianization is largely connected with the processes of urbanization and the reduction of the number of employees in agriculture. According to the data of the Republic Institute of Statistics of Serbia, in the last 30 years, the number of employees in agriculture decreased by almost 50%, and the share of agriculture in the gross domestic product (GDP) decreased from 12% to about 6%. This decline particularly affects rural communities, where young people are the main demographic segment that emigrates in search of better living and working conditions. Statistics show that in the period from 2002 to 2022, the number of inhabitants in rural areas of Serbia decreased by 15%, while the birth rate decreased by about 20% (Milijaš & Milić, 2023) . Demographic ageing, combined with the decrease in the number of young people remaining in the countryside, creates additional pressure on the social and economic systems of those areas. Data from the National Academy of Agricultural Sciences show that as many as 80% of agricultural farms in Serbia are run by the elderly population, while young people are increasingly withdrawing from the primary sector. These trends point to the need for urgent interventions, such as supporting young farmers and developing policies to revitalize rural communities. Through various funds and initiatives, the European Union offers subsidies for young farmers, which stimulates the return of young people to the countryside (European Commission, 2022) . For example, through the "Green Plan for Europe" program, investments of 10 billion euros are planned until 2027 in rural development, including agricultural modernization, youth education and infrastructure improvement, which can become a model for countries like Serbia (Marković & Vasiljević, 2022) .

3.3 Percentage participation of modern technologies in agriculture

Application of modern technologies in agriculture varies significantly between Serbia and the EU. While in the EU over 80% of agricultural farms use technologies such as GPS navigation, drones and sensors for crop monitoring, in Serbia that percentage amounts to only 25% (Vuković & Tasić, 2020). Lack of financial resources and insufficient education are the main obstacles to the wider implementation of these technologies in Serbia.

Table 2. Use of modern technologies in Serbia and the EU

Technology	Serbia (%)	EU (%)
GPS navigation	15	60
Drones	5	25
Crop monitoring sensors	5	60
Automated systems	10	50

Source: Eurostat, Agricultural Technologies in the EU (2022) ;
Statistical Office of the Republic of Serbia, Annual Agricultural Report (2022).

Differences in the use of technologies clearly show that Serbia is in the early stages of digitalization of agriculture (Tab. 2). While the EU is seeing significant benefits from the introduction of automation and digital tools, such as increasing work efficiency and reducing costs, Serbia must invest in the education of farmers and infrastructure. The use of GPS navigation, for example, allows more precise use of resources, which can reduce losses and costs.

Table 3. Use of modern technologies by farm tipe (N=250)

Farm type	% Using sensors	% Using automation
Family farms	8%	12%
Commercial farms	26%	38%
Mixed (semi-commercial)	14%	22%

Source: Authors

Results reveal low penetration of crop monitoring sensors (8%) and automation systems (12%), especially among small, family-run farms. Commercial farms demonstrate higher levels of adoption, with 26% using sensors and 38% employing automated systems (Tab. 3).

3.4 Cost-benefit analysis

Efficiency of agricultural production largely depends on the achieved yields and production costs (Swinnen, 2019) . The difference in these parameters between Serbia and the EU indicates the need for technological improvements in Serbia, as well as better access to subsidies and expertise.

Table 4. Analysis of yield and costs in cereal production

Indicator	Serbia	EU
Average wheat yield (t/ha)	4.5	6.0
Production costs (€/ha)	900	1200
Average corn yield (t/ha)	6.5	8.0
Production costs (€/ha)	850	1100

Source: FAO, Global Agriculture Report (2021) ;
Ministry of Agriculture of the Republic of Serbia, Yield Analysis (2022).

Yield analysis (Tab. 4) shows significant differences between Serbia and the EU. Although production costs are lower in Serbia, lower yields indicate the need to improve agrotechnical measures and introduce modern technologies. EU countries achieve higher

yields thanks to the integration of precision agriculture, better access to subsidies and more intensive professional support
(OECD, 2021).

One of the key success factors in the EU is the application of precise techniques that enable the optimization of resources, such as water and fertilizers. For example, "as-needed" irrigation reduces water loss and increases crop efficiency. Also, the use of high-quality seeds and integrated plant protection systems contributes to higher yields and long-term sustainability
(Đorđević & Jovanović, 2019) .

In Serbia, it is necessary to develop strategies that will include the education of farmers, strengthening of local infrastructure and increasing the availability of subsidies for technologies. Without these steps, the agricultural sector will continue to lag behind European standards.

3.5 Environmental challenges

Modern agriculture faces pressures to maintain a balance between productivity and environmental protection. Intensive use of pesticides, herbicides and mineral fertilizers endangers biodiversity, pollutes water resources and reduces soil quality. Overexploitation of irrigation water can lead to a decrease in the availability of this key resource.

In addition, greenhouse gas emissions from agricultural production, such as methane from animal husbandry and nitrous oxide from fertilizer application, contribute to global warming. Intensive farming systems can also cause soil erosion and loss of organic matter, which reduces productivity in the long term.

Table 5. Ecological data for Serbia and EU

Ecological indicator	Serbia	EU
Average CO_2 emission (t/ha)	1.2	0.8
Use of pesticides (kg/ha)	4.0	2.5
Organic matter loss (%)	20	10

Source: European Environment Agency (EEA), State of the Environment in the EU (2021).
Ministry of Environmental Protection of the Republic of Serbia, Impact of Agriculture on the Environment (2022).

Ecological data (Tab. 5) indicate serious challenges in Serbia. Higher CO2 emissions and more intensive use of pesticides lead to soil degradation and pollution. The EU is successfully reducing these negative effects through the application of agro-ecological measures and subsidizing sustainable practices (European Environmental Agency, 2021). Serbia could adopt these models in order to improve its environmental policy.

4. Conclusions

Modernization of agriculture represents a key chance for improving the quality of life in rural areas, but its success depends on a careful balancing of economic, ecological and social goals. Properly implemented modernization processes can lead to increased productivity, reduced costs, conservation of resources and creation of new jobs, which will enable the long-term development of these communities. However, in order to achieve sustainable development, it is necessary that modernization is not exclusively directed towards technological innovation, but that it is simultaneously dedicated to the preservation of natural resources and the improvement of social living conditions. Key recommendations include investing in education and training of the local workforce for the application of modern technologies, as well as strengthening cooperation between agricultural producers, scientific institutions and government authorities. Also, it is important to promote sustainable agriculture and implementation of ecological practices that will reduce negative effects on the environment, such as excessive use of pesticides and fertilizers , thus enabling the long-term sustainability of agricultural systems. Strong institutional support and engagement of local communities are key to a successful transition towards modernization and sustainable rural development. Supporting young farmers, facilitating access to subsidies and developing markets for organic products and ecological technologies can further motivate young people to stay in the countryside and start their own production activities. When these aspects are connected in a comprehensive approach, the modernization of agriculture can become the main driver of sustainable development of rural communities, bringing benefits both for the economy, and for society and the environment.

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