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CONTENT

EXPLORING THE IMPACT OF CONSUMERS' TRUST IN FOOD AUTHENTICITY ON THEIR PURCHASE INTENTIONS: A CASE OF 'Sen Hue' - A LOCAL LOTUS-GRAIN PRODUCT IN CENTRAL VIETNAM

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A B S T R A C T

There has been a significant increase in the global focus on food authenticity, leading people to closely examine the sources and quality of their food. The intricacy of culinary authenticity is shown in a regional lotus-grain product called 'Sen Hue', which suggests that they are from Hue, but in reality, they are obtained from other areas. Applying the Heckit model in the two-step approach for a sample of 426 local consumers, the study explored the drivers of the intention to purchase lotus-grain products. Findings from this study indicate that customers who perceive 'Sen Hue' lotus-grains as genuine and reliable have a stronger inclination to make a purchase, highlighting the importance of authenticity in the food industry. Stringent regulatory frameworks and labeling regulations are essential for preserving customer confidence. Additionally, this study highlights the need for a multi-pronged approach to understanding consumer behavior in this market by addressing safety, authenticity, and color specificity concerns.

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Introduction

There has been a recent global trend of individuals paying closer attention to the origin and authenticity of their food. This trend is particularly evident in Vietnam, where traditional and modern farming techniques intersect, raising significant concerns about food safety and authenticity. According to the World Health Organization's 2023 report, Vietnam averaged 668,673 cases of foodborne illnesses and 21 deaths annually between 2011 and 2016 (WHO, 2023). Thi et al. (2023) documented 184 incidents of food poisoning from unreliable sources, affecting 3,711 people across various food types.

The focus on lotus-grain products in Hue highlights the complexity of food authenticity issues. These products come from various regions of Vietnam, including Thua Thien Hue, Dong Thap, Quang Tri, Quang Binh, and others. Labeling these products as 'Sen Hue' implies their production in Hue, a city well-known for its lotus products, a notion that can be deceptive. Consumers often perceive these products as more authentic and of higher quality, assuming they originate from Hue. The discrepancy between branding and actual origin makes it difficult to verify product authenticity.

Understanding consumers' willingness to buy traced foods and their perceptions of authenticity is crucial for identifying strategies that improve food safety (Nguyen et al., 2018; Wang et al., 2019; Irshad et al., 2020; Mahliza, 2020; Tran, 2021; Užar et al., 2022). Consumers' concerns about the quality and authenticity of the food they consume consistently influence their willingness to pay a premium. According to Nguyen et al. (2019), personal characteristics and green marketing strategies are the key components relevant to consumers' intentions with regard to the planned purchase of organic foods in Vietnam. On the same note, Ngo et al. (2021) also explored the antecedents of consumers' willingness to purchase foods with safety certifications, underscoring the value of certifications in consumers' decision-making processes, especially when it comes to emerging markets such as Vietnam. A consumer is the last chain that determines the authenticity of food products, and this depends on the risk perception, trust, and habits put in place (Dang & Tran, 2020).

Recently, perceived authenticity and trust have been considered important aspects of food products that influence consumers' behavior and their tendency to make a purchase, as has been prescribed by studies like Kim & Baker (2017) and Ellitan (2021). Trust can give a consumer the ability to exercise his or her belief that sustainable, healthy, authentic food items, as well as safe food products, are trustworthy enough for them to make a decision (Kenning, 2008; Uzelac et al., 2022). Thus, the main area in this domain is 'authenticity', which includes characteristics like novelties, that is, being unique, and providing a guarantee of quality, tradition, rarity, divine nature, and purity (Sidali et al., 2021). Previous works have demonstrated the direct link between brand authenticity, consumer trust, and the purchase intentions of organic foods (Assiouras et al., 2015). Various contexts have explored the influence of risk perception and trust on purchase intentions, highlighting the complex interplay between consumer perceptions and behaviors (Lobb et al., 2007; Kanwal, 2021).

While there is a vast body of knowledge on consumer behavior and food safety across the world, literature specifically focusing on Vietnamese consumers' trust in the authenticity of food and how this impacts their decision to purchase the food is scarce. Some exceptions include the study by Dang & Tran (2020), which analyzed consumers' willingness to buy traceability pork in animal disease with a view to understanding the roles of food safety concern, risk perception, trust, and habit on purchase intention. However, a gap exists in the literature regarding consumers' intentions to buy traceable food products, considering the historical issues of food authenticity. Filling this gap is important to guide policymakers, the food industry, and consumer awareness activities seeking to strengthen food traceability and consumer trust in Vietnam. Therefore, this study seeks to investigate the interaction between consumers' perceptions of food authenticity, their attitudes toward lotus-grain products, and their purchasing behaviors in Central Vietnam. This study can fill in these gaps and complement the current literature by offering a more detailed view of consumers' attitudes and drivers toward food authenticity and safety in Vietnam. It will also be of importance to policymakers and other industry players to know how to increase the effectiveness of food traceability while increasing consumer confidence, thereby improving food safety and authenticity in the region.

Materials and methods

Data

Recent developments in lotus production and consumption

Lotus is grown in almost all parts of the world, especially in India, China, Japan, South Korea, South Africa, Russia, and the countries of Southeast Asia. In these areas, lotus plants are used as food, medicine, or as flowers. In Europe and America, lotus plants are used mostly as flowers. Nevertheless, there are a few global statistics concerning the areas occupied by cultivated lotuses. Nowadays, in Vietnam, lotus has been considered an emerging product in the food industry sector, along with traditional crops such as peanuts, soy, coffee, rubber, tea, cashew, pepper, etc. The cultivated area of lotus in Vietnam is over 30,000 ha.

The economic potential of lotus lies in its multipurpose usage in medicine, cosmetics, food, and decoration. Some of the parts of the lotus plant useful in remedies and common use include seeds, leaves, buds, and roots, which are commonly used in medicinal herbs, cosmetics, and dietary uses. The lotus seeds, for example, are used in creating processed products such as roasted seeds, lotus seed milk, lotus seed tea, and lotus seed wine. Additionally, there is a potential future market for lotus products, which has gradually gained attention due to the growing concern for natural ingredients and health benefits. This consumer preference caused the demand for lotus seeds, leaves, and other derivatives to increase in the domestic market as well as the international market. The emphasis on lotus-grain products in Hue highlights a significant challenge, given their diverse origins across Vietnam. Adding complexity is the branding approach, notably the labeling of products as ‘Sen Hue’, implying production in Hue, a historically significant city in the region. However, this branding strategy can be misleading, potentially distorting consumer perceptions of authenticity and origin. Consumers may mistakenly associate higher credibility and quality with products labeled as ‘Sen Hue’, assuming they originate from Hue, despite the actual source being elsewhere. This disparity between branding and true origin exacerbates the challenge of ensuring food authenticity and transparency in the lotus-grain product market, emphasizing the necessity for robust strategies.

Data collection

The data for this work were obtained from 426 respondents in Central Vietnam who were administered a semi-structured questionnaire. This survey was designed to capture overall evaluations from consumers regarding their perception, attitude, and practice towards lotus-grain products. As a measure to enhance the validity of the data collected and give more importance to the cultural differences, the questionnaire was pilot-tested before the actual administration of the study. Participants were chosen through quota sampling at the ‘Hue Lotus Festival’, a national exhibition concerning lotus-associated goods and services and arts that was held in Hue in the Central Region of Vietnam in 2023. This sampling technique is intended to include a wide group of clients with an interest in products containing lotus grain and food authenticity to increase the chance of including a more appropriate sample. To achieve this, the authors adopted simple random sampling, whereby a sample of 426 participants was drawn from the festival attendees.

As for data cleaning, it involves the process of making sure the collected data is accurate, complete, and consistent before transformation into a usable format. After that, the cleaning stage was completed, and the data was reduced to 419 observations, which, in turn, was ready for analysis. This preparation process involved some ordering of the variables, categorization of the variables into factors, and conversion of the data if needed to fit the model. The data were cleansed with quality measures used throughout the process to ensure only accurate information was used in subsequent analyses.

Analytical methods

When analyzing the factors that affect the intention to purchase lotus-grain products among clients seeking to buy authentic food, the Heckit model can help to minimize selection bias, as suggested by Van de Ven and Van Praag (1981). This model is indispensable for avoiding selection bias in analyzing the decision to buy lotus-grain products, a dependent variable that is meaningful only to consumers concerned with the authenticity of food. Components like perceived risk, available information, perceived product quality, and geographic specificity play a significant role in explaining this relationship (Vo & Nguyen, 2015; Benni et al., 2019).

The Heckit model correctly handles the selection effect by initially estimating the probability of selection (belief in food authenticity) via a probit or logit model. It then estimates the intention to purchase lotus-grain products for these individuals using either a linear regression or a probit model following selection. Applying the Heckit model in the two-step approach, therefore, helps to reduce the bias resulting from sample selection and improve the quality of the information collected regarding consumers' attitudes towards lotus-grain products. Analyzing these processes is critical for marketing and political decision-makers who aim to support real food products and satisfy consumers. Let us, for example, use the following:

- y_j^* as the latent variable representing the intention to purchase lotus-grain products.
- y_j^{probit} as the observed binary outcome variable (1 if $y_j^* > 0$, 0 otherwise).
- y_j^{select} as the observed binary selection variable (1 if $z_j\ \gamma + u_{2j} > 0$, 0 otherwise).

The equations are as follows:

(i). Latent equation: This equation models the relationship between the latent variable (in this case, intention to purchase lotus-grain products, yes=1) and the explanatory variables x_j .

$$y_j^* = x_j\ \beta + u_{1j} \qquad \textit{(Equation 1)}$$

(ii). Probit equation:

$$y_j^{probit} = (y_j^* > 0) \qquad \textit{(Equation 2)}$$

(iii). Selection equation: This equation models the relationship between the selection variable (belief in food authenticity or self-evaluation of origin of lotus-grain products with yes=1 indicating product form Hue) and the explanatory variables z_j .

$$y_j^{select} = (z_j\ \gamma\ +\ u_{2j}\ >\ 0) \qquad \textit{(Equation 3)}$$

Where: x_j is a vector of explanatory variables for the latent equation; is a vector of explanatory variables for the selection equation; the coefficients to estimate are β for the latent equation and γ for the selection equation.

The log likelihood is:

where *S* is the set of observations for which y_i is observed, $\Phi_2(.)$ is the cumulative

$$\ln L = \sum_{j \in S} w_j \ln \left\{ \Phi_2 \left(x_j \beta + \text{offset}_j^{\beta}, z_j \gamma + \text{offset}_j^{\gamma}, \rho \right) \right\}$$
$$+ \sum_{j \in S} w_j \ln \left\{ \Phi_2 \left(-x_j \beta + \text{offset}_j^{\beta}, z_j \gamma + \text{offset}_j^{\gamma}, -\rho \right) \right\}$$
$$+ \sum_{j \notin S} w_j \ln \left\{ 1 - \Phi \left(z_j \gamma + \text{offset}_j^{\gamma} \right) \right\}$$

bivariate normal distribution function, *Φ(.)* is the standard cumulative normal. In Stata, this study specified the Heckit model using the heckprobit command, specifying the selection equation and the outcome equation, along with their respective explanatory variables. This allows for estimation of both the selection process and the outcome of interest simultaneously, addressing potential selection bias using the maximum likelihood approach.

In this study, consumer trust in food authenticity is operationalized through several key variables, including consumers' perceptions of the trustworthiness of lotus-grain authenticity (participants were asked the degree of importance concerning trustworthiness of lotus-grains (scale of 1 not important to 5 very important); trust in the authenticity of lotus-grains: scale of 1 = very little trust to 5 = very high level of trust. As Macready et al. (2020) pointed out, this study has identified those two aforementioned variables for this study as our primary independent variables. These variables could be summed up to indicate people's perceptions, beliefs, and fears as producers and consumers when it comes to lotus-grain products. Authenticity perception refers to the ability of a consumer to rate products based on their personal understanding of the reliability of the particular products. Food authenticity and acceptability are therefore consumers' faith and assurance in the genuineness and reliance of foods from producers, distributors, processors, and retailers. Risk perceptions relate to consumer perceptions of the various possible risks and volatilities of consuming lotus-grain products, including pollution, contamination, or misrepresentation. Understanding these factors enables the study to identify potential impacts on consumer behavior and intentions to purchase lotus-grain products, providing a foundation for promoting food safety among consumers.

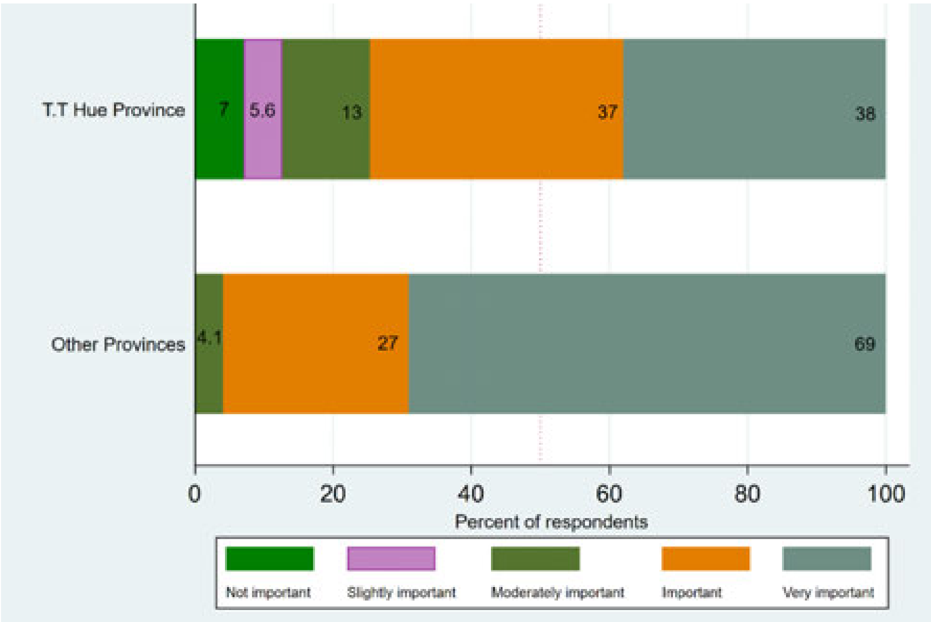
For a robust analysis regarding the relationship between perceived authenticity and purchase intentions of lotus grains in the lotus-grain product market, the control variables are indeed crucial in the investigation. According to the previous studies, demographic variables including age, gender, and income are included in the current study, as these features will impact the consumer's attitude and behavioral intention when consuming lotus products (Fritz et al., 2017; Halwani, 2020). Attitudes as consumption preferences refer to the perception customers have in matters to do with food origin, price, quality, branding, safety, availability, and certification and are deemed to provide an understanding of habitual and routine customer behaviors (Zniva & Weitzl, 2016; Chousou & Mattas, 2019). Furthermore, the knowledge of the consumer is an important factor, as consumers may be informed, and thus their perception of the lotus products may be altered. Thus, by including the aforementioned control variables, it will be possible to describe in detail the causal relationships between consumer fear of food authenticity and other factors that influence consumer choice in the lotus-grain product market. This has the advantage of making it easier to understand the factors that inspire consumers to have the intention of buying these products, and such information is useful to the stakeholders of the industry and policymakers who may find interesting the premise of private voluntary regulation.

Results

Descriptive analysis

This section provided valuable descriptive statistics about consumer preferences for lotus-grain products, broken down by location (Thua Thien Hue vs. other provinces) and overall sample. The perception of trustworthiness of lotus-grain authenticity appeared to be higher in other provinces compared to Thua Thien Hue province (Figure 1). For other provinces, the average score was 4.5 on a scale of 1 (not important) to 5 (very important). This suggested that consumers in other provinces placed a high value on the trustworthiness of lotus-grain authenticity when visiting Hue and bought lotus products as souvenirs. For consumers located in Hue, the average score was 3.88. This was lower than in other provinces, indicating that consumers from Hue might be slightly less trusting of lotus-grain authenticity.

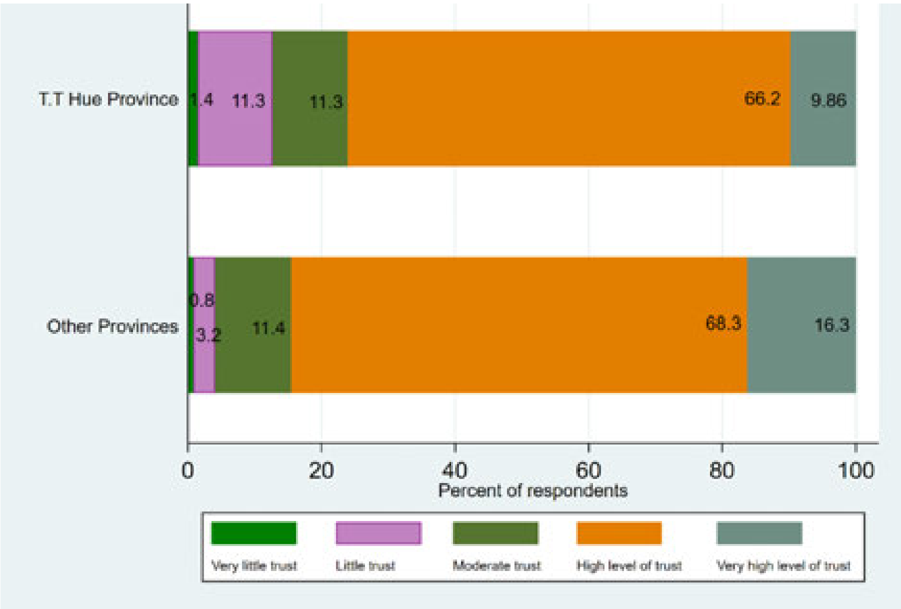
Figure 1.Perception on trustworthiness of lotus-grains authenticity



Source: Authors' calculations

Figure 2 demonstrated that consumers, on average, had a moderate to high degree of confidence in the lotus grains being genuine, although this varied across regions to some extent. Looking at the overall scale, the mean score for all respondents on the trust aspect was 3.7 on a scale of 1 to 5. This went a little above the scale, suggesting an overall confidence in the authenticity of lotus grain. As for the trust level of consumers from other provinces, they had a higher trust in lotus grain authenticity, with an average score of 4.25. This implied that they had more confidence in the product than the people in Hue. In addition, the consumers in Hue had relatively less trust, as they had given an average score of 3.71. This could be due to a variety of factors. Locals in Hue might be more familiar with the local production of lotus grain; they might be more sensitive to problems and therefore skeptical of authenticity. Furthermore, various locally established brands in Hue City could make consumers pay less attention to such overall indicators of authenticity and rely more on familiar brands instead.

Figure 2. Trust in authenticity of lotus-grains



Source: Authors' calculations

Table 1 below summarized some of the findings as a snapshot of consumer perception and behavior regarding lotus-grain products. In general, the results showed a relatively high level of trust in authenticity, along with moderate concern for threats. In fact, the results revealed that lotus-grain products had high consumer-perceived credibility, with a score of around 4 on average, with 1 being the least and 5 being the most. This meant that consumers understood that these products were authentic and did not contain any added chemicals. Consequently, the mean of trust in food authenticity was 4, which indicated that consumers were confident that the product was genuine. Notably, the level of trust was somewhat poorer in Hue City (3.7) in comparison with other provinces (4.25). This meant that even customers within the surrounding areas of the market had some level of concern as to whether the things they bought were original or fake. This implied that appropriate measures to increase confidence in lotus-grain products should be implemented, especially in the local markets. It also included other consumer demographics such as gender, age range, and monthly income of those who purchased lotus-grain products. In product evaluation, other ratings, which gave an insight into the overall consumer preference for attributes such as color, taste, size, shape, and cooking characteristics, were obtained in the range of 0.25 to 1.

Table 1. Descriptive statistics

Variables	Other provinces		Hue		Full sample	
	Mean	SD	Mean	SD	Mean	SD
Probit model: Intention to purchase *(yes=1)*	0.75	0.5	0.954	0.211	0.943	0.232
Explanatory variables						
Perception on trustworthiness of lotus-grains authenticity *(scale: 1 not important-5 very important)*	4.5	0.577	3.877	1.20	4.38	0.905
Trust in authenticity of lotus-grains *(scale: 1 = very little trust to 5 = very high level of trust)*	4.25	0.5	3.70	0.843	3.87	0.761
Control variables						
Gender *(male=1)*	0.25	0.5	0.477	0.503	0.361	0.481
Age *(group 1. <20….4.>60 years)*	2.50	1.29	2.27	0.893	2.42	0.874
Monthly income *(Mill.VND per month, in log)*	16.11	0	16.27	0.73	15.85	0.771
Overall perception of food origin *(scale: 1 not important-5 very important)*	4.30	0.765	4.48	0.78	4.40	0.815
Overall perception of food price *(scale: 1 not important-5 very important)*	3.78	0.736	3.74	1.03	3.76	0.934
Overall perception of food quality *(scale: 1 not important-5 very important)*	4.56	0.657	4.72	0.561	4.65	0.609
Overall perception of food branding *(scale: 1 not important-5 very important)*	3.90	0.781	3.94	0.958	3.93	0.894
Overall Perception of food safety *(scale: 1 not important-5 very important)*	4.4	0.721	4.797	0.442	4.66	0.591
Overall perception of food availability *(scale: 1 not important-5 very important)*	3.78	0.796	4.26	0.808	4.09	0.839
Overall perception of food certification *(scale: 1 not important-5 very important)*	4.10	0.864	3.95	1.036	4.01	0.972
Selection model						
Self-evaluation of origin of lotus-grain products *(yes=1 product from Hue)*	0.980	0.020	0.831	0.378	0.839	0.369
Self-evaluation on color *(right answer=1)*	0.75	0.5	0.625	0.488	0.49	0.501
Self-evaluation on taste *(right answer=1)*	0.25	0.5	0.703	0.46	0.632	0.483
Self-evaluation on size *(right answer =1)*	0	0	0.246	0.434	0.211	0.409
Self-evaluation on shape *(right answer=1)*	0.5	0.577	0.215	0.414	0.247	0.433
Self-evaluation on cook appearances *(right answer =1)*	0.5	0.577	0.492	0.504	0.531	0.5
Location dummy *(Hue=1)*	0	1	1	0	0.634	0.482

Source: Authors' calculations

The dependent variable for the Probit equation represented the latent variable of the intention to purchase lotus-grain products. Overall, consumers showed a high intention to buy lotus-grain products, specifically 'Sen Hue,' with an average of 94.3% intending to purchase. Consumers from other provinces such as Quang Binh, Quang Tri, Da Nang, Ha Noi, Ho Chi Minh City, Khanh Hoa, Thanh Hoa, and Quang Nam showed a lower intention to purchase (75%) as souvenirs. The dependent variable for the selection equation represented the consumer's self-evaluation of the origin of lotus-grain products based on users' consumption experience of 'Sen Hue' products. About 83.9% of respondents correctly identified the characteristics of 'Sen Hue' products, which included five different features: color, taste, size, shape, and cooked appearance.

Results

From Table 2, this study learned more about consumer behavior toward 'Sen Hue' lotus-grain products as distinct brands or types by using the Heckit model to determine the attitude and intention to buy their products, especially for those who were concerned about food authenticity. As expected, both the explanatory variables—perception of authenticity and trust in authenticity—had positive and significant coefficients; hence, these factors influenced purchase intention towards 'Sen Hue' lotus grains. When consumers had a higher degree of perceived authenticity, they had a greater intention to buy lotus-grain products. Moreover, there was a greater willingness to purchase the 'Sen Hue' lotus grains specifically for consumers whose confidence in the product was genuine and trustworthy. This finding supported the emerging concept of authenticity in the food market. Customers were becoming more selective in their purchase decisions, looking for products they considered authentic and conveying honest messages about the product. If the 'Sen Hue' lotus grains were able to establish themselves, it would give them a competitive edge as genuine ones. Thus, this study confirms the significant moderating role of perceived authenticity and trust in shaping consumers' purchase intentions toward regional specialty foods, using 'Sen Hue' lotus-grain products as a case study. This link is particularly novel in the context of an emerging market like Vietnam, where few studies have explored authenticity as a measurable construct in consumer behavior models.

Table 2. Factors influencing the intention to purchase 'Sen Hue' lotus-grains products

Variables	**Coefficient**	**Std.**	**P>z**
Probit model: Intention to purchase			
Perception on trustworthiness of lotus-grains authenticity	1.569**	0.756	0.038
Trust in authenticity of lotus-grains	1.147***	0.324	0.000
Gender	-0.356*	0.211	0.092
Age	1.334***	0.171	0.000
Monthly income	0.022	0.119	0.851
Overall perception of food origin	1.059***	0.373	0.005
Overall perception of food price	0.849***	0.048	0.000
Overall perception of food quality	-0.165	0.345	0.633
Overall perception of food branding	0.422	0.654	0.519

Variables	Coefficient	Std.	P>z
Overall Perception of food safety	0.830***	0.026	0.000
Overall perception of food availability	-1.838***	0.148	0.000
Overall perception of food certification	-2.468***	0.195	0.000
Selection model			
Self-evaluation on lotus-grains color	-0.432***	0.115	0.000
Self-evaluation on lotus-grains taste	0.066	0.352	0.851
Self-evaluation on lotus-grains size	0.085	0.197	0.667
Self-evaluation on lotus-grains shape	-0.101	0.167	0.548
Self-evaluation on lotus-grains cooked appearances	-0.098	0.260	0.707
Location dummy	-0.780***	0.044	0.000
Constant	1.201***	0.377	0.001

*Note: *** p<0.01, ** p<0.05, * p<0.1; Source:* Authors' calculations

This was in line with several previous studies that noted that trust and authenticity had an influence on purchase intention. Wang et al. (2019) also pointed out that trust represented a significant factor affecting purchasing behavior, which was why this attribute had a positive impact on the intention to purchase. In the same way, Hooge et al. (2022) also highlighted how authenticity, such as the notion that products were natural, locally produced, and seen as reliable, affected consumers' perceptions and purchase intentions. Additionally, Masri et al. (2020) and Refi et al. (2021) also supported the notion of the influence of trust in determining purchase intention, which again agreed with the argument that trust was a major factor in the decision-making of consumers in their purchase behavior. Moreover, this research demonstrated that the concept of authenticity played a role in the decision to purchase an item through trust as a mediating variable. Matthews et al. (2020) extended their argument that authenticity had evident effects on trust, thus increasing purchase intentions. Wijerathna & Wijesundara (2022) yielded an important link between perceived authenticity and purchasing intention: moderation by trust. To sum it up, it was imperative to state that the relationship between authenticity, trust, and purchase intentions was one of the vital aspects that defined consumers' behavior. Consumers who had some appreciation for real and credible products were more likely to have every intention of buying them on the market. If businesses wanted to improve consumer purchase intentions, they had to maintain authenticity in their operations.

Discussions

Findings from the study showed that trust positively impacted consumer behavior, increasing the willingness to purchase products or services (Nguyen et al., 2019; Wang et al., 2019; Irshad et al., 2020; Mahliza, 2020; Uzelac et al., 2022). Various factors, including brand image, perceived quality, and source trustworthiness (Lien et al., 2015), as well as customer trust, interpersonal trust, and source trustworthiness (Büttner & Göritz, 2008), could establish trust. Trust could act as a mediator, indirectly influencing purchase intention by reducing perceived risk and enhancing confidence in the product or service (Nursyirwan, 2021; Užar et al., 2022).

Another interesting finding was the positive and significant coefficient for consumers' age. This suggested that older individuals were more likely to intend to purchase lotus-grain products compared to younger consumers. The study could have further explored the reasons behind this age-related difference, which could potentially relate to health consciousness or familiarity with traditional ingredients. However, within the observed range, income appeared to have no statistically relevant impact on purchase intention. This suggested that lotus-grain products might have held appeal across different income brackets. The positive and significant coefficient for "age" in consumer preferences for 'Sen Hue' lotus grains suggested that older consumers might have had a stronger inclination towards purchasing this product. This inclination could have been attributed to the influence of traditional foods and local specialties on older generations (Zniva & Weitzl, 2016). Studies showed that consumer behavior changed significantly over the life cycle, indicating that age played a crucial role in shaping preferences and purchasing decisions (Gourinchas & Parker, 2002; Uzelac et al., 2022). Furthermore, the analysis of consumer motivations across different age groups revealed insights into the underlying factors that drove consumption behavior. Older adults, in particular, had distinct motivations and preferences that were influenced by their life experiences and generational values (Halwani, 2020). Understanding the nuances in consumer behavior among various age groups was essential for businesses to tailor their marketing strategies effectively and cater to the diverse needs of different demographic segments, such as targeting elder consumers for 'Sen Hue' products in our case.

Furthermore, the positive and significant coefficient for "overall perception of food origin" suggested that valuing the origin of food played a role in the purchase decision for 'Sen Hue' lotus grains. This aligned with the focus on authenticity; consumers who prioritized origin might have been drawn to 'Sen Hue' if it signified a specific geographical location and its associated production methods. This reinforced the importance of transparency and clear origin information for lotus-grain producers. The positive and significant coefficient for "overall perception of price" was an intriguing finding. It suggested that for 'Sen Hue' lotus grains, a higher perceived price might have been associated with better quality. This aligned with the "you get what you pay for" mentality observed in some consumer segments. Consumers might have been willing to pay a premium for 'Sen Hue' if they believed it translated to superior quality and justified the brand's positioning. However, the insignificant coefficient for "perceived quality" on its own was intriguing. This might have indicated that price alone was not a sufficient indicator of quality for consumers, and other factors like brand reputation or safety certifications could have come into play. Both safety (positive and significant) and certification (negative and significant) had a strong influence on purchase intention. This highlighted the paramount importance of prioritizing safety in the production and processing of lotus-grain products. Consumers were more likely to be drawn to products perceived as safe and might have been discouraged by a lack of certification, which could have indicated potential concerns about hygiene or quality control. Neither branding nor product availability had a statistically significant impact on purchase intention. However, this did not necessarily mean they were unimportant. This could have been because the brand hadn’t yet established a strong association with quality in the minds of consumers.

Interestingly, the study used a new variable, “location dummy,” indicating whether consumers came from Hue versus other provinces. The positive and significant coefficient suggested that, compared to consumers outside Hue City, those in Hue were more likely to prioritize ‘Sen Hue’ lotus grains. This could have been due to several reasons: Hue residents might have been well-acquainted with other local lotus grain options they perceived as equally authentic and high-quality. This could have led them to explore alternatives beyond “Sen Hue.” As ‘Sen Hue’ lotus grains might have been priced at a premium compared to other local options, Hue residents, potentially more price-sensitive, might have opted for familiar, well-established local brands offering similar quality at a lower price. Thus, the geographic contrast in trust levels and authenticity perceptions between local consumers in Hue and those from other provinces - revealing counterintuitive patterns where non-local consumers exhibit higher trust in the product’s authenticity than local consumers. This challenges assumptions in the regional branding literature and opens avenues for future place-based marketing strategies.

Conclusions

This study provides new insights into the role of consumer trust and perceived authenticity in shaping the purchase intentions for regional specialty products, using ‘Sen Hue’ lotus-grain products in Vietnam as a case study. Our findings confirm that both trust in authenticity and perception of authenticity significantly influence purchasing behavior, especially among consumers concerned with food origin, safety, and traceability. These results highlight the rising importance of authenticity signals in emerging food markets and the need to reassess how branding strategies impact consumer perception and decision-making.

Theoretically, the findings contribute to authenticity and trust literature by showing how these constructs jointly affect purchase intention. Managerially, the results underscore the importance of transparent labeling, certification, and branding tied to geographic origin. Firms and policymakers should promote authenticity cues to enhance consumer confidence and product competitiveness. Nevertheless, the study has limitations. First, the data were collected cross-sectionally from consumers attending a specific regional event, which may limit the generalizability of findings. Second, while the Heckit model helps address selection bias, the model assumes linearity and normal distribution, which may not fully capture complex consumer behavior. Finally, the study focused on only two trust-related constructs, while other psychological or contextual factors (e.g., social norms, cultural attachment, or past experiences) might also influence purchase intentions. For future research, longitudinal studies could help capture changes in consumer trust and authenticity perception over time, especially as certification systems evolve. Expanding the research to include more study sites would also enhance generalizability. By addressing these limitations and using a more comprehensive approach, future research can paint a finer picture of consumer behavior in the dynamic market for lotus-based products.

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Conflict of interests

The authors declare no conflict of interest.

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THE ANALYSIS OF THE NOMINAL RATE OF PROTECTION AND THE NOMINAL RATE OF ASSISTANCE TO SELECTED AGRICULTURAL PRODUCTS: A CASE STUDY OF THE REPUBLIC OF SRPSKA (BOSNIA AND HERZEGOVINA)

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A B S T R A C T

This paper aimed to estimate the protection of agricultural producers in the Republic of Srpska, Bosnia and Herzegovina, using prices of nine selected products during 2018 – 2023. Two widely recognised indicators were employed: the nominal rate of protection and the nominal rate of assistance. The findings highlight consistent gaps between domestic and EU reference prices, as well as discrepancies and insufficient budget allocation for certain agricultural products. Strong protection was recorded for beef, pig meat, poultry meat and egg producers, while milk and potato protection showed variability. Conversely, wheat, grain maize, and sheep meat were largely unprotected throughout the analysed period. These results suggest that agricultural policy in the Republic of Srpska should prioritise targeted budgetary support, reduce market price disparities and promote productivity-enhancing measures to improve competitiveness and ensure sector sustainability.

Introduction

Following the signing of the Dayton Peace Agreement in 1995, Bosnia and Herzegovina was established as a state with a unique structure, consisting of the Federation of Bosnia

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and Herzegovina (FB&H), the Republic of Srpska (RS) and the Brčko District (DB). This agreement shaped the country's political, economic, and administrative structures, and divided responsibilities, resulting in a complex internal organisation of the state. The state structure has had a significant influence on all sectors of the economy, including agriculture. In Bosnia and Herzegovina, various levels of government develop and implement their own strategies and agricultural policies, with the goal of improving the sector's productivity and competitiveness. This results in diverse approaches, objectives, and challenges in supporting producers and ensuring the sustainability of agricultural production. The agricultural support policies in Bosnia and Herzegovina are primarily directed toward boosting productivity and competitiveness, which remain key priorities for policymakers in this sector, particularly in the context of EU integration. Bosnia and Herzegovina has taken significant steps on this path by signing the Stabilisation and Association Agreement (SAA), attaining EU candidate status in 2022 and launching accession negotiations in March 2024. One of the key challenges for all levels of authority in the country will be aligning domestic agricultural policies with the Common Agricultural Policy of the EU (CAP).

Agriculture in the Republic of Srpska plays a vital role in ensuring food security, fostering rural development, and sustaining economic stability. Its significance is evident in the contribution of agriculture, forestry, and fishery to the GDP with an average of 7.40% (Statistical Yearbook, 2023), an employment rate of 29.8% (Labour Force Survey, 2019[5]), and an average of 6.20% share of the sector in the total exports[6]. Given its importance for economic development, the agricultural policy of the Republic of Srpska has been designed to meet the needs of domestic agricultural producers and to ensure the sector's stability. However, it often sparks discussions about its efficiency and alignment with modern challenges and global trends in agriculture. This sector in the Republic of Srpska (B&H) encompasses significant production of several agricultural products, such as cereals, potatoes, beef, pig meat, poultry meat, eggs, sheep meat and milk. From 2018 to 2023, wheat production averaged 196 thousand tonnes, while grain maize production reached 537 thousand tonnes. Potato production averaged 83 thousand tonnes, while beef production averaged 17 thousand tonnes annually. Pig meat production accounted for 72 thousand tonnes, and sheep meat reached 9 thousand tonnes. Additionally, poultry meat production included 29 thousand tonnes, with annual egg production amounting to 20 thousand tonnes. Milk production was the most significant, averaging 281 thousand tonnes annually[7]. This production made a significant contribution to the overall value of agricultural output, underscoring the importance of aligning development strategies and greater budgetary support in

5 Labour Force Survey (2019), the Agency of Statistics Bosnia and Herzegovina.

6 The calculation of average share of agriculture, forestry, and fishery in the GDP, total employment, and exports is based on data from the Statistical Yearbook (2023), the Institute of Statistics of the Republic of Srpska.

7 The calculation of average production is based on data from the Statistical Yearbook (2023), the Institute of Statistics of the Republic of Srpska.

order to improve productivity, ensure sustainability, and bolster the competitiveness of these sectors.

Taking into consideration strategic documents for agricultural development in the Republic of Srpska, four documents have been adopted so far, namely the Agricultural Development Strategy until 2015; Rural Development Strategic Plan 2009-2015; Agricultural and Rural Development Strategy 2016-2020 and 2021-2027. The agricultural budget was established in 2000 when funds for agriculture were allocated. Food security has been the primary goal of all development strategies for agriculture in the Republic of Srpska, supported by significant allocations of funds for production and income. This was confirmed in a research conducted by Mrdalj (2015), which analysed budgetary support using the APM methodology, excluding the support stemming from market–price policy measures. The findings revealed that the Republic of Srpska's agricultural policy was production and income-oriented, with an average share of 56% of the total budget allocated for direct producer support. Additionally, the research estimated the budget support to agricultural producers (PSE_b) according to implementation criteria and the level of commodity specificity, having highlighted the dominance of output-based payments (A.2), with an average share of 56%, and single commodity transfers (SCT), which accounted for an average share of 54%. Furthermore, Mrdalj (2015) compared the structure of the PSE_b between the Republic of Srpska and the European Union, using two criteria, having identified significant differences in the structure of support measures for agriculture and found notable differences in the structure of agricultural and rural development support measures, as well as in the scale of budget allocations. The pronounced misalignment between the domestic agricultural and rural development support system and the EU framework was largely the result of introducing specific systemic arrangements inherent to CAP reforms.

Therefore, this paper aims to complement the existing analysis by assessing the protection level for agricultural producers through domestic pricing of selected products. In addition, the paper contributes to identifying differences in support levels among selected agricultural products. In this way, the paper aims to provide an understanding of market-price measures and fiscal subsidies which support the Republic of Srpska's agricultural sector, specifically for the selected agricultural products.

The research on agricultural incentives became a key focus for international organisations such as FAO, OECD, and the World Bank. According to Anderson's global analysis of agricultural distortions (2009), information on agricultural incentives was scarce before the 1980s, when the OECD began collecting detailed data, although access to data for developing countries remained limited and fragmented. Later, several key institutions, including FAO, OECD, IFPRI, and the World Bank, jointly contributed to developing the agricultural incentives database (Laborde et al., 2024). Through its AgIncentives Consortium, the International Food Policy Research Institute (IFPRI) has maintained this harmonised database on agricultural incentives, which includes the nominal rate of protection (NRP), and has more recently expanded it to cover the nominal rate of assistance (NRA) (Laborde and Mamun, 2023). This addition provides a more comprehensive view of the support extended to agricultural producers, further enhancing the global–level analysis of agricultural incentives and their effects on the agricultural sector.

The Food and Agriculture Organization developed the Monitoring and Analysing Policies Incentives Indicators to assess how policies and market conditions affect agricultural prices and producer incentives. Generally, these indicators provide insight into how policies and markets support agricultural growth, food security, and rural development (MAFAP, 2015). The studies conducted by Tsakok (1990), Krueger et al. (1991), and Anderson and Masters (2009) served as a basis for the development and application of MAFAP indicators, used to assess agricultural producer support. The methodology for calculating agricultural support employs two widely applied indicators: NRP and NRA, both grounded in the OECD (2016) approach, especially through the market price differential (MPD), serving as a framework for understanding the effects of market and trade policies. The market price differential is defined as the difference between domestic and reference prices of a commodity, serving as the base for assessing price transfers between producers, consumers, and taxpayers (OECD, 2016). The NRP and NRA indicators measure the scope of influence of trade and market policies, as well as fiscal subsidies that affect domestic prices and support to agricultural producers.

Given that the Institute of Statistics of the Republic of Srpska has encountered challenges with agricultural data which do not ensure a satisfactory extent of reliability and prevent the computing of market price support (MPS) as a component of producers' support estimate indicator (PSE), the assessment of the protection provided for agricultural producers for selected products was conducted using these two indicators. The analysis of the NRP and NRA indicators for nine selected products at the level of the Republic of Srpska covered the period from 2018 to 2023 by examining trends in protection levels and fiscal support mechanisms.

Materials and methods

To achieve the research objectives, two main indicators were applied to evaluate the level of support granted to agricultural producers: The Nominal rate of protection (NRP) and the Nominal rate of assistance (NRA). These measures are based on a standardized methodological framework for policy assessment originally developed by the OECD (2016) and widely adopted by the FAO and other international organisations engaged in agricultural and food policy monitoring (FAO, IFAD, UNICEF, and WHO, 2022). Following the interpretation provided by Erjavec et al. (2017), as referenced in Makaš et al. (2018), the NRP quantifies the degree of price protection by calculating the percentage ratio between the domestic producer's price and the reference price for selected products. Variations in this ratio may arise from direct sectoral measures or product-specific interventions, such as market regulations, trade tariffs or subsidies; from macroeconomic policies, including exchange rate policies and interventions in related sectors; as well as non-policy factors such as market failure. Accordingly, it assesses the extent to which these policies either encourage (i.e., protect) or discourage (i.e., penalise) producers, offering an estimate of price incentives for an individual commodity, a product group, or the agricultural sector as a whole (FAO, IFAD, UNICEF and WHO, 2022).

Drawing on the methodological approach described by Erjavec et al. (2017) and cited in Makaš et al. (2018), the nominal rate of producer protection was derived according to the following equation:

$$\%NRP_i = \frac{PP_i}{RP_i} * 100 - 100 \quad (1)$$

where:

i – Individual product

%NRP –Nominal Rate of Protection

PP – Producer price

RP – Reference price

The %NRP can be interpreted as follows: a positive NRP at the farm gate level indicates that the producer receives a price for the commodity which is higher than the reference price that would exists without policy interventions. In contrast, a negative NRP means that the producer receives a price lower than the level that would prevail in the absence of intervention. Zero NRP reflects a neutral protection structure. While the NRP is intended to measure the impact of policy-related distortions, in some cases it may primarily reflect non-policy influences, such as the effects of general market performance on prices (FAO, 2022). In many low- and middle-income countries, inefficient market functioning is widespread, driven by factors that hinder price alignment between domestic and international markets. These include weak market integration, unequal distribution of market power, absence of adequate market institutions, and insufficient physical infrastructure (MAFAP, 2015).

The % NRA indicator expands upon the NRP by incorporating commodity - specific public expenditure into the analysis. It captures the combined effect of market price variations and budgetary transfers, offering a more comprehensive assessment of how policy interventions alter producer returns. This indicator expresses the percentage by which government policies through budgetary transfers rises the gross return of producers beyond the level that would be without these interventions.

According to Erjavec et al. (2017), as cited in Makaš et al. (2018), the following formula was used to calculate the NRA:

$$\%NRA_i = \frac{PP_i * QP_i + PE_i}{RP_i * QP_i} * 100 - 100 \quad (2)$$

where:

i – Individual product

%NRA –Nominal Rate of Assistance

PP – Producer price

QP – Quantity of production

RP – Reference price

PE – PSE BOT Budgetary transfer to producers / Fiscal subsidies to producers

The PSE indicator comprises various categories. The PSE category A.1 refers to transfers from consumers and taxpayers to agricultural producers, generated by policy measures that create a gap between domestic market prices and border prices for specific agricultural commodities at the farm gate level.

PSE BOT (PSEb) or fiscal subsidies to producers represent budgetary transfers from taxpayers to individual agricultural producers (sum of categories A.2 to G). These transfers can be granted on the following bases (OECD, 2016):

- *Output* – Category A.2: transfers from taxpayers to agricultural producers resulting from policy measures based on current output of a specific agricultural commodity;
- *Input use* – Category B: transfers from taxpayers to agricultural producers arising from policy measures based on the on –farm use of inputs, including variable inputs (B.1), fixed inputs (B.2) and on – farm services (B.3)
- *Current area, animal numbers, receipts or income, production required* – Category C: transfers from taxpayers to agricultural producers based on current area, animal numbers, receipts (C.2), or income (C.1) with the requirement for ongoing production;
- *Non – current (historical or fixed) area, animal numbers, receipts or income, production required* – Category D: transfers from taxpayers to agricultural producers based on historical or fixed area, animal numbers, receipts, or income, with obligation of current production of any commodity;
- *Non – current (historical or fixed) area, animal numbers, receipts or income, production not required* – Category E: transfers from taxpayers to agricultural producers based on non-current historical or fixed area, animal numbers, receipts or income, without the requirement for current production of any commodity;
- *Non – commodity criteria* – Category F: transfers from taxpayers to agricultural producers provided on the basis of policy measures related to long–term resource retirement or the delivery of specific non – commodity outputs;
- *Miscellaneous payments* – Category G: transfers from taxpayers to agricultural producers for which insufficient information is available to classify them into

the appropriate categories.

The policy support indicators refer to the set of policy instruments are described in Table 1.

Table 1. Overview of agricultural policy instruments and their corresponding indicators

Policy instruments	Corresponding Indicators
A.1 Trade and market–based price incentives	Nominal rate of protection (NRP)
A.2. Output–based fiscal subsidies to producers	Nominal rate of assistance (NRA)
B. Input–based fiscal subsidies to producers	Nominal rate of assistance (NRA)
C. Fiscal subsidies linked to current area, animal numbers, receipts or income, production required	Nominal rate of assistance (NRA)
D. Fiscal subsidies linked to historical (non–current) area, animal numbers, receipts or income, production not required	Nominal rate of assistance (NRA)
F. Fiscal subsidies based on non–commodity criteria	Nominal rate of assistance (NRA)
G. Other or miscellaneous subsidies to producers	Nominal rate of assistance (NRA)

Source: Adopted from FAO, IFAD, UNICEF and WHO, 2022.

Given the high diversity of agricultural production in the Republic of Srpska, the initial aim was to select products that cumulatively account for at least 70% of the total value of agricultural production (OECD, 2016). Due to limited data availability for certain individual commodities, the initial threshold was reduced to 50% to include representative products with sufficient data coverage for the observation period. The final criterion of agricultural product selection was the availability of product-specific data. Therefore, the paper used the data on producer prices for wheat, grain maize, potatoes, various types of meat (beef, pig meat, sheep meat, poultry meat), eggs and milk, sourced from the Economic Accounts and Prices for Agriculture (Bulletin 2023 and 2024), the Institute of Statistics of the Republic of Srpska. The data were obtained through official agricultural reporting systems and are regarded as reliable for the Republic of Srpska's level. To facilitate comparison with domestic prices, EU (world) reference prices were used from the OECD's Producer Support Estimate (PSE) database (2024). This database is widely recognised for its reliability due as result of the OECD's comprehensive methodology in collecting and processing data on producer support. The PSE data ensure consistency across countries and periods, making them highly representative of market conditions within the EU and globally. Anderson (2009) defines the reference price that would prevail in the absence of domestic price, market and trade policy interventions. The selection of an appropriate reference world price is determined by a country's net trade status for specific commodities. When import volumes substantially surpass exports, the commodity is classified as an import; conversely, if exports are greater, it is classified as an export. Due to its small and underdeveloped market, Bosnia and Herzegovina is a net importer of the majority of agricultural products, primarily sourced from the EU.

Given that the volume of trade in selected products with the EU is significantly higher than with other countries, the EU reference prices can serve as the most relevant benchmark. This is particularly important for EU aspirant countries (Erjavec et al., 2003). Following this approach, the authors also applied the EU reference prices to ensure consistency and relevance of the analysis. As each administrative unit in Bosnia and Herzegovina implements its agricultural policy, the quantitative assessment of budgetary support draws on data from the Ministry of Agriculture, Forestry and Water Management of the Republic of Srpska for the period 2018 – 2023. The fiscal support to producers (PSE_b) was analysed using the implementation criteria.

Results

The research results are divided into two parts. The first one estimates market price differential (MPD) and commodity-specific transfers for selected products, and the second shows the movement of NRP and NRA from 2018 to 2023.

The market price differential and commodity-specific budgetary transfers for selected agricultural products

The tables below display the findings on market price differentials and commodity–specific budgetary transfers for selected agricultural products in the Republic of Srpska (B&H). Since the exchange rate of the convertible mark (BAM) to the euro (EUR)[8] has been fixed and remained stable throughout the analysed period, exchange rate fluctuations did not impact the price analysis.

Table 2 presents the MPD and commodity-specific budgetary transfers to agricultural producers of wheat during 2018-2023.

Table 2. Market price differential (MPD) and fiscal subsidies to wheat producers in millions of BAM from 2018 to 2023

Wheat	MPD (BAM per tonne)	Fiscal subsidies		PE mil. BAM	PE/product (BAM per tonne)	Total PSE_b (mil. BAM)	Share of PE in total PSE_b
		A.2 (mil. BAM)	C.2 (mil. BAM)				
2018	-78.02	0.12	3.85	3.97	21.06	71.00	5.59%
2019	-48.73	3.26	3.33	6.59	34.83	71.00	9.28%
2020	-57.21	0.12	0.00	0.12	0.47	84.89	0.14%
2021	-75.54	0.27	0.00	0.27	1.48	101.45	0.27%
2022	-32.29	7.20	0.00	7.20	37.30	107.26	6.71%
2023	-103.13	11.80	0.00	11.80	69.88	202.25	5.75%

Source: Authors' calculations

8 1 EUR= 1.95583 BAM.

The negative price gap indicated a lower domestic wheat price than the EU reference price during the observed period. Based on the available data, output–based fiscal subsidies to producers (A.2) were identified as the predominant policy instrument for wheat production in the Republic of Srpska. The amount of these payments ranged from 0.12 to 11.80 million BAM. The highest share of budgetary transfers to wheat production, amounting to 9.28% in $PSE_{b,}$ was recorded in 2019. In period However, the share in the total PSE_b fell to 5.75% in 2023, indicating both a rise in overall budgetary transfers to agriculture and a reallocation of funds across various products.

During 2018-2023, domestic grain maize prices were lower than EU reference prices, leading to a negative price gap. Budgetary support for grain maize production was predominantly provided through subsidies linked to current area. However, while budgetary transfers for grain maize production remained stable over the years, their share in total PSE_b decreased. This can be explained as an increase in total agricultural transfers for agriculture, changes in support priorities, or allocation of funds for different agricultural products (Table 3).

Table 3. Market price differential (MPD) and fiscal subsidies to grain maize producers in millions of BAM from 2018 to 2023

Grain maize	MPD (BAM per tonne)	Fiscal subsidies		PE mil. BAM	PE/product (BAM per tonne)	Total PSE_b (mil. BAM)	Share of PE in total PSE_b
		A.2 (mil. BAM)	C.2 (mil. BAM)				
2018	-60.68	0.06	3.30	3.36	5.70	71.00	4.73%
2019	-89.04	0.07	3.30	3.37	5.91	71.00	4.75%
2020	-78.35	0.10	3.30	3.40	4.20	84.89	4.01%
2021	-121.26	0.20	2.75	2.95	6.86	101.45	2.91%
2022	-132.48	0.00	2.75	2.75	7.39	107.26	2.56%
2023	-141.80	0.00	4.13	4.13	9.21	205.25	2.01%

Source: Authors' calculations

Except in 2018, 2022 and 2023, potato producer prices in the Republic of Srpska remained below the EU reference price. Budgetary transfers based on output towards potato production were minimal from 2018 to 2023, mostly lower than one million BAM. The relatively small share of these transfers during the final three years of the observed period suggests that this crop had a lower support priority compared to other types of production (Table 4).

Table 4. Market price differential (MPD) and fiscal subsidies to potato producers in millions of BAM from 2018 to 2023

Potatoes	MPD (BAM per tonne)	Fiscal subsidies		PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b (mil. BAM)	Share of PE in total PSE_b
		A.2 (mil. BAM)	C.2 (mil. BAM)				
2018	43.87	0.00	0.00	0.00	0.00	71.00	0.00%
2019	-74.83	0.00	0.00	0.00	0.00	71.00	0.00%
2020	-109.18	0.00	0.00	0.00	0.00	84.89	0.00%
2021	-0.09	0.73	0.00	0.73	14.47	101.45	0.72%
2022	340.50	1.42	0.00	1.42	24.70	107.26	1.32%
2023	499.95	0.67	0.00	0.67	10.29	205.25	0.32%

Source: Authors' calculations

Table 5. presents the market price differential and commodity – specific budgetary transfers for different types of meat over the 2018 – 2023 period. Between 2018 and 2023, domestic beef prices consistently exceeded the EU reference price.

Similarly, the same was recorded for pig meat. Budgetary support for beef production was provided through direct payments per animal, including measures like cattle fattening ranging from 120 to 300 BAM and a cow-calf system, amounting from 200 to 400 BAM. The analysed budgetary transfers for beef production were primarily based on subsidies per animal. These transfers varied, with the highest amount recorded in 2021, reaching 4.16 million BAM. However, the budgetary transfers remained relatively stable. The share of these transfers within the total PSE_b declined from 4.39% in 2018 to 2.00% in 2023.

The production of pigs was supported through direct payments per animal, ranging from 90 to 250 BAM for fattening and from 30 to 60 BAM for breeding. From 2018 to 2023, budgetary transfers for pig production were primarily dependent on subsidies linked to animal numbers. Fiscal subsidies linked to animal numbers for pig production rose from 1.70 million BAM in 2018 to 5.52 million BAM in 2022. Although absolute transfers increased, the share of fiscal subsidies based on the number of animals towards pig production in total PSE_b declined after 2022. The negative difference between the domestic and EU reference prices was recorded for sheep meat in 2018-2022. In 2023, the domestic price for sheep meat exceeded the EU reference price, indicating a price disparity between the domestic and the EU market.

In the first three years of the observed period, fiscal subsidies linked to animal numbers for sheep meat production fell from 2.56 million BAM to 0.73 million BAM. These transfers increased from 2021 to 2023, reaching 2.42 million BAM. The share of transfers for sheep meat production showed significant variations in total budgetary support to agriculture during the analysed period. The production of sheep was supported through direct payments per animal, ranging from 20 to 40 BAM for breeding.

Poultry meat had high prices in comparison to the EU reference prices from 2018- 2023. The total fiscal subsidies based on current animal numbers for poultry meat production illustrated a steady increase from 2018 to 2023. They rose from 0.59 million BAM in

2018 to 2.70 million BAM in 2023, indicating a consistent upward trend in budgetary support. The share of these transfers in total PSE_b ranged from 0.83% to 1.32%, showing a gradual increase over the observed period. Broiler production was supported through direct payments, ranging from 0.05 to 0.15 BAM per beak.

Table 5. Market price differential (MPD) and fiscal subsidies to beef, pig meat, sheep meat, and poultry meat producers of in millions of BAM from 2018 to 2023

Beef	MPD (BAM per tonne)	Fiscal subsidies	PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b	Share of PE in total PSE_b
		C.2				
2018	3.642,49	3.12	3.12	164.00	71.00	4.39%
2019	3.049,06	1.83	1.83	101.67	71.00	2.58%
2020	2.127,34	2.38	2.38	140.20	84.89	2.97%
2021	1.842,42	4.16	4.16	267.15	101.45	4.21%
2022	3.395,03	2.75	2.75	183.11	107.26	2.56%
2023	5.223,81	4.10	4.10	256.13	205.25	2.00%
Pig meat	MPD (BAM per tonne)	Fiscal subsidies	PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b	Share of PE in total PSE_b
		C.2				
2018	842.39	1.70	1.70	28.79	71.00	2.39%
2019	184.36	2.95	2.95	42.69	71.00	4.15%
2020	72.83	2.81	2.81	37.44	84.89	3.31%
2021	126.65	4.02	4.02	51.55	101.45	3.96%
2022	599.37	5.52	5.52	73.57	107.26	5.14%
2023	2.160,36	5.25	5.25	69.10	205.25	2.56%
Sheep meat	MPD (BAM per tonne)	Fiscal subsidies	PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b	Share of PE in total PSE_b
		C.2				
2018	-496.30	2.56	2.56	284.56	71.00	3.61%
2019	-1.241,77	0.85	0.85	94.89	71.00	1.20%
2020	-4.749,80	0.73	0.73	91.50	84.89	0.86%
2021	-5.055,14	0.83	0.83	92.00	101.45	0.82%
2022	-2.206,34	0.94	0.94	117.75	107.26	0.88%
2023	538.74	2.42	2.42	302.00	205.25	1.18%
Poultry meat	MPD (BAM per tonne)	Fiscal subsidies	PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b	Share of PE in total PSE_b
		C.2				
2018	1.111,82	0.59	0.59	20.27	71.00	0.83%
2019	980.45	0.84	0.84	28.98	71.00	1.18%
2020	1.033,56	0.94	0.94	34.71	84.89	1.10%
2021	911.60	1.72	1.72	43.66	101.45	1.20%
2022	669.78	1.37	1.37	41.61	107.26	1.28%
2023	1.211,57	2.70	2.70	90.16	205.25	1.32%

Source: Authors' calculations

Milk is considered as one of the most heavily subsidised agricultural productions in the Republic of Srpska, consistently representing a substantial share of total agricultural budgetary support throughout the observed period.

Table 6. Market price differential (MPD) and fiscal subsidies to milk producers in millions of BAM from 2018 to 2023

Milk	MPD (BAM per tonne)	Fiscal subsidies			PE mil. BAM	PE/ product (BAM per tonne)	Total PSE_b	Share of PE in total PSE_b
		A.2	B.	C.2				
2018	-98.24	28.69	0.12	0.94	29.75	105.38	71.00	41.89%
2019	-83.09	27.32	0.17	1.84	29.33	112.09	71.00	41.30%
2020	-33.53	28.09	1.23	0.38	29.70	108.40	84.89	34.99%
2021	-137.23	29.91	0.71	0.64	31.26	114.54	101.45	30.82%
2022	-263.30	32.78	1.24	0.79	34.81	115.72	107.26	32.45%
2023	31.40	31.80	3.82	11.53	47.15	160.62	205.25	22.97%

Source: Authors' calculations

The share of fiscal subsidies for milk production in total PSE_b declined from 41.89% in 2018 to 22.97% in 2023. Almost one-third of the total budgetary transfers to agriculture referred to subsidies towards milk production from 2020 to 2022. These subsidies were mainly related to output-based production and animal numbers, while in recent years (2020, 2022 and 2023) the amounts for fiscal subsidies that were recorded related to input use, more precisely for fixed input use. The highest budgetary support for milk producers was secured through fiscal subsidies based on output, ranging from 27.32 in 2019 to 32.78 million BAM in 2022. The total support for milk production rose from 29.75 million BAM in 2018 to 47.15 million BAM in 2023. Domestic milk prices remained below EU reference prices throughout the period, except in the final year. Although the absolute amount of support for milk production increased, its share in the total budgetary support decreased. This can be attributed to a rise in overall budgetary transfers towards agriculture.

The nominal rate of protection and the nominal rate of assistance to selected agricultural products

This section of the paper is dedicated to analysing the NRP and the NRA to nine selected agricultural products in the Republic of Srpska (Figures 1-5). The analysed NRP indicator of wheat was negative, implying that wheat producers in the Republic of Srpska (B&H) faced low price protection from 2018 to 2023 compared to the EU producers. In 2022, a positive shift (0.75%) in the NRA and the least negative NRP (-4.85%) were recorded.

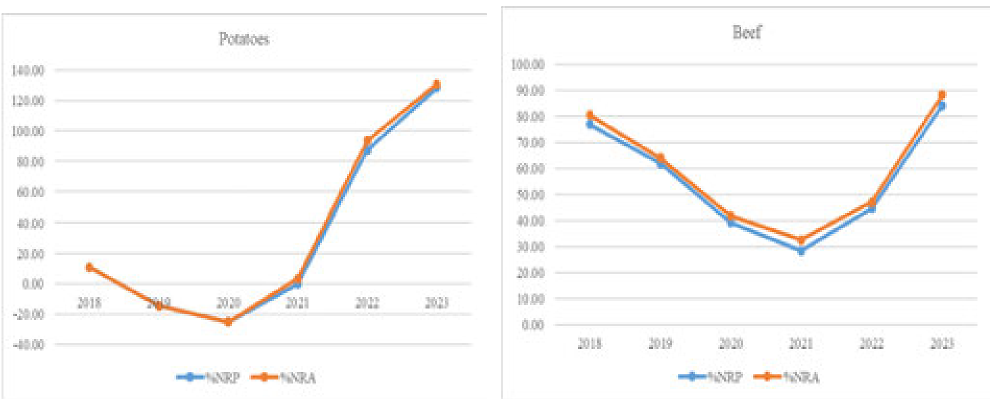
These results indicate the need for further improvement of government interventions and increased support for wheat producers. Negative market conditions influenced grain maize producers in the Republic of Srpska. Both negative NRP and NRA indicators indicated a lack of protection for them. The largest decline of the NRP (-25.25 %) and the NRA (- 23.61%) was recorded in 2023.

Figure 1. NRP and NRA for wheat and grain in the period 2018-2023

Source: Authors' calculations

The NRP indicator for potatoes varied during the observed period. A positive shift occurred in 2022 and 2023, with the NRP rising to 87.42% in 2022 and further to 128.18% in 2023, indicating that domestic potato prices exceeded the reference prices. The NRA indicator showed a similar variation to the NRP. In 2022 and 2023, the NRA was 93.76% and 130.81%, indicating higher budgetary support to the domestic producers of potatoes in the Republic of Srpska. The negative NRA in previous years suggested the absence (2018-2020) or less support (2021) for potato producers in the Republic of Srpska. Beef recorded a positive NRP during 2018-2023. This means domestic beef producers were exposed to higher domestic prices in comparison to EU reference prices.

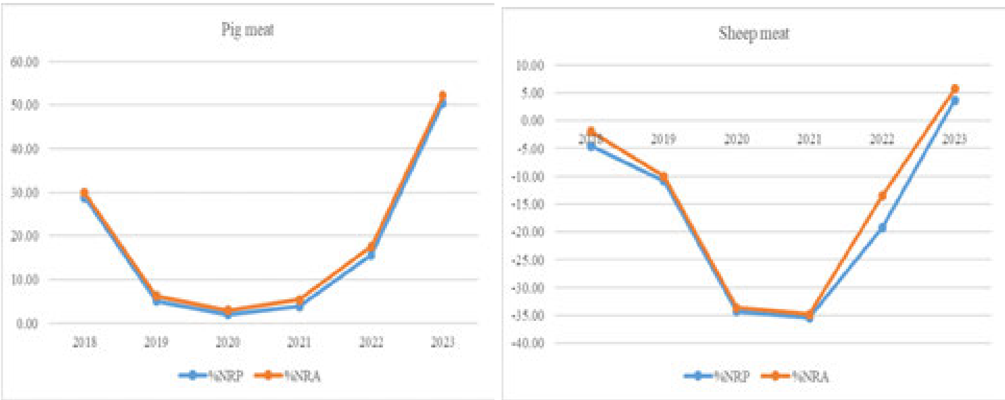
Figure 2. NRP and NRA for potatoes and beef in the period 2018-2023



Source: Authors' calculations

The highest decline of the NRP was recorded in 2021 (28.44%). Similar to the NRP, the NRA to beef was positive over observed period, meaning that beef producers had high budgetary support from the government. The highest decline in the NRA was recorded in 2021 (32.56%). The positive NRP for pig meat indicated that producers largely benefited from favourable market conditions, as domestic prices were higher than the EU reference prices. The positive NRA to pig meat over time implied high budgetary support for agricultural producers.

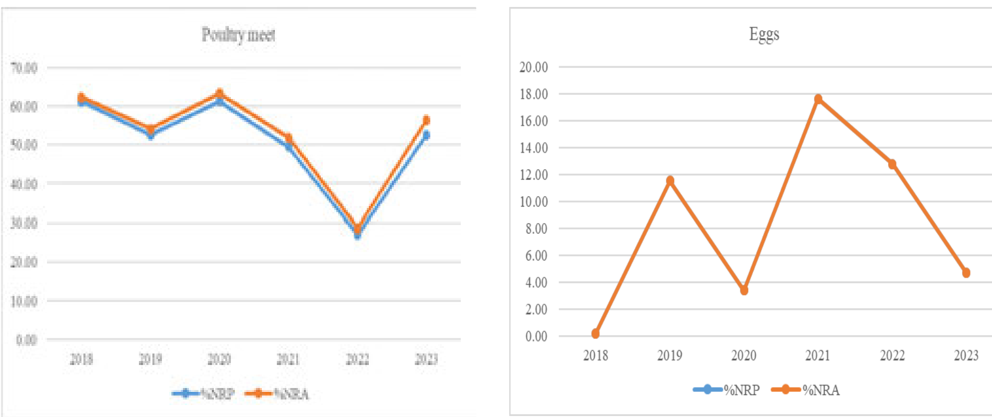
Figure 3. NRP and NRA for pig meat and sheep meat in the period 2018-2023



Source: Authors' calculations

Among all analysed various types of meat products, sheep meat recorded the negative NRP and NRA, with peaks observed in 2020 and 2021. These results highlight the need for increased investments and support for domestic sheep meat producers in the Republic of Srpska (Figure 3). However, the positive NRP and NRA were recorded in 2023 (3.62%; 5.66 %). In the Republic of Srpska, producers of poultry meat and eggs have largely received price protection and support over time (Figure 4).

Figure 4. NRP and NRA for poultry meat and eggs in the period 2018-2023

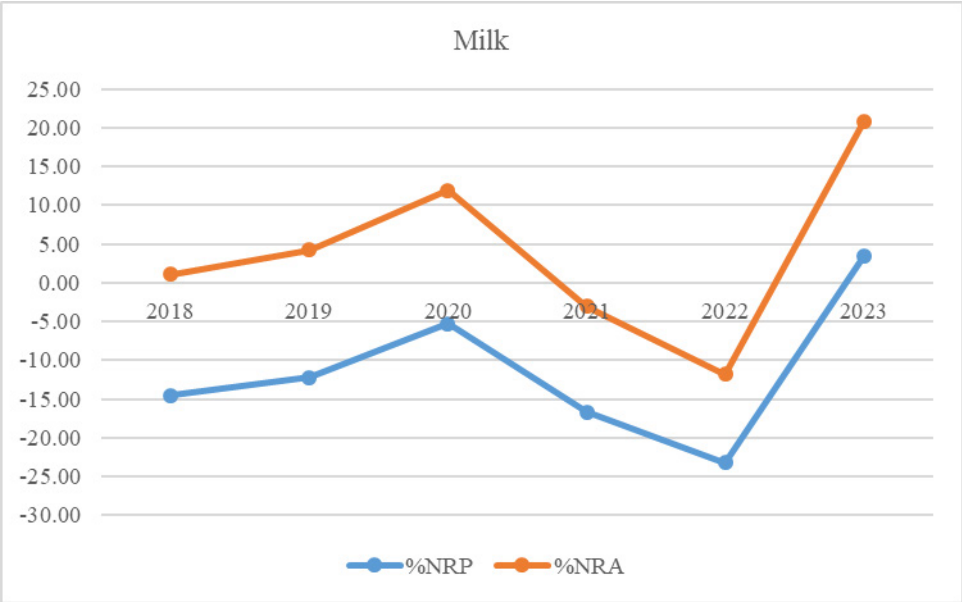


Source: Authors' calculations

The highest NRP and NRA for poultry meat were recorded in 2020 (61.24%; 63.30%). There was no recorded budgetary support for the production of eggs in the Republic of Srpska from 2018 to 2023. However, based on the NRP and NRA indicators calculated, the egg producers experienced favourable market conditions. The producer egg prices were higher than the EU reference prices. The highest NRP and NRA were recorded in 2021 (17.61%).

During the observed period from 2018 to 2022, the NRP indicator for milk was predominantly negative, except in 2023, when a positive NRP of 3.39% was recorded. The positive NRP for milk in 2023 indicated an improvement in the protection of domestic milk production, i.e., the milk price was higher than the EU reference price.

Figure 5. NRP and NRA to milk for the period 2018-2023



Source: Authors' calculations

On the other hand, the NRA indicator for milk exhibited variations; positive values were recorded during 2018-2020 and in 2023, while negative values were recorded during 2021-2022. A positive NRA indicated an increase in the assistance to domestic milk production in certain years of the analysed period, primarily owing to significant budgetary support. Without this support, it is questionable whether the NRA to milk would have been positive, which highlights the importance of government support to ensure the sustainability of domestic milk production.

Discussions

The analysed NRP and NRA indicators offered insight into the extent of price protection and support provided to agricultural producers in the Republic of Srpska, about both the EU market and domestic support measures. By comparing the results of the NRP and NRA indicators for nine selected agricultural products, the policy support for agricultural producers has shown to be heterogeneous across the selected products. The positive NRPs for beef, pig meat, poultry meat, eggs, and in some years for potatoes and milk, reflected domestic prices exceeding EU reference prices. This reflects price distortions and provides incentives for agricultural producers to increase production. Conversely, the negative NRPs for sheep meat and predominantly for wheat and grain maize, signified that EU reference prices were higher than the domestic prices. This suggests that domestic market and trade policies, together with possible market performance factors, have created disincentives for agricultural producers in the Republic of Srpska.The results of NRAs for selected agricultural products provided a comprehensive overview of the overall price distortions.

The positive NRA reflected the extent to which government policies, particularly budgetary transfers, boosted gross returns for producers of beef, pig meat, poultry meat, eggs, and in some years of the observed period for potatoes and milk, beyond the levels attainable without the government intervention. Conversely, the negative NRA indicated how these policies decreased gross returns to wheat, grain maize and sheep meat. The negative NRPs and NRAs collectively indicated a lower level of protection, highlighting potential weaknesses in the existing support policies and their inability to stimulate agricultural production effectively. As seen in comparable countries, the discrepancy in financial support across product groups had created incentive imbalances, as noted in the Republic of Srpska (FAO, 2022).

An examination of potential factors influencing price incentives for agricultural producers of selected products in the Republic of Srpska reveals several notable features of the agricultural sector: (1) *trade commitments*; as a part of the Bosnia and Herzegovin, the Republic of Srpska bound by free trade agreements with the EU and other partners, which affect domestic price levels; (2) *small size and fragmented agricultural holdings*; the prevalence of small-sized and fragmented agricultural holdings limits economies of scale and overall efficiency; (3) *limited market access*; the dominance of small-scale farmers with limited access to markets due to high competition and low resources hinders their competitiveness; (4) *low productivity and high production costs*; partly driven by the application of value-added tax (VAT) on both variable and fixed inputs; (5) *financial support discrepancy and insufficient budget allocations*; differences in the level of financial support across various products along with inadequate budget allocations have created imbalances in incentives.

The FAO (2022) also emphasized the influence of these factors as potential drivers of price incentives in the Eastern Europe, the Caucasus, and Central Asia, regions comparable to Bosnia and Herzegovina, and specifically the Republic of Srpska in terms of agriculture's significance for economic developments. By implementing policy adjustments for price support, improving the overall market environment and productivity, reducing production costs, harmonising financial support across products, and pursuing long-term structural reforms, the Republic of Srpska can create a more supportive environment for agricultural producers and ensure sustainable agricultural production. To more precisely evaluate the impact of market price policy measures on domestic producer protection, the effective rate of protection (ERP) can be calculated as a complement to the NRP and NRA. The effective rate of protection is calculated exclusively at the farm gate level and assesses the impact of tariffs on imported inputs on the domestic value added per unit of output (MAFAP, 2015). Specifically, it is expressed as the percentage difference between the value added per unit based on reference input and output prices at the farm gate, versus the value added per unit calculated using market prices. As the calculation of ERP requires farm-level production cost data to determine input cost shares relative to output value, which are not available in the statistical database at the level of the Republic of Srpska, this study faced constraints in calculating of this indicator. Hence, this remains a task for subsequent research.

Conclusions

The analysis of the NRP and the NRA provided a valuable insight into the level of protection for agricultural producers in the Republic of Srpska compared to the EU. The results revealed substantial variations in price incentives and public expenditure among selected agricultural products. Targeted policy adjustments and adequate budget allocations are crucial to enhance the efficiency and competitiveness of agricultural production in the Republic of Srpska. The recommendations for future research should also include the development of a comprehensive database for more accurate calculation of agricultural support indicators, enabling a more thorough assessment of how effective of the agricultural policy is, and its long-term impact on this sector in the Republic of Srpska.

Conflict of interests

The authors declare no conflict of interest.

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ASSESSING THE DEGREE OF INNOVATION IN ROMANIAN AGRICULTURE: THE IMPACT OF MODERN TECHNOLOGIES ON PERFORMANCE AND SUSTAINABILITY

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A B S T R A C T

This study investigates the adoption and perception of technological innovations and sustainable practices among farmers in the South-East region of Romania. The survey targeted mixed crop–livestock farms and post-harvest activities, providing a representative overview of the sector. Findings reveal a moderate uptake of digital tools, including farm management software, drones, and sensors, alongside notable reluctance toward biotechnologies. Conversely, respondents expressed greater receptivity to renewable energy solutions and organic farming. Overall, the level of digitalization remains low, with traditional practices prevailing, consistent with national patterns. These results highlight the need for targeted interventions—such as awareness campaigns, specialized training, financial incentives, pilot projects, and supportive public policies—to facilitate innovation and strengthen agricultural competitiveness. Future research should extend to a national scale and assess the specific economic and environmental impacts of individual technologies, thereby informing strategies to advance a more sustainable and resilient agricultural sector.

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Introduction

Innovations in agriculture are essential for increasing productivity, improving sustainability and responding to global challenges such as climate change, population growth and increasing demand for food [6]. In the specialized literature, innovation is described as a process that involves the development, testing and implementation of new ideas, product models, processes or functional structures intended for application in industry [1]. [The main innovations in agriculture at European level relate to precision farming, vertical farming and hydroponics, biotechnology and genetic modification, automation and robotics, efficient irrigation systems, sustainable and regenerative agriculture, blockchain technologies and digital platforms, the use of drones and artificial intelligence (AI), alternative food production and renewable energy for farms [17,19]. Andrei & Darvasi (2012) emphasizes that the challenges of digitalization in Romanian agriculture are the subject of analysis in various scientific studies that analyze the challenges and opportunities associated with the implementation of digital technologies in the agricultural sector [6]. A recent study shows that in Romanian agriculture, farms are medium-sized, with an average area of 150 hectares [9].

GPS and drone technologies allow farmers to monitor and manage fields with greater precision. Drones can provide aerial images to assess crop health, while GPS facilitates accurate planting and fertilization. Soil and climate sensors provide real-time data on moisture, soil temperature and other variables, helping farmers make informed decisions about irrigation and fertilizer application. Vertical farming is a method of growing plants in vertically arranged beds, which allows for more efficient use of space and can be carried out in urban or inland areas. Hydroponics and aeroponics involve systems that grow plants without soil, using only nutrient solutions, which save water and space and allow continuous production. Genetically modified (GMO) crops create plants that are more resistant to pests, drought and disease, or with improved nutritional value. CRISPR and other gene editing techniques allow precise modification of plant DNA to achieve resistance to adverse conditions or to increase yields [13].

Agricultural robots are used for various tasks such as planting, harvesting and monitoring crops. They can improve efficiency and reduce the need for manual labor. Autonomous irrigation systems are managed by software and sensors that adjust irrigation according to the actual needs of the plants. Drip irrigation saves water by delivering exactly the right amount of water to plant's roots. Sensor-controlled irrigation monitors soil moisture and triggers irrigation only when needed, reducing water consumption. Permaculture practices emphasize crop and livestock integration to reduce environmental impact and enhance biodiversity. No-till farming is a technique that reduces soil erosion and better maintains moisture.

Blockchain for supply chain traceability allows the origin of agricultural products to be traced and ensures transparency and security in food trade. Digital trading platforms connect farmers directly to markets, reducing intermediation and increasing producer income [16].

Artificial intelligence for analyzing agricultural data uses algorithms that can analyze data collected from sensors and drones to provide precise recommendations on the optimal time to sow, irrigate or apply treatments. Drones for spraying and monitoring allow precise application of pesticides and fertilizers, reducing the amount needed and minimizing waste, the use of unmanned aerial vehicles in precision agriculture, focusing on innovations in the field of fertilization and their impact on agricultural efficiency and sustainability, as a recent study examines [3]. Lab-grown meat is an alternative to traditional meat, produced from animal cells in the lab, which can reduce the environmental impact of animal farming. Protein from insects and other unconventional sources may be a solution to the increased demand for protein, exploring alternative sources such as insects, which require fewer resources for production. Solar panels and wind turbines are being installed on farms to generate electricity, reducing dependence on fossil fuels. Bioenergy involves using agricultural residues to generate energy in the form of biogas or liquid fuel [19]. Khan et al. (2022) investigated the adoption of mobile internet technology among wheat farmers to support sustainable agricultural practices [5]. Zheng et al. (2019) and Done et al., (2012) analyzed technology adoption among farmers, focusing on the factors influencing this adoption [21]. Ruzzante and Bilton (2018) conducted a meta-analysis of the literature on the adoption of agricultural technologies in developing countries [12]. Wongsim et al. (2018) studied the factors influencing the adoption of agricultural management information systems [20]. Ciurea (2020) discusses considerations regarding the digitalization of Romanian agriculture [2]. Girip & Cojocaru (2021) explore the use of the Internet of Things in Romanian agriculture [4]. Markovits (2024) assesses Romanian farmers' motivation for digitalization, using a research model based on the Unified Theory of Technology Acceptance and Use [7]. Șerban et al. (2023) investigates digitalization in Romanian farms [17]. Petrescu-Mag et al. (2019) investigates Romanian farmers' opinions on the effects of pesticides and their willingness to pay for biopesticides [8]. Rodino et al. (2023) present the challenges of digital transformation in Romanian agriculture [10]. Russian et al. (2023) study the acceptance of digital transformation, analyzing data from Romania [11]. Stanciu & Sârbu (2016) analyze the sustainability and competitiveness of Romanian farms through organic farming and research the use of GMOs in Romanian food production [14-15]. Vărzaru (2025) analyzes the digital revolution in agriculture and the use of predictive models to improve agricultural performance through digital technology [18].

The role of university education in promoting research and innovation is essential, thus there are studies that highlight the success of a Romanian university in using European funds to develop a horticultural research institute of excellence, demonstrating the positive impact of investments in scientific infrastructure on research, innovation and technology transfer [11]. These innovations contribute to a more efficient and sustainable agriculture, better adapted to modern challenges.

Materials and methods

The aim of this research is to assess farmers' adoption and perception of technological innovations and sustainable practices in agriculture. Specifically, the research aims to:

- ✓ To identify the level of use of digital technologies (GPS, sensors, drones) and precision farming among farmers and their perceived impact on efficiency and productivity.
- ✓ To analyze attitudes towards biotechnologies and alternative production, such as genetically modified crops, vertical farming and unconventional protein sources, in order to assess farmers' openness to these innovative methods.
- ✓ The investigation of sustainability measures and renewable energy practices implemented on farms to understand the level of awareness and involvement in sustainable farming approaches.

The quantitative research method used was a survey, based on a questionnaire as a working instrument, applied on a representative sample of agricultural enterprises, mainly in the South-East of Romania. The sample consists of 157 agricultural farms from the South-East region of Romania, taken into account as individual or organized agricultural holdings, managed by people who have a decision-making role regarding the technologies applied. This represents a significant section of the national agricultural context, given that this region is characterized by a great diversity of types of agricultural holdings and varied geographical conditions, and the results may provide a partial but relevant picture for the entire agricultural sector in Romania. In addition to applying the questionnaire survey, the analysis of the collected data was carried out using descriptive and inferential statistical methods. Comparative analysis of mean scores was used to evaluate the perception of the impact of technologies, and t-tests for independent samples were applied to verify the statistical significance of differences between groups (e.g. farmers using vs. non-using digital technologies). Pearson correlations were also used to analyze the relationships between variables such as farm size, education level and degree of adoption of innovations. The research aimed at testing three hypotheses, as follows:

Hypothesis 1: Farm businesses that use digital and precision farming technologies have a more positive perception of farm efficiency and productivity compared to those that do not. This hypothesis explores the relationship between the use of modern technologies (GPS, sensors, and drones) and farmers' perceptions of the impact of these technologies on farming efficiency. The hypothesis can be tested by analyzing the agreement scores on the statements in the "Digital Technologies and Precision Farming" section of the applied questionnaire.

Hypothesis 2: Farm businesses that are open to the use of biotechnologies (such as GM crops or gene editing) and alternative production methods (such as vertical farming or unconventional proteins) believe that these practices can improve the competitiveness and sustainability of their business. This hypothesis examines farmers' openness to biotechnologies and innovative methods and assumes that adopters perceive a high potential for improving yields and sustainability. Analysis of the responses in the "Biotechnology and Alternative Production" section can provide insights into the link between the adoption of biotechnology innovations and perceived on-farm benefits.

Hypothesis 3: Adoption of sustainability and renewable energy practices on farms is influenced by the level of awareness and access to information on the benefits of sustainability in agriculture. This hypothesis investigates whether farmers with high awareness of sustainable practices (controlled irrigation, bioenergy, renewable energy) are more likely to adopt sustainable measures. The scores obtained in the "Sustainability and Renewable Energy" section can be correlated with respondents' awareness and attitudes towards sustainability.

The questionnaire on the degree of innovation applied in agriculture was constructed to test the proposed working hypotheses and comprises three sections: Digital Technologies and Precision Farming, Biotechnology and Alternative Production and Sustainability and Renewable Energy. Each item corresponding to a section is constructed on a Likert-type scale with 5 response variants, regarding the degree of agreement on a scale from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was distributed by means of a google-form to agricultural enterprises, predominantly with an activity related to plant cultivation combined with animal husbandry and ancillary activities after harvesting. 157 responses were validated. The results were analyzed and interpreted using data analysis tools in Microsoft Office Excell. The survey conducted in this study has significant scientific importance as it provides valuable information on the adoption of modern agricultural technologies in Romania, which is essential for understanding the country's progress in agricultural innovation and sustainability. Professionally, the results can influence policy decisions, guide future investments in agricultural technology, and help develop strategies to support farmers in integrating sustainable practices, improving productivity, and enhancing overall farm performance.

Results

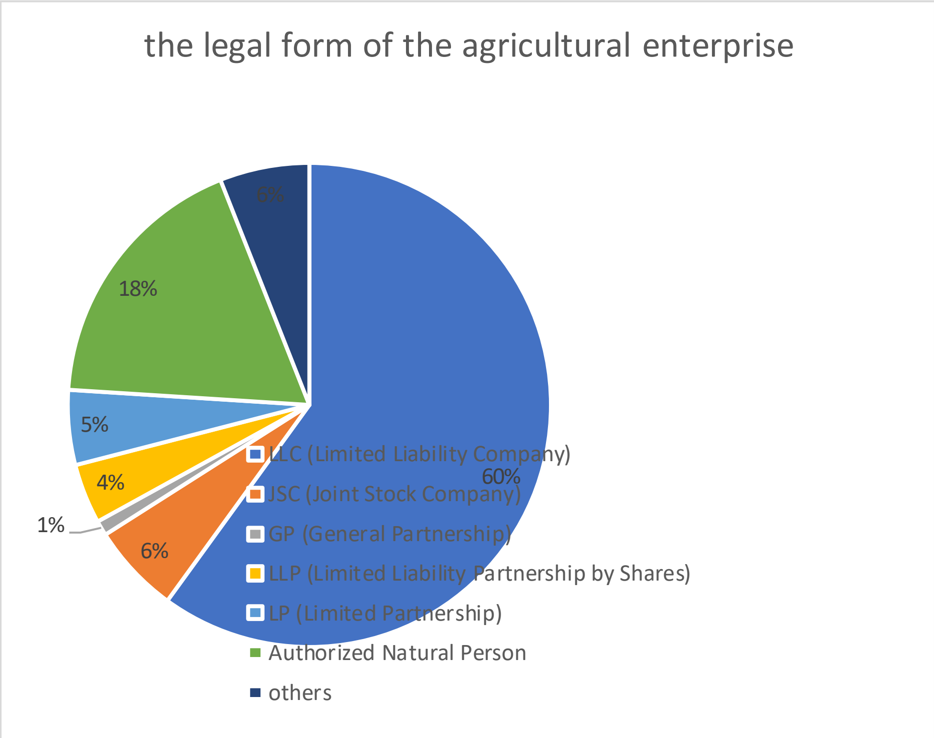
The dominance of Limited Liability Companies LLCs (60% of respondents) among farmers suggests that they prefer a business model that protects their personal assets, which is essential in a sector often plagued by risk and uncertainty. This choice may indicate an openness to adopting innovative technologies, as LLCs offer flexibility in managing resources and integrating sustainable practices.

The limited presence of JSCs, only 6% of total respondents, suggests that farmers are not attracted by more complex structures that impose strict requirements. This could reflect a reluctance to innovate in ways that require large investments and considerable financial risks. Only 1% of the surveyed enterprises have a GP as their legal form of organization, the rarity of the use of general partnerships may indicate a preference for structures that limit liability, which is important in the context of adopting risky technologies or experimenting with new farming practices.

In terms of Limited Liability Partnerships, 4% of respondents say they have this legal form. Close to 5% have Limited Partnership as their legal form, indicating that the limited use of limited partnerships may reflect a preference for simpler structures that are easier to manage in the context of implementing innovations. A significant share of 18% of ANPs suggests that many farmers opt for a simple structure, which allows them to test technological innovations and sustainable practices without engaging in the administrative complications of more complex organizational forms.

The 6% share for other forms of organization may indicate a diversity of approaches among farmers, which may include specific initiatives tailored to local needs, which is essential in the context of the adoption of technological innovations (Figure 1).

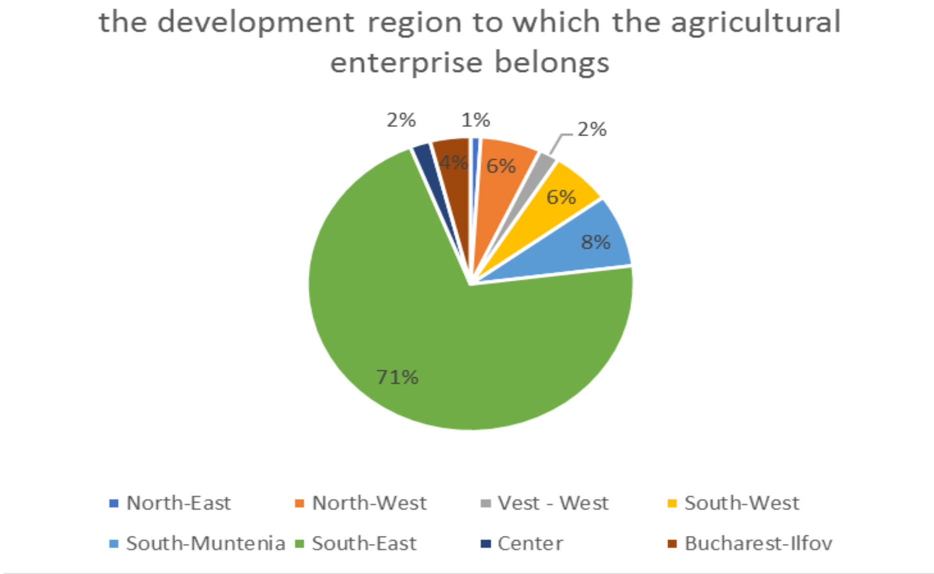
Figure 1. Distribution of responses by legal form of agricultural enterprises



Source: author's processing

In terms of the development region to which the agricultural enterprises participating in the survey belong, a majority 71% are from the South-East region, followed by a smaller percentage of 8% from the South-Muntenia region, then in equal percentages of 6% each from the North-West and South-West regions (Figure 2).

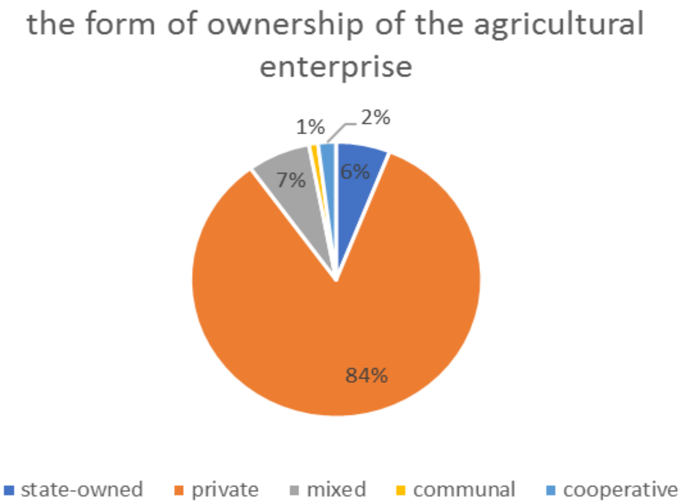
Figure 2. Distribution of responses by development region to which agricultural enterprises belong



Source: author's processing

With regard to the percentage distribution of responses for the form of ownership of the agricultural enterprises participating in the survey, the majority of 84% of the respondents had private ownership, followed by mixed and state ownership in relatively small percentages. (Figure 3)

Figure 3. Distribution of responses by form of ownership of agricultural enterprises



Source: author's processing

With regard to Section I of the questionnaire entitled “Digital technologies and precision farming”, the distribution of responses and the score obtained for each of the statements in the section are presented in Table 1.

Table 1. Distribution of responses and score obtained for Section I

	Strongly Disagree (-2)	Disagree (-1)	Neutral (0)	Agree (1)	Strongly Agree (2)	Total	Statement score
We use GPS technologies for efficient field management.	17	22	20	74	24	157	0.420382
We constantly monitor soil moisture and conditions using sensors.	19	31	13	63	31	157	0.356688
We use drones to monitor crop health and optimize resources.	36	44	25	29	23	157	-0.261146
Digital technologies help us make more informed and quicker decisions regarding irrigation and fertilizer application.	29	28	2	67	31	157	0.273885
Digital platforms facilitate our access to markets and new clients.	6	16	3	41	91	157	1.242038

Source: author’s processing

Claim 1 - “We use GPS technologies to effectively manage our fields” Score: 0.420. This positive but relatively low score indicates moderate agreement with the use of GPS technologies. GPS is probably used but is not an essential or very common element of field management.

Claim 2 - “We constantly monitor moisture and soil conditions using sensors” Score: 0.357

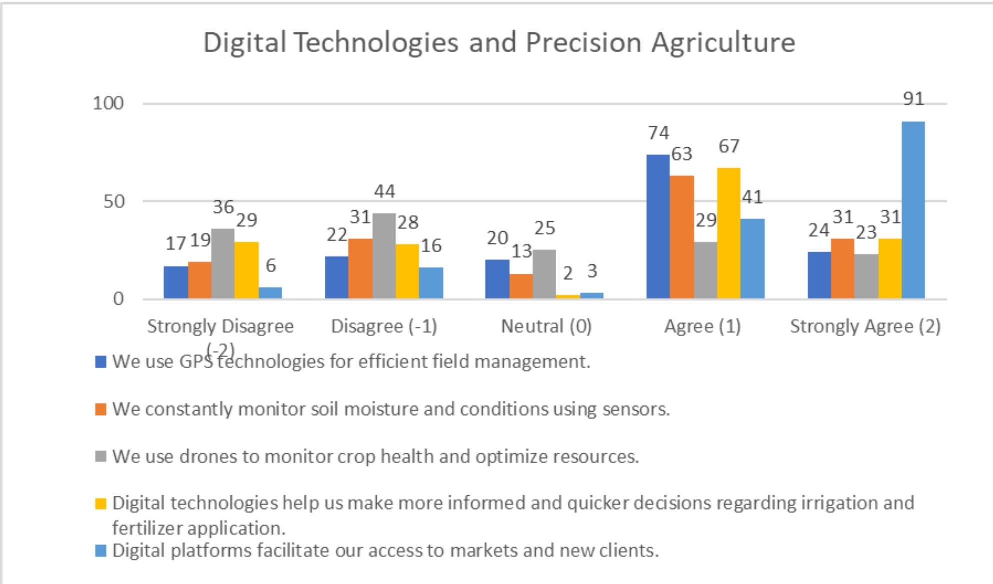
Similar to the first statement, this low positive score indicates poor agreement. Moisture and soil condition monitoring is probably used, but not intensively or consistently.

Claim 3 - “We use drones for crop health monitoring and resource optimization” Score: -0.261. The negative score indicates weak disagreement, suggesting that drones are rarely or only occasionally used, and their deployment for monitoring and optimization is not common practice in this context.

Claim 4 - "Digital technologies help us make more informed and faster decisions about irrigation and fertilizer application" Score: 0.274. A positive but low score, indicating a slight acceptance that digital technologies are useful in irrigation and fertilizer decisions, but they are not seen as a central solution in decision making.

Claim 5 - "Digital platforms facilitate our access to markets and new customers" Score: 1.242. This significantly positive score shows strong agreement, indicating that digital platforms are seen as a highly valuable tool for expanding access to markets and customers, likely to bring significant benefits to marketing and sales activities.

Figure 4. Distribution of responses Section I



Source: author's processing

Overall, the scores indicate a varied use of digital technologies in agriculture, with the highest appreciation for the impact of digital platforms in opening access to new markets.

Regarding Section II of the questionnaire entitled "Biotechnology and Alternative Production", the distribution of responses and the score obtained for each of the statements in the section are presented in Table 2.

Table 2. Distribution of answers and score obtained Section II

	Strongly Disagree (-2)	Disagree (-1)	Neutral (0)	Agree (1)	Strongly Agree (2)	Total	Statement score
We are implementing genetically modified crops (GMOs) to increase yield and pest resistance.	37	24	20	65	11	157	-0.070064
Genetic editing technologies such as CRISPR have been used to improve the quality of our production.	27	38	13	54	25	157	0.076433
We are interested in using insect proteins or other unconventional sources to expand our product range	61	30	25	23	18	157	-0.592357
We are considering integrating vertical farming or hydroponics into our production systems	54	51	2	33	17	157	-0.585987
We believe that no-till farming could enhance the sustainability of our farm	45	61	3	19	29	157	-0.471338

Source: author's processing

Claim 1 in section II: "We implement genetically modified crops (GMOs) to increase yield and pest resistance" scores -0.070063694, being close to zero, with a slight negative trend, indicating a rather balanced perception, where the potential advantages of GMOs are recognized, but there are also reservations about possible risks or disadvantages.

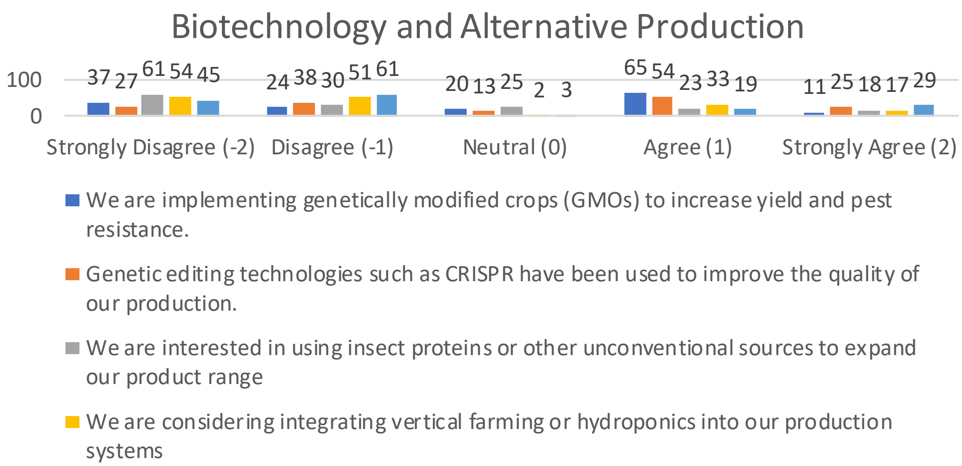
Claim 2 in section II: "Gene editing technologies such as CRISPR have been used to improve the quality of our output" scores 0.076433121, being close to zero, with a slight positive skew, reflecting a moderately favorable attitude towards the use of CRISPR, possibly due to the recognition of the advantages in terms of efficiency and quality, but also to a focus on ethics and safety.

Claim 3 in Section II: "We are interested in using insect protein or other unconventional sources to expand our product offerings" scores -0.592356688. This stronger negative score suggests a significant reluctance to introduce insect proteins, likely due to cultural perceptions and consumer acceptance concerns.

Claim 4 in Section II: "We are considering integrating vertical farming or hydroponics into our production systems" scores -0.585987261. This moderate negative score indicates a clear hesitancy towards the adoption of vertical farming or hydroponics, possibly due to high initial investment, yield uncertainty or technical limitations.

Claim 5 in Section II: "We believe that no-till farming could improve the sustainability of our farm" scores -0.47133758. The moderate negative score suggests a somewhat reserved stance towards no-till farming, perhaps due to implementation challenges on the farm or a perception that the benefits are not very clear in the current context.

Figure 5. Distribution of responses Section II



Source: author's processing

Overall, the scores reflect a cautious openness to modern technologies and innovative production methods, combined with a pragmatic assessment of risks and challenges.

As regards Section III of the questionnaire entitled "Sustainability and Renewable Energy", the distribution of responses and the score obtained for each of the statements in the section are presented in Table 3.

Table 3. Distribution of answers and score obtained Section III

	Strongly Disagree (-2)	Disagree (-1)	Neutral (0)	Agree (1)	Strongly Agree (2)	Total	Statement score
We use solar panels or wind turbines to generate energy on the farm.	11	31	1	77	37	157	0.624203822
We have implemented drip irrigation systems to reduce water consumption and improve efficiency.	15	19	0	47	76	157	0.955414013
Our irrigation systems are controlled by sensors, optimizing water resources.	30	47	0	39	41	157	0.089171975
Sustainability is a priority in our agricultural management decisions.	17	16	2	72	50	157	0.777070064
We use or are considering using agricultural residues to generate bioenergy.	19	35	18	51	34	157	0.292993631

Source: author's processing

Claim 1 in Section III: "We use solar panels or wind turbines to generate energy on the farm" scores 0.624203822, a moderate positive score, indicating good support for the use of solar or wind energy, suggesting that this practice is seen as beneficial, even though there may be some degree of reluctance to full or continued implementation.

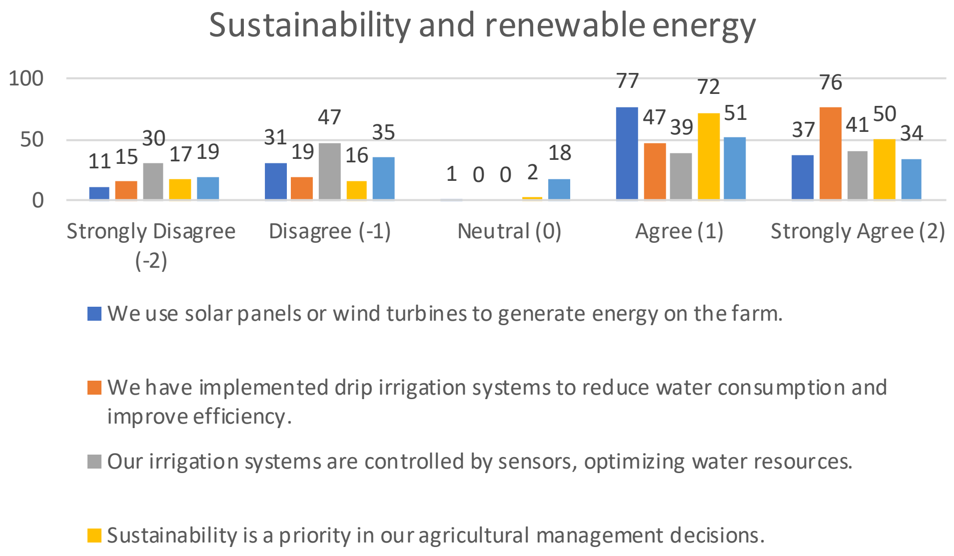
Claim 2 in Section III: "We have implemented drip irrigation systems to reduce water use and improve efficiency" scores 0.955414013, a high positive score, shows strong agreement, suggesting that drip irrigation is considered highly effective and desirable for the goals of saving water and increasing efficiency on the farm.

Claim 3 in Section III: "Our irrigation systems are controlled by sensors, optimizing water resources", gets a Score: 0.089171975, close to zero, this score suggests a neutral perception, perhaps with slight support for the use of sensors in irrigation. This may reflect some caution, either due to cost or a lower level of confidence in fully implementing the technology.

Claim 4 in Section III: "Sustainability is a priority in our agricultural management decisions" scores 0.777070064, a strong positive score suggesting high agreement, showing that sustainability is perceived as a clear priority in agricultural management decisions, although there may be a small reservation about implementation.

Claim 5 in Section III: "We use or are considering the use of agricultural residues to generate bioenergy" scores 0.292993631. This positive, but lower, score indicates moderate support, suggesting an interest in bioenergy, but perhaps a lack of full implementation at present, either due to technical challenges or costs involved.

Figure 6. Distribution of responses Section III



Source: author's processing

Overall, these scores suggest a clear openness and support for renewable energy and sustainability practices, with varying levels of enthusiasm, but all in a positive direction, indicating a commitment to sustainable practices on the farm.

The results of this questionnaire contributed to the assessment of the degree of innovation in agriculture and the identification of potential areas for development. The interpretation of the scores obtained using the Likert scale is based on the analysis of the mean values of the responses, their trends and variation in order to understand the degree of agreement or disagreement of the respondents with different statements. The low or medium scores obtained indicate that innovation management requires additional support, such as funding, training or awareness campaigns to be better adopted in Romanian agriculture.

As regards the evaluation of hypotheses based on the results obtained, the following is observed:

Hypothesis 1: Partially confirmed. Farmers using digital technologies have a positive perception of efficiency and productivity, but the scores suggest varied and moderate use of these technologies. The use of digital platforms for market access scored highest, indicating an appreciation of their impact, but not all technologies (e.g. drones) have been widely adopted.

Hypothesis 2: Not confirmed. Farmers show reluctance towards biotechnologies and alternative production methods such as GM crops and insect proteins. Negative scores suggest considerable reluctance to adopt these innovations, which contradicts the hypothesis that these practices are seen to improve competitiveness and sustainability.

Hypothesis 3: Partially confirmed. There is evidence that levels of awareness and access to information affect the adoption of sustainability and renewable energy practices. Although farmers consider sustainability a priority, actual implementation of sustainable practices is not uniform, suggesting that information and awareness may influence their decisions, but are not sufficient to ensure full adoption. The present study highlighted that most farms in the South-East region of Romania use traditional technologies, with a limited adoption of advanced digital tools, which reflects the concordance with national trends, according to a recent report published by the Government of Romania [12], the level of digitalization in Romanian farms is low, although the use of advanced technologies such as sensors, drones, satellite imaging or artificial intelligence could significantly increase the profitability of the sector.

Conclusions

Based on the results obtained from research and the assessment of hypotheses, several recommendations are highlighted to support the adoption of digital technologies, biotechnologies and sustainability practices in agriculture: awareness and education campaigns, financial support and subsidies, partnerships with research institutions, implementation of favorable policies, pilot projects, feedback and continuous adjustments. The study on the adoption of innovative technologies in Romanian agriculture highlights a moderate degree of their use, confirming hypothesis H1 on the positive impact of digital technologies on farm performance. The results show that farmers using digital technologies, such as farm management software or drones for crop monitoring, reported significant improvements in efficiency and productivity. Also, larger farms, with a size of over 50 ha, play an important role in the adoption of modern technologies, which supports hypothesis H3 on the impact of farm size on the capacity to implement innovations. In contrast, reluctance towards biotechnologies and advanced technologies, such as genetically modified organisms, is mainly due to lack of information and restrictive regulations, and this aspect aligns with the perceptions of farmers reported in the survey.

Develop awareness campaigns to inform farmers about the benefits of using digital technologies, biotechnologies and alternative production methods. These campaigns could include training sessions, workshops and seminars addressing the myths and fears associated with these technologies. Implement subsidy and financial support programs for farmers willing to invest in digital technologies, biotechnologies and sustainable farming practices. This could include providing funds for the purchase of equipment, such as sensors or drones, and for the implementation of efficient irrigation systems. Increase collaboration between farmers, research institutions and universities to develop innovative solutions tailored to local needs. These partnerships could facilitate technology and knowledge transfer between researchers and practitioners. Advocate for agricultural policies that support the adoption of innovations, such as regulations favoring the use of genetically modified organisms (GMOs) and incentives for organic production methods. Pilot projects demonstrate the effectiveness and benefits of digital technologies and alternative production methods. These projects can serve as case studies for other farmers and encourage wider adoption. Create feedback mechanisms for farmers to share their experiences and challenges in adopting new technologies. This feedback could be used to adjust training and support programs.

These recommendations can contribute to increasing innovation and adoption of sustainable practices in Romanian agriculture, facilitating a transition towards a more competitive and sustainable agriculture. The results of the study suggest that, although there is a growing interest in sustainable technologies, such as renewable energy sources and organic farming, more support from authorities is needed to encourage the transition to digital technologies and to facilitate smallholder farmers' access to resources and training. Public policies need to focus on the education and continuous training of farmers, as well as on developing the infrastructure necessary for the large-scale integration of these technologies. Implementing subsidies and incentives for investments in digital technologies and renewable energy sources would significantly contribute to accelerating the modernization process of the Romanian agricultural sector. Steps for future research could include expanding the study to include a larger sample of farms from other regions of Romania, in order to obtain a complete picture of the adoption of innovative agricultural technologies at the national level. It would also be useful to analyze the specific impact of each technology on the sustainability and economic performance of farms, as well as the socio-economic factors that influence farmers' decision to adopt these technologies.

Conflict of interests

The authors declare no conflict of interest.

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Annex:1 Questionnaire

Instructions: For each statement, please indicate the degree of agreement using the scale from 1 (strongly disagree) to 5 (strongly agree).

Section I: Digital Technologies and Precision Farming

Claim	Total disagreement	Disagreement	Whatever	Agreement	Total agreement
1. We use GPS technologies for the efficient management of our fields	1	2	3	4	5
2. We constantly monitor moisture and soil conditions using sensors	1	2	3	4	5
3.We use drones to monitor crop health and optimize resources.	1	2	3	4	5
4. Digital technologies help us make more informed and faster decisions on irrigation and fertilizer application.	1	2	3	4	5
5. Digital platforms facilitate our access to markets and new customers.	1	2	3	4	5

Section II: Biotechnology and Alternative Production

Claim	Total disagreement	Disagreement	Whatever	Agreement	Total agreement
1. We implement genetically modified (GM) crops to increase yield and pest resistance.	1	2	3	4	5
2. Gene-editing technologies such as CRISPR have been used to improve the quality of our production.	1	2	3	4	5
3. We are interested in using proteins from insects or other unconventional sources to expand our product offering.	1	2	3	4	5

Claim	Total disagreement	Disagreement	Whatever	Agreement	Total agreement
4. We consider integrating vertical farming or hydroponics into our production systems	1	2	3	4	5
5. We believe that no-till farming could improve the sustainability of our farm.	1	2	3	4	5

Section III: Sustainability and Renewable Energy

Claim	Total disagreement	Disagreement	Whatever	Agreement	Total agreement
1. Use solar panels or wind turbines to generate energy on the farm	1	2	3	4	5
2. We have implemented drip irrigation systems to reduce water consumption and improve efficiency.	1	2	3	4	5
3. Our irrigation systems are controlled by sensors, optimizing water resources.	1	2	3	4	5
4. Sustainability is a priority in our agricultural management decisions.	1	2	3	4	5
5. We use or consider using agricultural residues to generate bioenergy	1	2	3	4	5

MARKET PERSPECTIVES AND SUSTAINABLE AGRICULTURE IN THE CASE OF THE REPUBLIC OF SERBIA

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ABSTRACT

Sustainable agriculture (SA) represents an ecological and economic development path with the aim of applying the best agricultural practices and technologies for the production of healthy food, increasing productivity and competitiveness on the market. The aim of the work is to research the perspectives of the market and SA in the territory of Serbia - Mačva. The research was conducted through a survey with 26 questions and 110 respondents. Analysis of the results shows that young people (50%) are familiar with the concepts of SA (57%) and circular economy (50%). Respondents are interested in SA, purchasing products or starting production, with the main motives: health and environmental protection. The main problems are the high price and poor financial support. For the development of sustainable agriculture, education on the implementation of the circular economy in sustainable agriculture systems, financial support and the availability of the necessary inputs for production are necessary.

Introduction

The term sustainable agricultural development appeared in response to changes in the practice and policy of agricultural development on a global scale, which relate to the longest possible survival of agricultural systems (Vujičić i sar., 2006). Sustainable agriculture implies the use of various technologies, measures and methods in agriculture, which have a positive effect on: increasing the productivity and profitability of agricultural products, reducing pollution and other negative effects, but also the

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preservation and rational use of environmental resources (water, air, soil, biodiversity, etc.) (Santiteerakul et al., 2020). The European Union has defined decarbonization by 2050 as its long-term strategic development goal, while one of the ways to achieve carbon neutrality is the transition from a linear to a circular economy (Ignjatović et. al. 2024a). In addition to contributing to the fight against climate change, reducing pollution and using resources in a sustainable way (Ignjatović et al, 2024b), the circular economy requires significant financial investments by all actors and changes in the concept of business model (Blagojević et al., 2024). There is increasing concern regarding the negative impact of conventional agricultural production on the environment, so the impact of production practices on various factors is being observed, where the characteristics of the soil, consumption of non-renewable resources and environmental pollution are primarily in the center of attention (Sanaullah et al., 2020; Janković & Golubović, 2024; Lakićević et al., 2022; Pantović et al., 2023). The difference between sustainable and conventional production prioritizes soil fertility, pest control and energy consumption. The name conventional agriculture is used in the discursive construction as an alternative approach to agriculture (ie an alternative to conventional agriculture) (Giller et al., 2017). The problems with population growth and the growing need for food certainly go hand in hand with conventional production, and these needs are shown by numerous researches (Tripathi et al.,2019; Slavković et al., 2024; Elder i Hayashi, 2018). That is why there is a growing awareness of the importance of sustainable agriculture, and the evidence of this is the increase in the use of these practices in recent times (Clark et al., 2017; Chen et al., 2009). Reduced tillage increases organic carbon and at the same time limits greenhouse gas emissions (Curtin et al., 2000; Kumara et al., 2023), while integrated nutrient management increases yield and soil carbon and enables better availability of plant nutrients (Choudhury et al., 2018).

Accordingly, the aim of this paper is to explore the perspectives of the market and sustainable agriculture on the territory of the Republic of Serbia in the Mačva region. The task of the questionnaire is to explore the awareness of young people (students) about the market and sustainable agriculture.

Materials and methods

The scientific contribution of this paper relates to research into the awareness of young people (students) about the market and sustainable agriculture. The research was conducted on the territory of the Republic of Serbia (Mačva District), based on surveyed students and employees in vocational education in the city of Šabac. The survey period is September-November 2024. The data collection process used a quantitative approach to surveying the target group in the form of a closed, anonymous questionnaire and a statistical method through the sample method. The survey is based on an indirect, random sample through 26 questions. The total number of respondents who participated in the survey was 110. The summarized data were processed through descriptive and graphical analysis.

Results

In accordance with the number of respondents, i.e. 110 respondents, in percentage terms, 38% of respondents are male, and 62% are female (Figure 01). For the age structure of the respondents, four defined groups were used: the first group up to 20 years old, the second group from 20-40 years old, the third group from 40-60 years old and the fourth group over 60 years old (Figure 02). The first group participates with 47% of the respondents (52), the second group with 50% of the respondents (55), while in the third group there are only 2% of the respondents (2), or 1% of the respondents (1) in the fourth group.

Figure 01. Gender

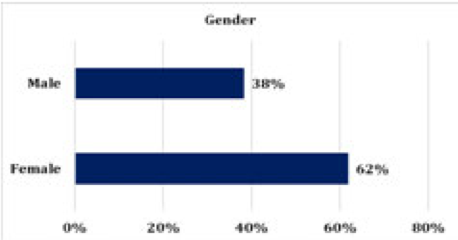

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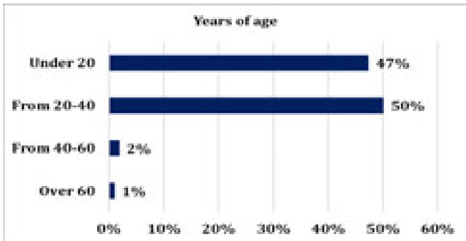
Figure 02. Age



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When it comes to education level, the largest number of respondents has secondary vocational education 84% (92), which is in correlation with the target group of respondents, which are young people. Then, 7% of respondents (8) have completed secondary school, 5% of respondents (6) have completed college or university, then 3% have PhDs (3) and 2% have master's degrees (2). The level of education with completed primary school and completed university is not recorded (0%) (Figure 03).

The place of residence of the respondents includes urban and rural areas and suburban settlements (Figure 04). The analysis determined that the largest number of respondents lives in suburban settlements, 52% (57), while 29% of respondents (32) live in urban areas, and 19% of respondents (21) live in rural areas.

Figure 03. Level of education

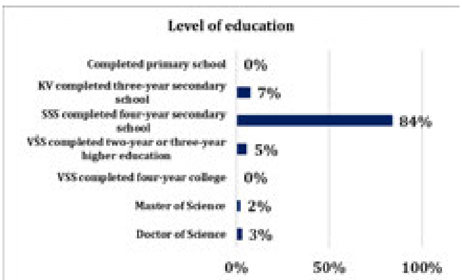

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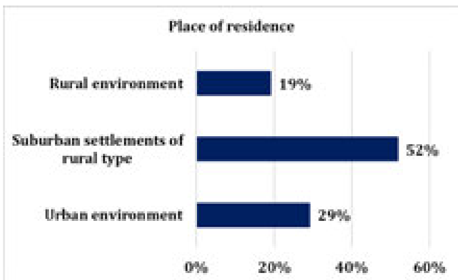
Figure 04. Place of residence



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When asked about the type of household in which respondents live (agricultural, non-agricultural and mixed households), the largest number of respondents live in non-agricultural households, 40% (44), while 35% (39) of respondents live in agricultural households, and 25% (27) in mixed households (Figure 05).

The amount of monthly income distributed into four groups is shown in Figure 06. An analysis of the respondents' income shows that the first group of incomes of less than 50,000 includes 26% of respondents (29). The second group (incomes between 50,000-65,000 dinars) includes 22% of respondents (24). 20% of respondents (22) have incomes between 65,000-85,000 dinars, which belong to the third group. The fourth group with monthly incomes above 85,000 dinars is also the largest group by affiliation, accounting for 32% of respondents (35).

Figure 05. Type of household in which you live

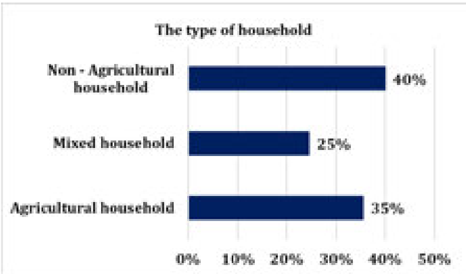

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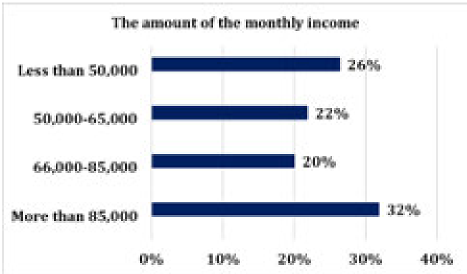
Figure 06. Amount of monthly income



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Analyzing participation in the agricultural market, it is concluded that 69 respondents (63%) do not participate in the market, while 24% of respondents (26) participate as producers, 7% of respondents (8) as sellers, 4% of respondents (4) participate as intermediaries, while 3% of respondents (3) participate as both producers and sellers (Figure 07).

When asked whether respondents think that agriculture is one of the polluters, as many as 81% (89) of respondents think that it is not, while 19% (21) of respondents answer in the affirmative (Figure 08).

Figure 07. Are you a participant in the agricultural market?

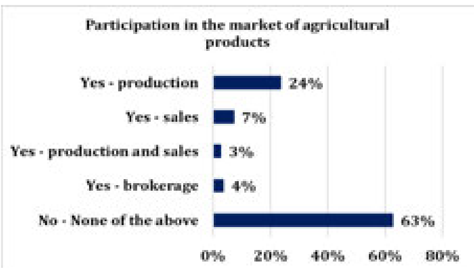

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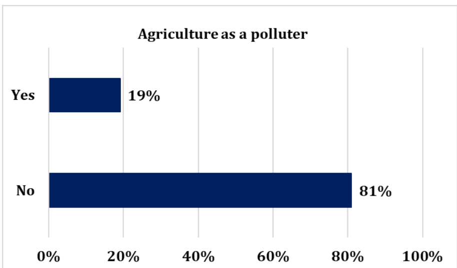
Figure 08. Do you think that agriculture is one of the polluters of the environment?



Source: Authors

According to the selected sources of pollution, listed in the question, 50% of respondents (55) answered that the biggest polluter is industry (Figure 09). This is followed by traffic (24%, i.e. 26 respondents), landfills (17%, i.e. 19 respondents). According to the respondents, the smallest polluters are urbanization (1%, i.e. 1 respondent) and agriculture (8%, i.e. 9 respondents).

As many as 57% of respondents (63) believe that they are partially or insufficiently informed about sustainable development and sustainable agriculture (Figure 10). In addition, 23% of respondents (25) believe that they are aware of it, and that it is a system based on high respect for environmental principles, while 20% of respondents (22) believe that they are not informed at all.

Figure 09. Which of these sources do you think is the biggest polluter?

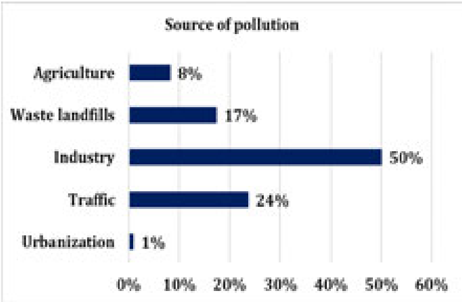


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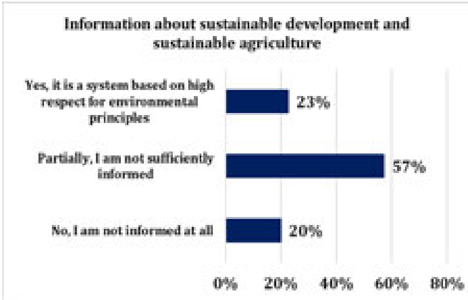
Figure 10. Are you aware of basic information about sustainable development and sustainable agriculture?



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Regarding the equivalence of studying sustainable and circular economy, 75% of respondents (83) believe that they are different things, while 25% of respondents (27) believe that they are the same concepts (Figure 11).

The definition of the concept of circular economy is the use and reuse of raw materials, where the largest number of respondents (69%, or 76) correctly understand it as take-make-use-reuse, while 25% of respondents (28) understand it as take-make-recycle-use-throw away and 5% of respondents (6) understand it as take-make-use-throw away (Figure 12).

Figure 11. Do you believe that sustainable and circular economy are the same?

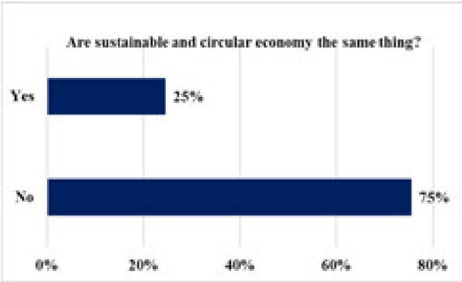

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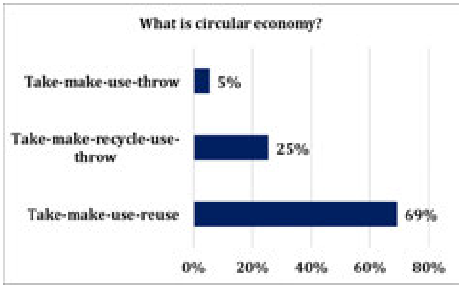
Figure 12. What is a circular economy?



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Regarding the survey of respondents on their knowledge of various systems that belong to sustainable production, 55% of respondents (61) think that it is organic agriculture, 7% of respondents (8) that it is good agricultural practice, 12% of respondents (13) think that it is integral production and 6% of respondents (7) opted for precision agriculture. As many as 19% of respondents (21) believe that none of the above systems belong to sustainable agriculture (Figure 13).

When asked to what extent respondents buy products from sustainable production, 15% (17) of respondents buy often, 7% of respondents (8) buy constantly or never buy, while the largest number of respondents are occasional buyers of these products (70% of respondents, i.e. 77 respondents) (Figure 14).

Figure 13. Name at least one production system that you believe belongs to sustainable production?

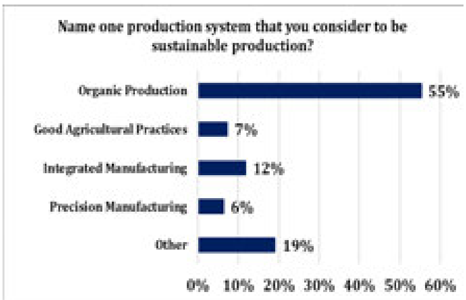

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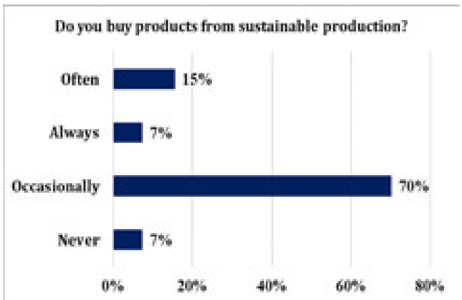
Figure 14. Do you buy products from sustainable production?



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Regarding the opinion on healthier products from sustainable production, 75% of respondents (82) believe that they are healthier than products from conventional production, and 25% of respondents (28) believe that they are not (Figure 15).

According to the given motives for purchasing products from sustainable production, the largest number of respondents, 45% of respondents (50), chose the health safety of the product. Furthermore, 29% of respondents (32) chose the quality of the product, 5% of respondents (5) chose the origin of the product, 4% of respondents (4) chose the certified product, 5% of respondents (6) chose the recommendation motive, 2% of respondents (2) chose the taste of the product, and 10% of respondents (11) believed that the motives for purchasing were other (Figure 16).

Figure 15. Do you think that products from sustainable production are healthier than products from conventional production?

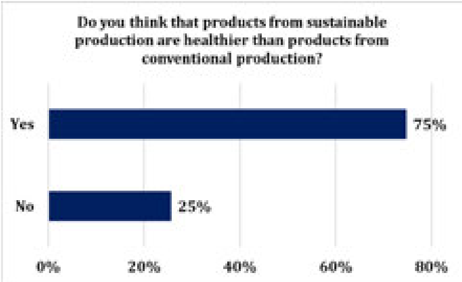

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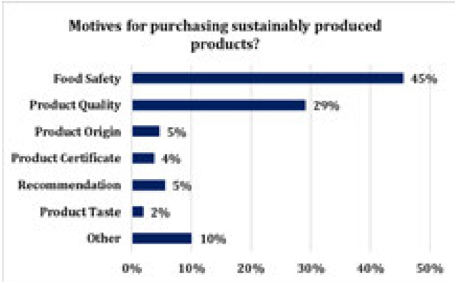
Figure 16. Motives for purchasing products from sustainable production?

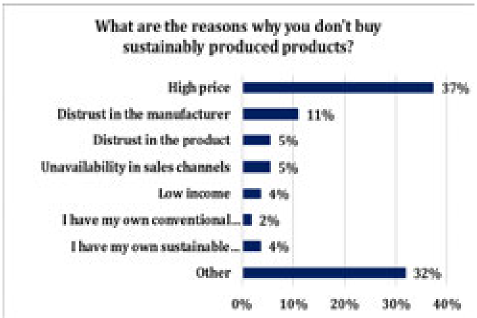


Source: Authors

Regarding the reasons why respondents do not buy products from sustainable agriculture, the following were listed: 37% of respondents (41) cited the high price of the product, 11% of respondents (12) do not trust the producer, 5% of respondents (6) do not trust the product, 5% of respondents (6) do not trust the product, 5% of respondents (6) have a problem with product availability in sales channels, 4% of respondents (4) have a low income, 2% of respondents (2) own their own conventional production, 4% of respondents (4) are engaged in sustainable production, and 32% of respondents (35) listed other reasons (Figure 17).

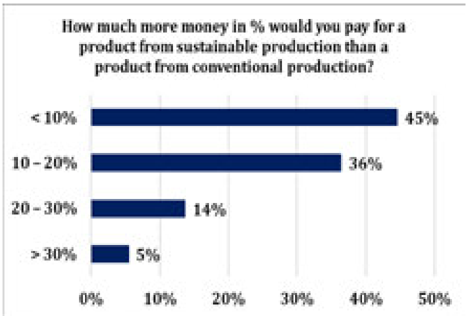
The fact that products from sustainable systems are more expensive than products from conventional production, when asked about the percentage higher amount that would be allocated for products from sustainable systems, as many as 45% of respondents (49) could allocate 10% more money, 36% of respondents (40) would allocate 10-20% more money, 14% of respondents (15) are able to allocate 20-30% more money, while 5% of respondents (6) are willing to spend more than 30% of money on sustainable products (Figure 18).

Figure 17. Please list the reasons why you do not buy products from sustainable production?



Source: Authors

Figure 18. How much more money in % would you pay for a product from sustainable production than a product from conventional production?

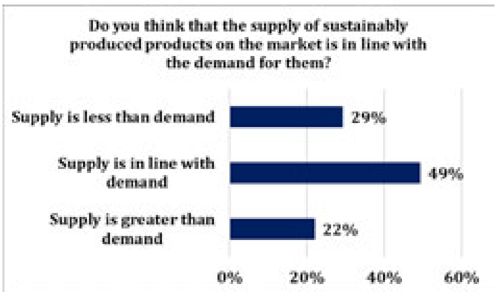


Source: Authors

Opinion regarding the supply and demand ratio of products from sustainable systems, 29% of respondents (32) believe that the supply is lower than the demand, 49% of respondents (54) believe that the supply is in line with the demand, and 22% of respondents (24) believe that the supply is higher than the demand (Figure 19).

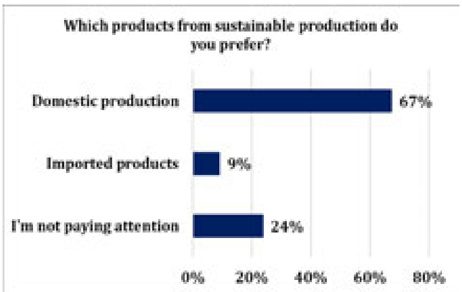
Regarding the preference for the origin of products from sustainable production, 67% of respondents (74) opt for domestically produced sustainable products, 9% of respondents (10) prefer imported products, while for 24% of respondents (26) it is not important (Figure 20).

Figure 19. Do you think that the supply of products from sustainable production on the market is in line with the demand for them?



Source: Authors

Figure 20. Which products from sustainable production do you prefer?

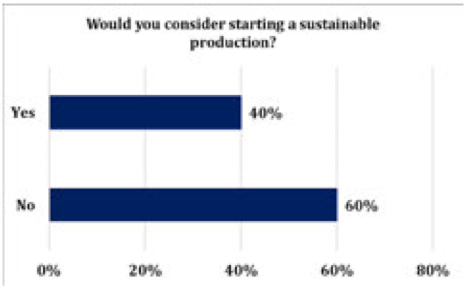


Source: Authors

When asked about considering the possibility of starting a sustainable production, 40% of respondents (44) were interested in starting a business, while 60% (66) had not considered this topic (Figure 21).

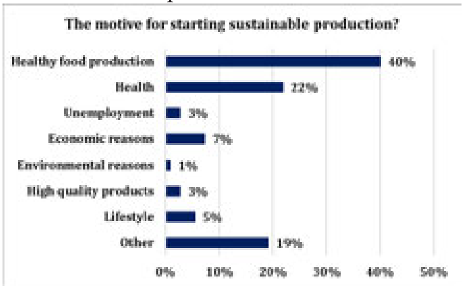
Regarding the motives for starting sustainable production, the largest number of respondents, 40% (44), opted for the motive of producing healthy food, 22% of respondents (24) considered health, 3% of respondents (3) unemployment, 7% of respondents (8) cited economic reasons, 1% of respondents (1) considered it to be an environmental motive, 3% of respondents (3) cited high product quality as a motive, 5% of respondents (6) said it was a way of life, and 19% of respondents (21) believed that the motives were other (Figure 22).

Figure 21. Would you consider starting a sustainable production?



Source: Authors

Figure 22. Motive for starting sustainable production?

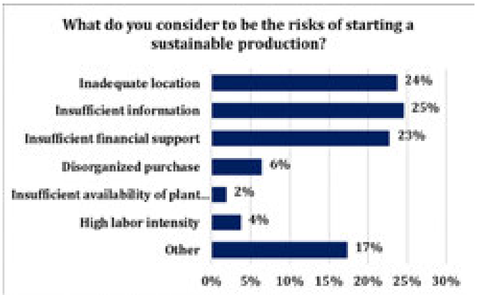


Source: Authors

Regarding the risks to starting sustainable production, 24% of respondents (26) cited inadequate location, 25% of respondents (27) considered it insufficient information, 23% of respondents (25) considered it lack of financial support, 6% of respondents (7) considered it disorganized purchasing, 2% of respondents (2) considered it insufficient availability of plant protection products, 4% of respondents (4) believe that the work intensity is high, while 17% of respondents (19) believe that the risks are other than those listed (Figure 23).

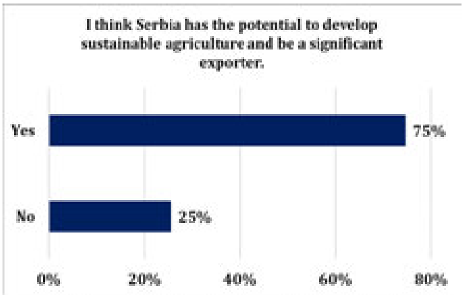
Of the 110 respondents, 75%, or 82 respondents, believe that the Republic of Serbia has the potential to develop sustainable agriculture and to become exporters on that basis, while 25% of respondents (28) have the opposite opinion (Figure 24).

Figure 23. What do you consider to be the risks of starting sustainable production?



Source: Authors

Figure 24. I think that Serbia has the potential to develop sustainable agriculture and to become significant exporters.

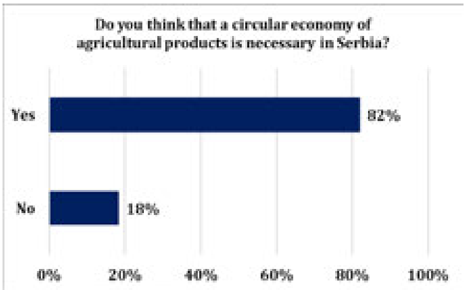


Source: Authors

When asked whether a circular economy of agricultural products is necessary in the Republic of Serbia, 82% of respondents (90) answered positively, and 18%, or 20 respondents, answered negatively (Figure 25).

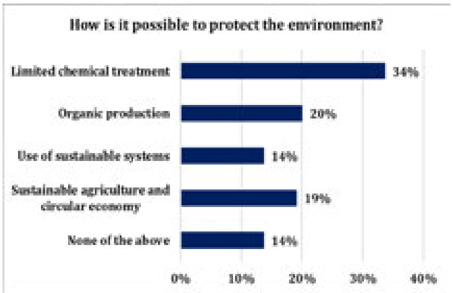
Regarding the way in which it is possible to protect the environment, 34% of respondents (37) are of the opinion that limited chemical treatment is necessary. 20% of respondents (22) opted for the introduction of organic production, 14% of respondents (15) for the use of sustainable systems, 19% of respondents (21) think that it is necessary to introduce sustainable agriculture and a circular economy, while 14% of respondents (15) believe that it is impossible to use any of the above (Figure 26).

Figure 25. Do you think that a circular economy of agricultural products is necessary?



Source: Authors

Figure 26. How, in your opinion, is it possible to protect the environment?



Source: Authors

Discussions

The results of the research, which mostly relate to young people living in suburban settlements and mixed-type households, are familiar with the concepts of sustainable agriculture and circular economy, which correlates with the research of Ignjatović et al., (2024c), who state that the development of sustainable systems, especially for rural areas, can be successfully realized by implementing e-learning through the E-Academy. According to Geza et al., (2021), young people living in rural areas most often opt for agricultural production due to meeting personal needs or the inability to find employment elsewhere.

It implies introducing support, innovation and ensuring accessible resources for stakeholders. A growing body of knowledge suggests that part of the solution to promoting youth participation in agriculture should include supportive policies and frameworks that promote capacity building (Chinsinga & Chasukwa, 2018). As a result, Gardiner & Goedhuys (2020) state that it is crucial to educate stakeholders with important skills, knowledge, and influence their ambition and motivation for sustainable development.

Mureithi (2023) explains that the necessary changes in environmental protection, sustainability and more complex systems are more accepted by younger farmers, and that in this regard they should be provided with all the necessary resources and incentives. The same authors state that farmers, in general, are increasingly interested in some of the sustainable systems, such as organic, integral or precision agriculture. Bajagić and Ignjatović (2025) and Radosavljević et al. (2025) states that these systems are essential for the survival of humanity, given that sustainable development, through a circular economy and sustainable agriculture, directly impacts the production of healthy and safe food and environmental preservation for future generations.

Conclusions

Sustainable agriculture represents one of the possible perspectives of the market of agricultural products in Serbia. In addition, sustainable agriculture is considered both an ecological and an economic way to develop agriculture in order to apply the best agricultural practices, but also technologies that increase productivity and competitiveness on the market.

In order for production to be sustainable, within conventional agriculture, it is necessary to apply the rules of good agricultural practice: the correct use of synthetic pesticides with respect to the dose, time of application, as well as the method of application, but also the use of an alternative that is reflected in the application of biopesticides, as well as a more rational application, above all, of mineral and organic fertilizers. Fertilization should be based on the combined use of mineral and organic fertilizers, as it increases the carbon content of the soil. The recommendation is plowing of crop residues, green fertilization and growing intercrops, as well as a reduction in the number and intensity of operations when performing soil processing, depending on the type of soil and weather conditions.

Circular economy is an economic concept focused on reducing waste and pollution, producing and using materials and products, and restoring natural systems. It directly impacts rural areas through effective communication, empowers local communities and can inspire innovation and enterprise in rural areas, through sustainable ventures such as ecological agriculture, renewable energy production, recycling, green tourism. Research has shown that half of young people are familiar with the concepts of sustainable agriculture and circular economy. The largest number of respondents expressed an interest in sustainable agriculture, purchasing products or starting production, where the main motives are the health safety of food production and the preservation of the environment.

However, the biggest problems for the use of products from sustainable systems are the high price, lack of trust in the manufacturer or the unavailability of the product. On the other hand, the biggest problem for production is insufficient information and poor financial support. The authors conclude that in addition to the potential and resources of the state and those interested in starting a business, education on the implementation of the circular economy in sustainable agricultural systems, financial support and the availability of the necessary inputs for production are necessary.

Conflict of interests

The authors declare no conflict of interest.

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INSTITUTIONAL AND FINANCIAL CONDITIONS FOR THE DEVELOPMENT OF RURAL TOURISM IN THE REPUBLIC OF SERBIA: A CASE STUDY

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ABSTRACT

This paper explores the institutional and financial conditions that determine the development of rural tourism in the Republic of Serbia, as well as the challenges faced by entrepreneurs in rural areas. Through a systematic examination of relevant institutional policies and financial mechanisms, the study aims to identify key factors that foster development and influence the sustainability of rural tourism. Additionally, by conducting interviews with the owners of five rural tourism households in Serbia as representative stakeholders, the authors analyzed specific circumstances and challenges in rural tourism, providing valuable insights into the practical aspects of institutional and financial regulation in this sector. This analysis offers policy recommendations for improving institutional and financial conditions for rural tourism, and provides guidelines for potential investors. Furthermore, the research aims to contribute to the promotion of entrepreneurship in rural areas, the further development of rural tourism in Serbia, and, consequently, the strengthening of rural sustainability.

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Introduction

Rural tourism is a form of tourism that provides visitors with a rural environment, which includes a range of experiences related to nature, culture, and people who have a distinctly rural personality. Rural living is all about immersing visitors in authentic, one-of-a-kind, and fundamental experiences (UNWTO, 2011). The primary objective of promoting this kind of tourism is to increase rural residents' incomes through a range of programs, services, and extra offerings (Bogdanov et al., 2007). By supporting and improving the region's underdeveloped tourism services through the provision of resources, whether in the form of funding or another kind, public and governmental institutions, as well as non-profit organizations, greatly aid in the growth of rural tourism (Gajić et al., 2017).

Unspoiled nature, or protected regions, such as national parks, are the destination of choice for both domestic and foreign travelers seeking active vacations and leisure (Tasić, 2018). A true cultural experience and intimate contact with the inhabitants are becoming more and more sought after by contemporary tourists. Tourists are increasingly drawn to images of ethnic communities in cultural attractions such heritage sites, museums, galleries, villages, cultural theme parks, performing arts venues, and festivals (Yang, 2011). The form of financial support still only somewhat addresses the growth of the rural sector through assistance for improving infrastructure and diversifying agricultural household incomes. (Official Gazette of the Republic of Serbia, No. 85, 2014). An organization must be established at the national level to promote balanced rural development. This organization should have branches in every administrative district and be instrumental in advancing Serbian rural tourism (Radović, 2020).

Although the Republic of Serbia's regulatory and legal environment for rural tourism has started to take structure recently, it is still inconsistent with service providers' demands and is centered on the industry's explosive growth. However, the growth of rural tourism also reduces the number of unresolved management, organizational, and institutional challenges (Radović et al., 2018). At least modest investments in material infrastructure are crucial, in addition to the required expenditures in organizational and human resource structures and the execution of systematic educational programs for the local population, which are intended to better integrate them into the development of the tourism offer and assist them in realizing the advantages of tourism development (Pavlović & Berleković, 2018). Starting from the assumption that institutional and financial issues are key to regulating and further developing the rural tourism sector in Serbia, the authors conduct a comprehensive and in-depth analysis of these factors from various perspectives and levels of analysis. The research aims to shed light on and enhance the understanding of the theoretical aspects of the subject matter, provide recommendations to policymakers for improving institutional and financial conditions for engaging in rural tourism, and develop guidelines for potential investors in this sector. The purpose of the research is most appropriately reflected in the formulation of practical recommendations for policymakers to enhance existing support policies in this field.

Literature review

For certain rural areas, rural tourism is a crucial development strategy (Carneiro et al., 2015). This type of travel has grown in popularity in recent years. It includes social, economic, ecological, and sustainable development since it helps to preserve values that are vital to the welfare of future generations (Tasić, 2018). Serbia is one of the most agrarian countries in Europe, with a large rural population. Notwithstanding the fact that 85% of Serbia is rural, the country has never targeted rural tourism in its tourism development (Radović, 2020). Furthermore, case studies of rural tourism in the literature go back to the late nineteenth century, proving that the idea is not new. It is frequently referred to as a strategy for reviving falling rural production or socioeconomic development (Rosalina et al., 2021). Along with natural resources, a diverse cultural and historical legacy, customs, and hospitality, rural tourism is an important tool for improving the quality of living and social vitality of people living in rural areas (Nedeljković, 2021).

Rural tourism makes up a sizable portion of the worldwide tourism business. Its proportion of the global tourist flow ranges from 12% to 30% (Ivolga & Shakhramanian, 2019). Employment in rural areas may rise as a result of rural tourism. Additionally, by drawing workers from seasonal or hidden jobs, rural tourism might increase agricultural productivity. Compared to other industry sectors, it is different (Smolović, 2022). The most important advantages of this type of tourism for rural economic diversification are its use as a distribution channel and its ability to effectively valorize rural areas' natural and cultural resources (Vujović et al., 2020). Rural regions could profit from the innovative dynamics established by small tourism organizations, especially if associated with the lifestyle incentives of respective entrepreneurs (Cunha et al., 2020). The demand for rural tourism is still rising. In order to escape from the rise of urbanization and industrialization, more and more people are looking for the natural beauty and authentic folk customs in the serene countryside, which is helping to boost rural tourism (Liu, 2020).

Serbia's rural areas offer a wealth of heritage or a strong sense of cultural identity, and they are rich in historical significance and tradition. According to Vukoičić et al. (2022), local culture is a source of activity, pride, and a warm welcome. The importance of traditional cuisine in the growth of rural tourism is also frequently underlined (Cvijanović et al., 2018). Numerous customs and traditions are manifestations of the rich spiritual culture of the rural community. Serbian tradition is kept alive by folk musical instruments, choreography, the costumes, traditional trades, myths, tales, and customs (Vukoičić et al., 2022). Rural tourism combines the economic, social, and environmental aspects of rural areas, and its growth would have positive economic and financial effects on the level of service providers (usually agriculture entities), on the level of local economic communities, as well as at the macro level and at the state level, during the actual transition period (Radović et al., 2018). In the following phase, businesses use that policy support to promote rural development (Yang et al., 2021). The findings (Kumar & Valeri, 2021) show that the main factors channeling rural tourism development are infrastructure development, growing environmental consciousness, community and local government support, government funding availability, and private sector participation. Based on the "polluter pays" theory, the EU Environmental Liability Directive (2004/35/CE) offers a solid foundation for preventing and eradicating environmental harm (Sredojević et al., 2019). We contend that this viewpoint can provide insightful information on the interaction between rural social entrepreneurs and their institutional setting, which is still poorly understood (Lang & Fink, 2019). Nevertheless, the capacity of social entrepreneurs to promote innovations in structurally poor areas may be severely limited by several elements of the rural institutional setting, both in its social and regulatory meaning (Kibler et al., 2015). According to Van der Ploeg et al. (2017), rural development theory fundamentally departs from the determinism of modernization approaches by emphasizing the dialectics between the real and the prospective. After reviewing the literature, the authors (Radović et al., 2018) recommend the creation of new domestic financial institutions like Specialized Agricultural Banks and microcredit organizations, which call for a revision of the existing regulatory framework. Along with the pre-accession funds of the European Union (IPARD) and the current Strategy for Agriculture and Rural Development, it is also necessary to include the financing of rural tourism through potential financing modalities like joint ventures, public-private partnerships, and "business angels" as creative financing techniques in the Republic of Serbia (Radović et al., 2018).

Materials and methods

The research methodology of this study combines several methodological approaches to provide a comprehensive insight into the institutional and financial conditions for the development of rural tourism households in the Republic of Serbia. 1) The first step involves a thorough review of the current literature on rural tourism, focusing on relevant theoretical frameworks and previous research. This step provides the theoretical context for the analysis, helping to identify key concepts and factors that influence the success of rural tourism. 2) The next step is the analysis of relevant legal, strategic, and other documents (from agriculture and tourism), including institutional policies and financial mechanisms that shape the conditions for the development of rural tourism in Serbia. This approach provides the foundation for understanding the formal support structures and potential limitations faced by entrepreneurs. 3) A key part of the methodology is the case study, in which five representative rural tourism households (RTHs) are selected for interviews (2 RTHs from Vranje; 2 RTHs from Leskovac; 1 RTH from the municipality of Knić). Through semi-structured interviews with the owners of the surveyed households, we explore experiences and challenges related to the institutional and financial aspects of rural tourism at the micro level (Table 1). This step enables a direct understanding of the practical implications, contributing to a real understanding of the conditions faced by rural entrepreneurs in the process of developing tourism households. The interviews were conducted by telephone, with each interview lasting approximately one hour with each RTH owner. The research was conducted from November 2023 to March 2024. 4) The combination of these methods enables a holistic approach to analyzing the conditions for the development of rural tourism in the Republic of Serbia. 5) For the conclusion, we used inductive-deductive methods to reach the most realistic conclusions and recommendations for improving the situation in this field.

Table 1. Interview questions for owners of rural tourism households (RTH) in Serbia

Key area	Questions for RTHs (Rural Tourism Households)
Institutional Framework	1. How would you describe the process of registering and formally aligning your rural tourism household with the applicable laws and regulations in Serbia?
Financial Support	2. Have you utilized or considered using financial mechanisms such as IPARD funds or other available sources of financing for the development of your rural tourism business?
Administrative Challenges	3. How have you managed the complex institutional framework encompassing rural tourism, considering the different jurisdictions of the Ministry of Tourism and the Ministry of Agriculture?
Administrative Challenges	4. Have you had the opportunity to use advisory services or support from consulting agencies regarding the laws and regulations related to rural tourism, and what was your experience?
Investments and Costs	5. What have been your key investments and costs in the process of developing rural tourism, particularly in relation to accommodation and food offerings?
Food Production	6. How have you met the requirements that the food provided in rural tourism is predominantly locally sourced, and what challenges have you encountered in doing so?
Hygienic Standards	7. How have you dealt with the hygienic-sanitary conditions and procedures that must be fulfilled for a rural household to offer food services?
Tax Environment	8. How would you describe the tax environment, particularly with regard to the possibilities of lump-sum taxation related to rural tourism?
Advantages and Benefits of Institutional and Financial Conditions	9. What are the advantages and benefits you have experienced through the existing institutional and financial conditions, such as low tax burdens or diversification of income sources?
Recommendations for Improvements	10. Based on your experience, what specific recommendations would you give to policymakers to improve the institutional and financial conditions for rural tourism in Serbia?

Source: Author’s Research, November 2023 - March 2024.

Results and Discussion

Institutional and financial conditions in rural tourism activities in Serbia

An establishment or group of establishments that provide lodging services, food and drink preparation and service, or simply lodging-related hospitality services in a rural setting with elements of the local culture and tradition is known as a rural tourist household (RTH). The services are provided by a person using food, drinks, and beverages that are primarily manufactured from products they have made themselves. In lodging facilities with up to 30 individual beds, a single person can provide hospitality services to a maximum of 30 service consumers (Official Gazette of the Republic of Serbia, No. 17/2019a). Among other things, the local government's tourism agency handles duties pertaining to enabling service delivery in rural tourism houses and handicrafts (Official Gazette of the Republic of Serbia, No. 17/2019b). According to the Law on Hospitality, Article 2, Item 16, A business corporation, other legal entity, entrepreneur, or individual that engages in hospitality activities in accordance with the guidelines set forth by this legislation is referred to as a hospitality provider. Additionally, the law's provisions state that, as long as they are the owner, co-owner, etc., an individual may provide hospitality services in lodging facilities with up to 30 individual beds for a maximum of 30 service users. Through the Rulebook on Incentives for the Improvement of Economic Activities in Rural Areas through Support for Non-Agricultural Activities (September 27, 2021), the Ministry of Agriculture, Forestry, and Water Management of the Republic of Serbia outlines the requirements that a household engaged in rural tourism must fulfill in order to apply for support measures for the development of rural tourism. The registry of rural households is currently maintained by the Ministry of Tourism and Youth, specifically through eTurista (https://www.eturista.gov.rs/). At the same time, as a form of diversification of activities and income on agricultural holdings, the registry of rural tourism households (RTHs) is also maintained by the Ministry of Agriculture, Forestry, and Water Management of the Republic of Serbia, specifically through the Directorate for Agrarian Payments (holdings registered in the Register of Agricultural Holdings). The number of RTHs is as follows: (1) in the eTurista database, 724 registered RTHs (Table 2), as of mid-2023 (internal data obtained from eTurista); (2) according to data from the Statistical Office of the Republic of Serbia (Agricultural Census 2012 and Agricultural Household Structure Survey 2018), the number of agricultural holdings engaged in rural tourism activities was 514 in 2012 and 302 in 2018 (https://www.stat.gov.rs/sr-latn/).

Table 2. Report on the total number of facilities by type and sub-type, and by the structure of accommodation units, 2023. year

	TOTAL BY TYPE: Rural Tourist Household: (724)			
Serial number	**Structure of the facility**	**Number of accommoda-tion units**	**Number of beds**	**Number of individual beds**
1.	Double room with two separate beds, sleeping area for one person	652	1,304	1,304
2.	Double room with a double bed, sleeping area for two people	740	740	1,480
3.	Single room with a bed, sleeping area for one person	217	217	217
4.	Triple room with three separate beds, sleeping area for one person	195	585	585
5.	Triple room with a double bed, sleeping area for two people, and one separate bed, sleeping area for one person	269	538	807

	TOTAL BY TYPE: Rural Tourist Household: (724)			
Serial number	**Structure of the facility**	**Number of accommoda-tion units**	**Number of beds**	**Number of individual beds**
6.	Quadruple room	225	771	903
	Total:	2,298	4,155	5,296
	Total number of camping plots:	169		

Source: RTH e Turista; https://www.eturista.gov.rs/

Since they are an essential precondition for the growth of rural tourism, Table 3 lists all of the incentives for regional development in the Republic of Serbia from 2018 to 2021. Sixty-two percent of the entire structure of these incentives was made up of cash acquired from the state budget (Radović et al., 2024, p. 346). However, because these incentives "were not directed towards the priorities of regional development," the State Audit Institution (SAI) found that they have not made a substantial contribution to lowering regional development inequalities in the Republic of Serbia (SAI, 2023).

Table 3. Incentives for Regional Development in the Republic of Serbia 2018-2021.

Sources of Funding for Incentives	**Total Incentive Amounts 2018-2021 (in billions of dinars)**
Ministry of education, science, and technological development	196
Ministry for european integration	169
Ministry of construction, transport, and infrastructure	153
Other sources of funding	311
Total:	829

Source: State Audit Institution (SAI), 2023.

According to the Law on the Budget of the Republic of Serbia and the Regulation on the Conditions, Methods, Allocation, and Use of Incentive Funds for the Development and Improvement of Rural Tourism and Hospitality in the Territory of the Republic of Serbia, the Ministry of Tourism and Youth issued a public call in February 2025 for the allocation of funds to support the growth and enhancement of rural tourism and hospitality (Official Gazette of RS, No. 13/25). The following standards, which are listed in Table 4, will be followed for allocating incentive payments.

Table 4. Criteria for Evaluating the Approval of Funds by the Ministry of Tourism and Youth

Serial num.	Criterion	Description	Maximum number of points
1.	Type and scope of project activities	The working group for decision-making on participation in the financing of rural tourism and hospitality development and improvement projects evaluates the type and scope of works (construction of new facilities, adaptation or reconstruction of existing structures, as well as accompanying content aimed at enhancing tourist traffic).	**35**
2.	Contribution to sustainable development, preservation of natural resources, and engagement of the local population	The decision-making working group evaluates whether and to what extent the project contributes to the preservation of natural resources in the rural environment, as well as the creation of new employment opportunities.	**25**
3.	Contribution to the improvement of the quality of rural tourism offerings	The decision-making working group assesses the extent to which the project's implementation contributes to the quality of rural tourism offerings.	**20**
4.	The fulfillment of objectives and alignment with planning documents	It is assessed to what extent the proposed project impacts the increase in tourist traffic through the development of rural tourism, encourages more balanced regional and local development while preserving the natural environment, local culture, traditions, and customs, as well as its alignment with the Tourism Development Strategy and other planning documents in the field of tourism.	**20**
Maximum number of points			**100**

Source: "Official Gazette of the Republic of Serbia", number 13/25.

Additionally, a competition to promote Vojvodina's rural tourism has been announced. The deadline for applications is April 22. The Provincial Secretariat for Agriculture stated a competition to promote non-agricultural enterprises in Vojvodina in 2025 in order to stimulate economic growth in rural regions. A maximum of two million dinars in non-refundable money may be requested per application. The purpose is to increase rural employment, female employment, and rural tourism through the allocation of non-refundable support. (Provincial Secretariat for Agriculture, Water Management, and Forestry, 2025). In 2021, the Ministry of Agriculture, Forestry, and Water Management – Agrarian Payments Administration held a competition to determine the terms and procedures for obtaining the right to incentives for enhancing rural economic activity through support for non-agricultural activities. According to Article 5 of the regulation, the maximum incentive amount per beneficiary for investments is 2,350,000 dinars. Municipal support is also available. The municipality of Pirot, for instance, announced a competition called "Competition on the conditions and procedures for obtaining the right to incentives for the improvement of economic activities in rural areas through support for non-agricultural activities in 2024." In order to align with the CAP and improve the sustainability of agriculture and rural areas, the EU offers users financial and technical assistance through IPARD, the pre-accession assistance instrument for rural development, which is part of the Instrument for Pre-accession Assistance (IPA) for countries in the process of joining the EU. Albania, Montenegro, North Macedonia, Serbia, and Turkey are the candidate countries for membership and the beneficiaries (Umetić, 2023).

Table 5. Implementation of Measure 7 of the IPARD II program as of August 31, 2023

	First call	**Second call**	**Total**
Budget - EU contribution 2014-2020.	15,000,000 €	11,251,837 €	26,200,000 €
Total number of submitted projects	311	294	605
Number of rejected projects	95	23	118
Number of withdrawn projects	31	12	43
Number of contracted projects	110	71	181
Number of discontinued projects	2	0	2
Number of contracted projects - number of canceled projects	108	71	179
Realized budget contribution to the EU 2014-2020.	12,437,219 €	10,019,993 €	22,457,212 €
Realization of the available budget	82,91%	89,05%	85,71%

Source: http://www.minpolj.gov.rs/ipard-program-2014-2023/#

The Republic of Serbia is confronted with significant obstacles in creating a competitive economy and changing domestic laws to more closely resemble those of the European Union (Vapa Tankosić et al., 2023). As of August 31, 2023, 179 projects were contracted for Measure 7, based on the demands of potential customers that were evaluated and submitted. There are 108 contracted projects based on the First Call and 471 based on the Second Call. 605 requests were made during the two public calls (Table 5); however, none of the requests met the requirements, meaning they did not adhere to the established standards (Radović et al., 2023., str. 471). Advisory services for producers, forest owners, and small and medium-sized companies in rural areas are included in the list of priority activities and programs meant to be financed by the EU. These services are meant to help these enterprises improve their economic performance and integrate them into the value chain and the development of rural tourism (Official Gazette of the Republic of Serbia, No. 98/2016). As of February 29, 2024, the European Union had 26.2 million euros in total available funding based on Measure 7 of the IPARD II Program, of which 82.59% had been realized. 28.9% of the projects submitted (Table 6) satisfied the requirements (Radović et al., 2024). The ability to use available resources effectively over an extended period of time for tourism purposes is a crucial component of competitiveness in the tourism sector, which helps both inhabitants and end users, or tourists (Cvijanović et al., 2011).

Table 6. Implementation of Measure 7 as of February 29, 2024

Number of published calls(competitions)	Budget - EU contribution 2014-2020(in €)	Submitted projects	Contracted projects	Realized budget contribution to the EU2014-2020(in €)	Realization of the available budgetto the EU2014-2020(in %)
First call	15,000,000 €	311	102	11,321,556	75.48
Second call	11,251,837 €	294	73	10,318,050	91.70
Total	26,200,000 €	605	175	21,639,605	82.59

Source: http://www.minpolj.gov.rs/download/29.2.2024.pdf.

Results and discussion of interviews with owners of rural tourist households

Financial support. Representatives of rural tourism in the city of Vranje (only two rural tourist households - RTHs) considered the IPARD program and Measure 7 as a source of financing, with one of them planning to apply for the announced competition for this year. On the other hand, one entity used the credit line from the Ministry of Tourism, while another applied this year for funds under the Public Call of the Ministry of Tourism for the development of rural tourism, which was open until April 15 of this year. There was increased interest in the categorization of rural tourist households after the announcement of the Ministry of Tourism's Public Call for the development of rural tourism due to its favorable conditions (90% non-refundable funds and 10% own contribution). Therefore, the state's measures for the development of rural tourism positively influence the encouragement of the rural population to engage in accommodation and catering services, generate income, and, of course, remain in the countryside. An interviewed owner of a rural tourist household from Leskovac states that they have not used available funding sources for the development of their rural tourism business but are considering utilizing them. They have currently submitted documents for the Ministry of Tourism's competition for funds intended for rural households with a project for the purchase of garden furniture. The owner of another rural tourist household from Leskovac also mentions that they have not used any financial support (neither from the state nor from the city of Leskovac). All investments were financed with their own capital. They are considering using subsidies from the Ministry of Tourism of the Republic of Serbia for the development of their rural tourist household. "We only received a small financial grant from a non-governmental organization from Switzerland," says the owner of an RTH from the municipality of Knić. The rural tourist household is located near a nearby lake. They cannot receive financial support from domestic funds because no legal regulations have been passed regarding the construction of buildings near the lake, and therefore, they cannot legalize their facility. As a result, they cannot obtain financial support for rural tourism.

Challenges in administration. On the website of the city of Vranje, under the "Tourism" banner, all the information needed for the process of categorizing household accommodation facilities is highlighted, along with phone numbers for further inquiries. Additionally, there is an option to visit the City Administration offices of the city of Vranje by appointment, where all necessary logistical, technical, and administrative assistance is provided for submitting categorization requests. Since October 1, 2020, the process has been carried out electronically via the e-Turista portal (eturista.gov.rs). There is also cooperation with the Tourist Information Center, the Tourist Organization of the City of Vranje, for forwarding relevant information. Practice has shown that due to digital illiteracy, elderly individuals face difficulties; however, this is compensated by involving younger people. “The household was registered with the help of the relevant department of the City Administration, as they assisted me with properly registering the plots,” says the owner of an RTH from Leskovac. The registration was done electronically, they were registered on e-Turista, and the officials at the City Administration were very helpful. They were provided with instructions for categorization, and after submitting the request and paying the fee, a commission came and categorized the facility, issuing a decision. “The rest we are learning as we go,” they emphasize in this RTH. The owners of the second household from Leskovac are a husband and wife who are professionals in law and economics. Initially, they had a dilemma about which institution to approach for the categorization of their household. They see the biggest problem in obtaining feedback from the relevant institutions. At the same time, there is a need for education in this field. They assist other rural households in this activity. For example, if a rural household intends to breed indigenous animal breeds in a traditional manner, they direct them to the appropriate institutions. The categorization of rural households is carried out by the Department of Economy and Agriculture, Division for Sustainable Development, City of Leskovac. An interviewed owner of an RTH from the municipality of Knić mentions that they are registered as an ethnographic rural household; however, the problem will arise with re-registration, as they are the only household engaged in rural tourism near the nearby lake. They rate the support of the local self-government regarding familiarization with the legal regulations in this area as average.

Advisory support. In the City Administration of Vranje, specifically within the Department for Economy and Economic Development, expert tasks related to tourism are carried out, while a separate unit for agricultural matters has recently been established. Within these units, advisory services are provided, although a higher level of cooperation and synergistic action is needed both locally and nationally. This cooperation is primarily required between the Ministry of Tourism, the Ministry of Agriculture, and other relevant stakeholders, particularly regarding the status of: 1) rural tourism households and 2) agricultural holdings. In the process of categorizing RTH, the clients are informed about the regulations, including the minimum technical requirements and the prescribed standards depending on the category, ranging from one * to four **** stars, for the arrangement and furnishing of the facilities, as well as the necessary documentation required for the acceptance of the categorization request to ensure that the request is complete. Similarly, financial obligations are outlined, including the regular payment of taxes and accommodation fees, as well as operation within the e-Turista system – regular guest check-ins and check-outs and the issuance of receipts in the prescribed manner, all in accordance with the Ministry of Tourism's user manual. "We have not used advisory services or support from consulting agencies regarding the laws and regulations related to rural tourism," says the owner of an RTH from Leskovac. At the same time, the owner of another RTH from Leskovac notes that they hired a private tourism consultant. At that time, they did not have the support of the Leskovac Tourist Organization. However, today they do have the support of this organization (they requested that their flyers be taken to the Tourism Fair in Belgrade). The owner of the RTH from the municipality of Knić has used consulting services from an NGO based in Switzerland. They also use the platform www.selo.rs for education and have simultaneously utilized advisory services from the Tourist Organization of the Knić Municipality.

Investments and costs. In addition to investments in the facilities themselves and their equipment, there are costs associated with categorization, including the payment of national administrative fees for submitting the application (currently 380.00 RSD) and for the issuance of a decision (660.00 RSD), as well as the costs for obtaining a medical certificate, sanitary book, and notary services (if there are co-owners of the property, notarized authorization or consent is required). Once the categorization application is accepted and the decision is issued, the rural tourism household (RTH) becomes active, and from the date the categorization decision is delivered to the applicant, the obligations, such as paying the accommodation tax and tax, are activated for the next three years. Since 2019, changes in the legal regulations in the field of tourism and hospitality have provided benefits for individual entrepreneurs – owners of rural tourism households, as they are no longer taxed based on turnover or overnight stays, but rather based on the total accommodation capacity or the number of individual beds. This change is supported by data showing that, in 2020, there were 10 categorized accommodation facilities in the city of Vranje, and as of March 1, 2024, this number has increased to 86, with 67 in Vranje (45 apartments, 1 RTH, 1 house, and 20 rooms) and 19 in Vranjska Banja (17 rooms, 1 apartment, and 1 RTH). Taxes are collected in a flat rate based on a decision from the Vranje branch of the Tax Administration, while the accommodation tax is based on a decision from the Local Tax Administration (LTA), which determines the annual accommodation tax amount, to be paid quarterly. The total annual amount is determined by multiplying the prescribed coefficient for non-categorized areas (Vranje is a non-categorized tourist area) of 1000.00 RSD by the number of individual beds in the respective facility. The owner of an RTH from Leskovac, when asked about the key investments and costs in the registration process and later involvement in rural tourism, mentions the following: "The costs for obtaining cadastral property lists, fees for categorization, and there will be other costs as well, since we haven't started working with guests yet, but we hope to do so by summer. We haven't finished arranging the yard and equipping some important rooms and supporting facilities. We also plan to build new facilities." He further points out that obtaining construction permits is very slow, and the fees for requests, projects, location conditions, permits, and decisions from the Ministry of Environmental Protection, opinions, and nature protection conditions are priced at tens of thousands of dinars. The costs for geodetic measurements and parcel marking, certificates from the police, courts, tax certificates, and concludes that the administration is expensive in every sense and slow. This owner covers all the previously mentioned costs with personal funds, and also invests in the equipment, reconstruction, and construction of the facility. Additionally, he projects future costs for advertising the household, etc. The owner of another RTH from Leskovac points out: “The categorization fees are the largest costs in the process. Also, there is a fee per bed. Income tax is calculated on a flat-rate basis. We invested in new construction as well as in the reconstruction of an old, traditionally built building. The cost of construction materials was high. Since our household is located in the mountains, we also incur logistics costs. The road infrastructure was poor; otherwise, we would have more guests.” The owner of an RTH from the municipality of Knić states that, in order to register their rural tourism household, they had to build a septic tank with a treatment plant. On the other hand, the largest investment was the construction of a kitchen. At the same time, due to the expansion of capacity, four new bathrooms were built, so each room now has its own bathroom for better categorization (3 stars: ***). The total investment in the kitchen and bathrooms amounted to 30,000 euros.

Food production. The practice among rural tourism households in Vranje has demonstrated that the most common service offered is bed and breakfast, although half-board services are also available. This contributes to the development not only of agritourism but also of rural tourism, as local households establish networks, collaborate, and derive mutual benefits. If a household does not engage in its own agricultural production, it is required to procure such products from the same or neighboring villages to serve its guests—tourists. In rural tourism households, only locally sourced products, homemade food, and traditional beverages may be served. Therefore, a stronger connection is needed between rural tourism households and food producers and processors. An interviewed owner of a rural tourism household (RTH) from Leskovac stated that they have not yet started hosting guests and are still in the early stages of their business. Initially, they will only offer accommodation, with plans to introduce food services later. They will assess the necessary requirements for this expansion. Currently, they lack information on conditions and standards but would like to have accurate and reliable guidance. Another interviewed RTH owner from Leskovac emphasized: “In our household, we prepare food. However, the livestock population in the village has declined, making it difficult to obtain local meat and dairy products. We do have locally sourced eggs. Our goal is to motivate agricultural producers who have ceased production to start supplying us and the wider market. With the support of GIZ and the Ministry of Tourism of the Republic of Serbia, a lecture on ‘Rural Tourism and Agriculture’ is being held at our household. We host between 30 and 40 young participants in these sessions. Additionally, we are launching a new educational program on ‘Agricultural Production and Livestock Farming.’ There is a strong interest in this training.” The owner of an RTH in the municipality of Knić owns a land parcel, while his parents are engaged in agricultural production, ensuring a stable food supply.

They grow their own fruits and vegetables, while meat, milk, and dairy products are sourced from other local agricultural producers within the village.

Hygienic standards. For the categorization process of rural tourism households in Vranje, the applicant is required to obtain a sanitary booklet, which is issued by the competent Institute of Public Health after the necessary sample testing. Following this, an active rural tourism household undergoes inspections not only by the tourism inspection authorities but also by the sanitary inspection services. Both interviewed owners of rural tourism households (RTH) in Leskovac stated that they have encountered no complications. They submit samples to the Hygiene Institute of Leskovac, which then issues the sanitary booklet. Inspectors from the Department of Inspection Affairs in Leskovac conduct on-site visits to rural tourism households. An interviewed RTH owner from the municipality of Knić explained that they converted their old kitchen into an apartment while simultaneously constructing a new kitchen, which represented a significant investment. The hygienic and sanitary conditions and procedures that must be met for a rural household to provide food services are quite demanding for the average individual or household.

Tax environment. The tax environment for rural tourism in Vranje is highly stimulating, as noted in response to question number 4 (investments and costs). The favorable taxation policy has led to an increase in the number of categorized accommodation facilities. The owner of a rural tourism household (RTH) in Leskovac considers the tax environment for rural tourism to be beneficial. However, they emphasize that they are still in the early stages of business development and will become more familiar with taxation as their operations expand. Another interviewed RTH owner from Leskovac highlighted the following: “We are categorized as a fourth-tier tourist destination, and the tax rate for this category is excessively high. There is a significant disparity in the development of mountain and lowland villages, making it necessary to provide incentives for mountain villages, as they are the most vulnerable.” On the other hand, the RTH owner from the municipality of Knić operates only during the summer season and points out that the tax system does not accommodate seasonal operations. They work from May to September, while taxes are calculated for the entire year. Additionally, they receive warnings from the e-Taxes platform for not reporting guests, despite having no visitors outside the season. This issue underscores the misalignment between the digital taxation system and the realities of seasonal rural tourism, making the tax environment less favorable.

Recommendations for improvement. Interviewed rural tourism households (RTH) in Vranje (two households) suggest that enhanced and more intensive intersectoral cooperation between tourism and agriculture is necessary. This should begin with the harmonization of legal regulations, followed by the development of strategic planning documents at both the national and local levels. These documents must be consistent and aligned, with mutual recognition and integration of shared measures and objectives. The ultimate goal is to foster rural development, including rural tourism as a distinct form of tourism, and to promote non-agricultural activities as recognized by the Agricultural

Law. These activities are closely related to other non-agricultural enterprises, which in turn correlate with the development of tourism in unspoiled nature, clean environments, and rural areas. To facilitate this, it is crucial to reduce administrative procedures, lower fees for various permits and certifications, increase financial incentives, organize informational meetings and training sessions, and distribute instructional materials either in print or online. Prospective and existing household owners should be guided on the necessary requirements to encourage them to expand their offerings, meet standards, and receive the necessary support. This would enable them to operate successfully, generate income, and contribute taxes to the state (Interviewed RTH owner from Leskovac). A significant disparity exists between rural tourism in Southern and Eastern Serbia compared to Western Serbia and Vojvodina. Mountainous rural villages are generally neglected. Out of 20 rural households, only 7 are actively engaged in tourism (second interviewed RTH owner from Leskovac). These households commenced operations in 2020 with incoming guests. They believe that young people would return from abroad to engage in rural tourism if provided with adequate support. In contrast, in Vojvodina, large land parcels receive substantial subsidies, whereas in mountainous regions, land parcels are small and fragmented. Women in rural (mountainous) areas require additional support, such as eligibility for early retirement benefits. They face challenging working conditions and, in most cases, do not own the land or properties where they reside. They participated in an educational program in Italy and, upon returning, motivated others in their communities. However, institutional support on the ground remains essential. A notable innovation in the sector is the introduction of scientific and educational tourism, attracting teachers and students for outdoor lectures. This model follows the “Diffuse Hotel” concept, inspired by Italian cooperative models where agriculture is inseparable from tourism. The initiative promotes the idea of uniting rural households engaged in tourism. A shared reception desk and joint promotional efforts are implemented, while other agricultural households are also integrated into the network (second interviewed RTH owner from Leskovac).

Infrastructure deficiencies (roads, sewage systems, electricity, etc.) present major barriers to the registration of rural households. Additionally, the stringent requirements for registering rural tourism enterprises create further obstacles (interviewed RTH owner from Knic). Consequently, a key recommendation is to introduce tax relief measures during the initial 1-2 years of operation for rural tourism businesses. It is also necessary to officially recognize seasonal rural tourism enterprises and ensure that small rural farms have improved access to financial resources. Given that re-registration is required every two years, the registration process should be simplified. Although legalization applications have been submitted, the status of many structures remains unresolved. Furthermore, it would be beneficial to assist elderly individuals in adapting to digitalization by providing both educational and financial support. One interviewed rural tourism operator has been in business for approximately 20 years and states that, given the administrative demands of the sector, at least one employee should be dedicated solely to electronic guest registration and deregistration. They argue that digitalization has complicated rather than facilitated the operations of rural tourism businesses (interviewed RTH owner from Knic).

Conclusions

Considering the analyzed institutional and financial conditions for the development of rural tourism in the Republic of Serbia, the following challenges in this sector have been identified: 1) A complex institutional framework regulating this domain; 2) Jurisdiction shared between two ministries (tourism and agriculture); 3) Limited support for potential investors in terms of administrative and legal advice; advisory services are insufficient, while consulting agencies are private and expensive; 4) High investment costs, especially for those aiming to offer both accommodation and food services; 5) The requirement that food services must predominantly use domestically produced ingredients, implying that households must engage in food production; 6) Numerous hygiene and sanitary requirements and procedures that must be met for a household to provide food services. On the other hand, the benefits provided by the existing institutional and financial conditions include: 1) Low tax burdens for individuals; 2) Various available funding sources, including the Ministry of Agriculture, Forestry, and Water Management, the Ministry of Tourism and Youth, and municipal-level support; 3) The accredited Measure 7 within the IPARD program; 4) Diversification of income sources, among others. Based on the conducted research, the key policy recommendations for public policymakers in this field are as follows: enhancing advisory services in terms of their human capacity to provide better support for potential investors; improving logistical support at the level of local self-government units (LSG); and increasing support funds at the national level (from the state budget) through funding calls issued by the Ministry of Agriculture, Forestry, and Water Management or the Ministry of Tourism and Youth.

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Conflict of interests

The authors declare no conflict of interest.

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INNOVATIVE HOSPITALITY MODEL AS A CATALYST FOR SUSTAINABLE RURAL DEVELOPMENT

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A B S T R A C T

This study explores the role of innovative hospitality models in fostering sustainable rural development through cultural integration and community engagement. Conducted in Terlan (Terlano), South Tyrol, Italy, the research surveyed 403 tourists to examine motivations related to sustainability, cultural curiosity, and authentic experiences. Using a five-point Likert scale, three motivational factors were identified: Sustainable Escape, Rural Immersion, and Authentic Stay. Results indicate that visitors increasingly value eco-friendly practices, local gastronomy, agritourism, and culturally rooted accommodations. These findings highlight how authentic, community-centered experiences not only support local economies but also nurture entrepreneurship and environmental stewardship. The Terlan model demonstrates a practical pathway for rural destinations, such as Fruška Gora, to enhance competitiveness by integrating sustainability with cultural authenticity, thereby offering high-quality rural tourism experiences aligned with contemporary tourist expectations.

Introduction

The travel industry is undergoing a transformation as sustainability and environmental values increasingly influence tourist destination choices (Vicente, 2024). According to Arsić et a., (2025) Modern travelers prioritize eco-friendly practices and immersive nature-based experiences, viewing sustainability as an investment rather than an expense (Zhou et al., 2025). This shift highlights the importance of clear communication

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about the benefits of sustainable tourism, which enhances overall tourist experiences while considering economic, social, and environmental impacts (Bojović et al., 2024). According to Cammarota et al., (2025), the demand for authentic culinary experiences in rural destinations, driven by food-motivated tourists, underscores the role of local gastronomy and agritourism in enriching travel experiences and supporting rural economies (Moliterni et al., 2025). To meet evolving tourist expectations, accommodation providers must focus on quality service, cultural integration, and diverse offerings that reflect the unique heritage of their destinations (Balderas-Cejudo et al., 2025).

The innovative hospitality model can be defined as a multifaceted approach to hospitality that integrates local culture, environmental stewardship, and community engagement into its operations, aiming to provide unique experiences that highlight the distinctiveness of rural settings (Asghar et al., 2023). Unlike traditional hospitality models, which often prioritize standardized services and profit maximization, the innovative model seeks to create a symbiotic relationship between tourism and local communities (Vujko et al., (2024b). It places a strong emphasis on authenticity, encouraging visitors to engage with local traditions, cuisine, and crafts, thereby enriching their travel experience while simultaneously benefiting the host community (Pantović et al., 2023; Paspalj et al., 2024; Chaisriya et al., 2024). According to Turčinović et al., (2025), initiatives like community-based tourism (CBT) in countries such as Italy showcase how local residents can offer accommodations, guided tours, and cultural experiences that reflect their heritage, thus enhancing the visitor's experience while ensuring economic benefits for the community. According to Candeloro & Tartari (2025) innovative practices such as eco-lodges and farm stays exemplify the integration of sustainable practices within hospitality, where environmental conservation efforts are woven into the very fabric of the visitor's stay. These models not only attract environmentally conscious travelers but also promote a sense of ownership among local populations, who become stewards of their cultural and natural resources.

The implementation of the innovative hospitality model has profound implications for sustainable rural development. One of the most significant impacts is the economic benefit it brings to local communities. By attracting tourists who are interested in unique, authentic experiences, rural areas can unlock new revenue streams that were previously inaccessible. According to (Randelli & Martellozzo, 2019) regions in Italy that focus on agritourism allow visitors to participate in grape harvesting and traditional winemaking, effectively turning local agricultural practices into profitable ventures (Nesto & Di Savino, 2016). This not only enhances the livelihoods of farmers but also stimulates local economies by creating demand for related services and goods. According to Grillini et al., (2025), the innovative hospitality model is instrumental in job creation, providing employment opportunities in various sectors such as hospitality management, tour guiding, and artisan crafts. A case study in rural Ghana demonstrates how the establishment of eco-lodges led to the creation of over 200 jobs, empowering local youth and women, in particular, to gain financial independence (Adom, 2019).

The model supports local businesses and artisans by encouraging tourists to purchase handmade crafts and local produce, thus fostering a circular economy where profits remain within the community (Jog et al., 2024). This collaborative approach not only strengthens the economic base of rural areas but also cultivates a culture of entrepreneurship, as community members are incentivized to innovate and develop new business ideas that align with tourism trends (Islam & Sadhukhan, 2025).

The innovative hospitality model in agritourism combines agriculture with tourism, offering visitors immersive experiences that enhance their understanding of food production while supporting local farming practices (Galluzzo, 2022). Key elements of this model include farm-to-table dining, educational tours, and sustainable practices, which not only enrich the visitor experience but also promote environmental stewardship (Canovi, 2019). Agritourism provides significant economic benefits to farmers by creating new revenue streams and job opportunities, while fostering community engagement and cultural preservation (Grilli et al., 2024). Successful case studies, such Tuscany, highlight the potential of agritourism to invigorate local economies and emphasize the importance of branding, marketing, and collaboration in developing compelling tourist attractions (Abraben et al., 2017; Turčinović et al., 2025).

The research is grounded in the hypothesis that rural tourists are motivated by a combination of environmental values, cultural curiosity, and a desire for authentic experiences, which collectively influence their destination choices and travel behavior. By identifying and understanding these motivational dimensions, the study aims to explore how the positive experiences and innovative hospitality models developed in Italy—particularly in regions such as South Tyrol—can serve as a catalyst for fostering sustainable rural tourism development in Fruška Gora. The ultimate objective is to inform the design of an innovative, culturally rooted, and sustainability-driven hospitality model that can enhance rural attractiveness, support local economies, and promote long-term regional development in Serbia.

Highlighting agritourism as an innovative hospitality model, the authors wanted, through the example of best practice in Terlan (Terlano), South Tyrol (Alto Adige), Italy, to show the key motives that attract tourists to rural destinations and transform them into tourist regions that annually attract millions of visitors. The research conducted in Terlan (Terlano), South Tyrol, Italy, involved 403 tourists and aimed to explore their motivations for visiting rural destinations. Three key factors influencing tourist motivations were identified: Sustainable Escape, Rural Immersion, and Authentic Stay, each characterized by specific variables related to eco-friendliness, cultural engagement, and genuine experiences. The research employed a positivist approach, utilizing quantitative data collection and structural equation modeling to analyze the relationships between these motivational constructs, ultimately aiming to provide insights into tourist behavior in rural settings. Applying this methodology locally can provide evidence-based insights into the preferences and expectations of visitors, thereby guiding the design of tailored agritourism experiences. For a region like Fruška Gora, this means there is strong potential to transform its rural and wine-growing landscape into a competitive, sustainable tourism destination by adopting similar approaches as those seen in Terlan (South Tyrol). The identification of key motivational factors—Sustainable Escape, Rural Immersion, and Authentic Stay—offers a framework for understanding what drives tourists toward rural destinations. By applying this research model locally, Fruška Gora can gain data-driven insights into what its visitors truly value—be it eco-friendly practices, local food and wine, or authentic rural lifestyles. This knowledge can then inform the development of targeted agritourism offers, enhance the visitor experience, and guide investment into green infrastructure, cultural programming, and community-based tourism.

Literature review

The innovative hospitality model in agritourism is characterized by a multifaceted approach that enhances the visitor experience while simultaneously supporting agricultural practices (Wang et al., 2021). Agritourism can be defined as any activity that combines agriculture with tourism, enabling guests to experience farm life, partake in agricultural activities, and enjoy locally sourced products (Ndhlovu & Dube, 2024). The interplay between local gastronomy and agritourism significantly enhances rural immersion experiences for tourists, driven by a variety of motivations and preferences (Alcívar-Vera et al., 2025). Tourists are increasingly seeking authentic culinary experiences that allow them to engage with local cultures, making gastronomic tourism a powerful tool for rural development and marketing (Arsić et al., 2025). The consumption of local food and beverages, which is central to agritourism, becomes an integral part of the tourist experience, allowing individuals to immerse themselves in the rural way of life while enjoying farm-fresh produce (Ohorodnyk & Finger, 2024). Such interactions not only provide educational opportunities but also facilitate escapism and cultural immersion, further enhancing the likelihood of repeat visits to these rural destinations (Zhou et al., 2023; Paraušić et al., 2025). By prioritizing local gastronomy, agritourism creates a vibrant link between visitors and their destinations, enriching both the tourist experience and the livelihoods of rural residents (Rachão et al., 2021; Pantović et al., 2025).

This model is significant for the hospitality industry as it caters to the growing demand for authentic, immersive experiences that foster a deeper understanding of food production (Vujko et al., 2024a). Key components of this model include farm-to-table experiences, educational tours, and sustainable practices. Farm-to-table initiatives allow visitors to savor meals prepared from fresh, locally sourced ingredients, often harvested from the very farms they are visiting (Moliterni et al., 2025). Educational tours, on the other hand, provide insights into farming techniques, the life cycle of crops, and the importance of biodiversity, enriching the guests' appreciation for agricultural endeavors. Acccording to Vujko et al., (2024), sustainable practices, such as organic farming and eco-friendly operations, not only enhance the attractiveness of agritourism but also promote environmental stewardship. According to Fusté-Forné & Filimon (2025) technology plays an increasingly pivotal role in this innovative model, enhancing guest experiences through online booking systems, interactive apps that provide information about the farm and its products, and virtual tours that expand access to those who cannot visit in person. By integrating these components, the innovative hospitality model in agritourism creates a unique and enriching experience that benefits both visitors and the agricultural community (Chan, 2025).

The implementation of the innovative hospitality model in agritourism yields significant benefits for farmers and local communities (Damnet et al., 2024). Economically, agritourism creates new revenue streams for farmers, allowing them to diversify their income beyond traditional crop sales (Panić et al., 2024). This diversification is especially crucial in times of market fluctuation or poor harvests, providing farmers with a stable financial foundation. According to Tew & Barbieri (2012) job creation is another primary advantage; agritourism ventures often require a workforce to manage tours, hospitality services, and farm operations, thus generating employment opportunities in rural areas that may otherwise face economic decline. Socially, agritourism fosters community engagement by encouraging collaboration between farmers, local artisans, and tourism operators. This interaction can lead to cultural preservation, as local traditions, crafts, and culinary practices are showcased and celebrated through agritourism experiences. According to Gütte et al. (2025), the model promotes environmental sustainability by advocating for eco-friendly practices such as organic farming, water conservation, and habitat preservation. Many agritourism operations are committed to educating their visitors about the environmental impacts of agriculture, inspiring them to adopt sustainable practices in their own lives (Lupi et al., 2017). This interplay between economic viability, social responsibility, and environmental sustainability illustrates how the innovative hospitality model not only supports farmers but also enriches local communities and the ecosystems in which they reside (Josimović et al., 2024; Klopfenstein, 2025).

Several case studies exemplify the success of innovative hospitality models in agritourism, demonstrating their potential to invigorate local economies while providing unique visitor experiences. One notable example is the Provence region in France, which has transformed itself into a world-renowned agritourism destination through its emphasis on wine production, farm-to-table dining experiences, and vineyard tours (Bainville et al., 2025). Local wineries have embraced the agritourism model by offering tastings, educational workshops, and culinary events that showcase local produce, effectively attracting tourists and stimulating economic growth (Mekbel et al., 2025). This region's success can be compared to other agritourism ventures, such as those in Tuscany, Italy, where agriturismos (farm stays) provide visitors with immersive experiences in Italian rural life (Domi & Belletti, 2022). Both regions illustrate how agritourism can leverage local resources, culture, and cuisine to create compelling tourist attractions that benefit the economy. Lessons learned from these successful implementations include the importance of branding, marketing, and community collaboration, which can be applied to other regions seeking to develop their agritourism offerings. By fostering a sense of place and authenticity, agritourism ventures can attract not only tourists but also foster a stronger sen.odations fosters a sense of ownership and connection to the experience, making their stay more meaningful. Collecting feedback through surveys allows managers to gather valuable insights into tourists' experiences, enabling them to identify strengths and areas for improvement that can inform future decisions (Dedeoğlu, 2019). By embracing these strategies, accommodation providers can better meet the evolving expectations of tourists seeking authenticity in their travel experiences.

The research methodology

The research was conducted among tourists in Terlan (Terlano), South Tyrol (Alto Adige), Italy, with a total of 403 participants involved. Although specific statistics regarding annual tourist arrivals for Terlan (Terlano) are not accessible to the public, we can deduce its tourism activity from regional data. The local tourism office reports that South Tyrol overall experiences more than 8.4 million tourist arrivals each year. Considering that Terlan is a prominent wine village situated along the South Tyrolean Wine Road, it is reasonable to conclude that a substantial number of these visitors are drawn to the area. According to Ahmed (2024), a suitable sample size for a population of around 8,000,000 tourists, maintaining a confidence level of 95% and a margin of error of 5%, would require 389 respondents. Consequently, the sample drawn from Terlan that participated in the study is both credible and reliable.

The tourist demographic in Terlan, based on the data provided, reveals the following characteristics: Among the tourists surveyed, there is a higher proportion of female visitors, with 59.3% of the total being female (239 out of 403). Male tourists make up 40.7% (164 out of 403), showing a noticeable but not overwhelming gender imbalance in favor of women. The age distribution of tourists indicates that the largest group is between the ages of 35 and 44, comprising 48.4% (195 out of 403) of visitors. Following this group are tourists aged 45-54, who make up 28.8% (116 out of 403). Younger tourists aged 18-24 are in the minority, representing only 1.5% (6 out of 403), while those aged 25-34 account for 5.5% (22 out of 403). Older visitors, aged 55-64, make up 6.9% (28 out of 403), and tourists aged over 65 account for 8.9% (36 out of 403). Overall, Terlan seems to attract a significant number of tourists in the 35-54 age range, with a notable portion of older visitors as well. The educational background of tourists in Terlan shows a well-educated group. The largest portion of tourists (46.4%, or 187 out of 403) have completed high school. A significant number, 39.7% (160 out of 403), have attended college or university, while 10.9% (44 out of 403) have earned a master's degree or Ph.D. Only a small portion, 3.0% (12 out of 403), have completed only elementary school. This suggests that Terlan attracts a predominantly well-educated crowd, with most visitors having at least a high school education. According to this Terlan appeals to a diverse group of tourists, with a higher number of female visitors, the largest age group being 35-44, and a well-educated demographic. This reflects the region's appeal to a mature, educated, and predominantly female audience, likely drawn to its wine tourism and rural charm.

The research started from the starting hypothesis of the paper H that Rural tourists are motivated by a combination of environmental values, cultural curiosity, and a desire for authentic experiences, which collectively influence their destination choices and travel behavior. In order to verify the starting hypothesis, it was necessary to establish three additional ones:

H1: Tourists who are motivated by sustainability and environmental values are more likely to choose destinations that emphasize eco-friendly practices and nature-based experiences.

H2: Tourists with a high interest in rural immersion are significantly influenced by opportunities to engage in local gastronomy and agritourism activities.

H3: Tourists who prioritize authentic stay experiences are more likely to seek non-commercialized, culturally rooted accommodations in rural settings.

From March 2024 to March 2025, the authors of this paper made several visits to the Terlan (Terlano), South Tyrol (Alto Adige), Italy to collect the requisite data. A questionnaire comprising 25 questions was developed, necessitating responses on a five-point Likert scale. The analysis of the gathered data revealed three distinct factors: Sustainable Escape (variables suggest that travelers motivated by Sustainable Escape are guided by pro-environmental values and are inclined to support destinations that demonstrate ecological responsibility and offer opportunities for interaction with nature), Rural Immersion (demonstrates that tourists motivated by Rural Immersion are not merely passive observers, but actively seek involvement in rural life. Their travel motivations are rooted in cultural curiosity and the desire for authentic rural engagement), and Authentic Stay (tourists associated with this factor are typically seeking immersive, community-based tourism experiences that foster cultural understanding and support local ways of life).

Factor 1: Sustainable Escape represents a dimension of tourist motivation centered on environmental consciousness and the pursuit of eco-friendly travel experiences. This factor captures the psychological orientation of travelers who prioritize sustainability in their decision-making processes. It is operationalized through the following observed variables:

- **Sustainable Appeal**: Refers to the extent to which the destination’s reputation for sustainability and eco-friendliness influences travel planning. This item suggests that environmentally responsible image plays a significant role in attracting sustainability-oriented tourists.
- **Nature Bond**: Reflects a personal desire to establish a meaningful connection with nature. Tourists endorsing this item seek destinations that offer natural environments, valuing opportunities for ecological immersion and restoration.
- **Sustainable Preference**: Denotes a general preference for destinations that engage in and promote sustainable tourism practices. It indicates an internalized value system in which sustainability principles guide destination choices.

Factor 2: Rural Immersion captures tourists' interest in engaging with rural culture, traditions, and lifestyles, particularly through gastronomic and agricultural experiences. This factor is characterized by an appreciation for sensory, cultural, and participatory elements of rural tourism. It includes the following indicators:

- **Culinary Motivation**: Highlights the importance of local gastronomy—such as regional food and wine—as a key motivator for travel. It implies that culinary experiences serve as a cultural entry point and play a decisive role in destination selection.
- **Farm Curiosity**: Reflects an interest in agritourism activities, including direct participation in farm life. This suggests a desire for hands-on, experiential learning and interaction with local agricultural practices.

Factor 3: Authentic Stay represents a motivational construct focused on the pursuit of genuine, non-commercialized tourism experiences. It emphasizes a preference for staying in environments that preserve traditional lifestyles and local character. The factor is defined by:

- **Authentic Travel**: Captures the intentional search for destinations offering authentic and culturally intact experiences. It reflects tourists' rejection of mass tourism and preference for destinations where culture is experienced in its original context.
- **Rural Stay**: Refers to the motivation to stay in local farm accommodations or rural settings. This variable suggests a preference for lodging options that allow tourists to live in close proximity to host communities and engage with rural routines.

This study adopts a positivist epistemological approach, which is grounded in the belief that reality is objective, observable, and measurable through empirical methods. Positivism assumes that knowledge can be obtained through systematic observation and quantifiable data, allowing researchers to identify patterns, test hypotheses, and establish causal relationships between variables. In line with this approach, the study examines tourist motivations through quantitative data collection and analysis, employing structural equation modeling (SEM) to assess the relationships between latent constructs such as Sustainable Escape, Rural Immersion, and Authentic Stay. These constructs are operationalized using measurable indicators derived from survey responses, reflecting the positivist emphasis on objective measurement and statistical analysis. Furthermore, the use of SEM reflects a commitment to hypothesis testing and explanatory modeling, aiming to uncover the underlying structure of tourist behavior in a replicable and generalizable manner. The researcher maintains a value-neutral stance, allowing the data to speak for itself through rigorous empirical testing, consistent with positivist principles.

Key Insights on South Tyrol (Alto Adige) Region and Fruška Gora (Vojvodina)

South Tyrol, located in the northeastern part of Italy between the Alps and the Dolomites, and Fruška Gora, a picturesque mountain range in northern Serbia along the Danube River, represent two rural regions with notable potential for sustainable tourism and agritourism development. While both regions share a rich agricultural heritage, scenic landscapes, and a growing interest in sustainable tourism, their stages of development, institutional support, and integration of agriculture and tourism differ significantly. South Tyrol is internationally recognized for its advanced integration of agriculture and tourism, facilitated through well-established models such as the Roter Hahn certification system, which regulates and promotes over 1,600 certified farm stays (Grillini et al., 2025). These accommodations offer tourists immersive experiences in farming life, access to local organic products, and high-quality, authentic rural hospitality. The region has implemented a comprehensive approach to sustainability, which includes widespread use of organic farming methods, eco-certifications, and climate-neutral accommodations (Grillini et al., 2023). Sustainable mobility is actively promoted through public transportation cards, e-bikes, and cable cars. South Tyrol's tourism model is further supported by strong institutional frameworks, including the South Tyrolean Farmers' Association and regional government programs that provide financial incentives for farm diversification. This coordinated approach has enabled balanced regional development, reduced urban overcrowding, and fostered long-term economic sustainability.

In contrast, Fruška Gora remains in the early stages of developing its agritourism potential. The region is known for its fertile hills, vineyards, orchards, and cultural heritage, including a network of historic Orthodox monasteries and the Fruška Gora National Park, which covers approximately 25,000 hectares (Vujko et al., 2024a). Fruška Gora has a long-standing tradition of wine production, particularly of native grape varieties such as Vranac and Prokupac, which forms a strong foundation for wine tourism. However, while the region offers opportunities for nature-based and cultural tourism, agritourism initiatives remain largely fragmented and lack the institutional and certification structures present in South Tyrol. There is increasing recognition of the need for sustainable tourism development, with growing interest in organic farming, traditional hospitality, and rural lifestyle tourism. The proximity to major urban centers such as Novi Sad and Belgrade enhances accessibility and potential market reach, yet coordinated policy measures and branding strategies are still needed to fully capitalize on this potential.

Table 1. South Tyrol (Italy) and Fruška Gora (Serbia)

Criteria	South Tyrol (Italy)	Fruška Gora (Serbia)
Landscape	Mountainous, vineyards, alpine pastures	Gentle hills, vineyards, forests
Tourism Type	Agritourism, wine tourism, wellness, farm stays	Wine tourism, rural tourism, monasteries, nature-based experiences

Criteria	**South Tyrol (Italy)**	**Fruška Gora (Serbia)**
Agriculture	Small family farms, organic production, apple orchards, viticulture	Family farms, vineyards, fruit production (e.g., plums, apples), honey
Cultural Identity	Multilingual (German/Italian/ Ladin), Alpine traditions	Multicultural heritage (Serb, Slovak, Hungarian), Orthodox monasteries
Hospitality Models	Certified agritourism under *Roter Hahn*, strong regional branding	Emerging rural accommodations, unbranded but growing initiatives
Protected Areas	Natural parks (e.g., Dolomites UNESCO site)	Fruška Gora National Park
Sustainability Focus	Well-developed eco-labeling, policy support	Growing interest in sustainability, but limited institutional support

According to Table 1 South Tyrol serves as a benchmark region for sustainable rural tourism, combining high-quality agricultural production, environmental stewardship, and well-structured tourism practices. Its success is largely due to its cohesive regional planning, institutional support, and effective promotion of authenticity and sustainability. Fruška Gora, while rich in natural and cultural assets, remains at an earlier phase of development. However, with targeted investment, strategic planning, and support for local producers and tourism entrepreneurs, it holds significant promise to evolve into a leading destination for sustainable agritourism in the Balkans.

Result and Discussion

The factor analysis (see Table 2) resulted in a model that groups the variables into three distinct factors, collectively explaining 86.524% of the total variance. As shown in Table 1, each of the three factors has an eigenvalue greater than 1, confirming the adequacy and sufficiency of the extracted factors based on the Kaiser criterion.

Table 2. Total Variance Explained

Factor	**Initial Eigenvalues**			**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**		
	Total	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**	**Total**	**% of Variance**	**Cumulative %**
1	3,224	40,298	40,298	3,033	37,912	37,912	2,981	37,261	37,261
2	2,120	26,494	66,792	1,884	23,548	61,459	1,893	23,664	60,925
3	1,579	19,732	86,524	1,599	19,986	81,446	1,642	20,520	81,446
4	,646	8,075	94,599						
5	,187	2,338	96,937						
6	,135	1,685	98,622						
7	,066	,829	99,451						
8	,044	,549	100,000						

Source: Autor’s research

The factor matrix (Table 3) provides insight into the relationships between the observed variables (items) and the three latent constructs: Sustainable Escape, Rural Immersion, and Authentic Stay. Each value in the matrix represents the factor loading, which indicates how strongly each item is associated with one of the factors. Higher factor loadings (closer to 1 or -1) suggest a stronger relationship between the item and the factor. Positive values indicate a direct relationship, while negative values indicate an inverse relationship.

Table 3. Factor Matrix

	Factor		
	Sustainable Escape	**Rural Immersion**	**Authentic Stay**
Authentic Travel	,016	,177	,948
Culinary Motivation	-,420	,835	-,020
Rural Stay	-,045	,122	,832
Farm Curiosity	-,475	,877	-,015
Sustainable Appeal	,939	,338	-,008
Nature Bond	,843	,323	,032
Sustainable Preference	,910	,266	-,003

Source: Autor's research

Sustainable Appeal (0.939), Nature Bond (0.843), and Sustainable Preference (0.910) are all strongly related to Sustainable Escape. These items reflect motivations driven by sustainability, eco-friendly practices, and a desire to connect with nature. The high positive loadings suggest that these items clearly align with the Sustainable Escape factor, highlighting that travelers motivated by sustainability are drawn to destinations with strong environmental values and practices. This confirms sub-hypothesis H1: Tourists who are motivated by sustainability and environmental values are more likely to choose destinations that emphasize eco-friendly practices and nature-based experiences.

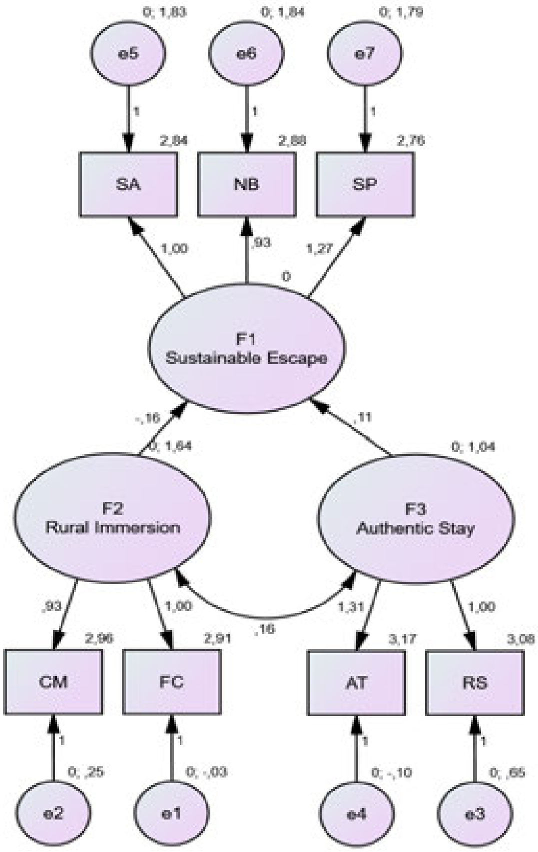
Culinary Motivation (0.835) and Farm Curiosity (0.877) are highly associated with Rural Immersion, reflecting the strong connection between rural tourism experiences and an interest in local food, wine, and farm activities. The positive loadings indicate that these items contribute significantly to the Rural Immersion factor, emphasizing the importance of authentic, hands-on rural experiences in shaping tourist motivations. This confirm sub-hypothesis H2: Tourists with a high interest in rural immersion are significantly influenced by opportunities to engage in local gastronomy and agritourism activities.

Authentic Travel (0.948), Rural Stay (0.832) are strongly linked to Authentic Stay. The high factor loadings suggest that tourists who prioritize cultural authenticity and non-commercialized experiences are more likely to be attracted to rural stays and authentic travel opportunities. The Authentic Stay factor is predominantly influenced by these items, highlighting that travelers value genuine cultural immersion through accommodation and authentic local experiences. This confirm sub-hypothesis H3: Tourists who prioritize authentic stay experiences are more likely to seek non-commercialized, culturally rooted accommodations in rural settings.

Figure 1 illustrates the relationships between three key motivational factors that influence tourists' preferences and decisions regarding sustainable and rural tourism. The factors identified are Sustainable Escape, Rural Immersion, and Authentic Stay. Each of these latent variables is measured using specific observed variables that reflect distinct aspects of the travel experience. Sustainable Escape reflects a traveler's motivation to engage with environmentally conscious destinations. It is measured through three observed variables: Sustainable Appeal (SA), Nature Bond (NB) and Sustainable Preference (SP). These variables are strongly correlated with the Sustainable Escape factor, as indicated by high standardized loadings (SA = 1.00, NB = 0.93, SP = 1.27). This suggests that these three aspects are important and reliable indicators of a traveler's sustainable mindset.

Rural Immersion captures tourists' interest in engaging deeply with rural life and agricultural practices. It is represented by: Culinary Motivation (CM) and Farm Curiosity (FC). These indicators also load strongly onto the Rural Immersion factor (CM = 0.93, FC = 1.00), indicating that both culinary and farming experiences are central to the concept of rural tourism. Authentic Stay refers to the pursuit of genuine, non-commercialized tourism experiences. It includes: Authentic Travel (AT) and Rural Stay (RS). Both variables equally define the factor with standardized loadings of 1.00 each, highlighting the significance of authenticity in the rural tourism experience.

Figure 1. Structural Equation Modeling (SEM)



Source: Prepared by the authors (2025)

Sustainable Escape and Rural Immersion are negatively related (path coefficient = -0.16), suggesting that travelers who highly value sustainability may not always prioritize immersive rural experiences. Sustainable Escape and Authentic Stay show a positive relationship (path coefficient = 0.11), indicating that sustainability-minded travelers are also somewhat inclined toward authentic tourism experiences. There is a positive correlation (0.16) between Rural Immersion and Authentic Stay, signifying a meaningful overlap in the motivations for rural and authentic tourism, with potential shared values or experiences. This model reveals that traveler motivations for sustainable tourism are multi-dimensional. While Sustainable Escape emphasizes eco-conscious values and a connection with nature, Rural Immersion focuses on interactive, local experiences like food and farming, and Authentic Stay emphasizes a desire for genuine, uncommercialized tourism. The interplay between these factors helps to understand how tourists form their preferences for specific types of destinations and activities. All this confirmed main hypothesis H that rural tourists are motivated by a combination of environmental values, cultural curiosity, and a desire for authentic experiences, which collectively influence their destination choices and travel behavior.

The table 4 presents standardized regression weights derived from a structural equation model assessing relationships between latent constructs (factors) and their associated observed variables, as well as the inter-factor pathways.

Table 4. Standardized Regression Weights: (Group number 1 - Default model)

			Estimate
F3	<---	F1	-,931
F3	<---	F2	,498
Farm Curiosity	<---	F2	1,011
Culinary Motivation	<---	F2	,922
Rural Stay	<---	F3	,785
Authentic Travel	<---	F3	1,031
Sustainable Appeal	<---	F1	,164
Nature Bond	<---	F1	,153
Sustainable Preference	<---	F1	,209

Source: Autor's research

F1 (Sustainable Escape) → F3 (Authentic Stay): Estimate = -0.931 This coefficient indicates a strong negative relationship between Sustainable Escape and Authentic Stay. As the importance of sustainable and eco-friendly travel motivations increases, the tendency to prioritize authentic, non-commercialized stays decreases. This suggests these two motivational dimensions may represent distinct or even conflicting tourist profiles.

This is possible explanations for the negative relationship: 1. different tourist priorities and lifestyles, 2. perceived trade-off between comfort and authenticity, 3. tourism marketing and segmentation and 4. cognitive dissonance or choice overload.

1. Tourists motivated by sustainability (F1) may prioritize environmental responsibility,

low carbon footprints, or eco-certifications in choosing destinations. Their decisions are often driven by values related to climate action, conservation, and resource efficiency. In contrast, those motivated by authentic stay (F3) are more focused on cultural immersion, personalized experiences, and non-commercialized local lifestyles. Their priority is authenticity of interaction, not necessarily environmental performance. These represent different motivational frameworks: one is ideological/environmental, the other is experiential/cultural.

2. Sustainable destinations or accommodations are sometimes perceived as minimalist or functionally eco-centric, which may conflict with the desire for authentic rural charm, traditional settings, or cozy, lived-in environments. Likewise, authentic stays (like a rustic farmhouse or homestay) may lack formal sustainability labels or infrastructure, making them less attractive to sustainability-focused tourists, even if they are eco-friendly in practice.

3. Many destinations market sustainability and authenticity separately. Eco-resorts and green-certified tourism often appeal to a different segment than agritourism, cultural tourism, or heritage travel. A tourist booking an eco-lodge might be drawn by recycling systems and solar panels. A tourist booking a rural homestay might be more interested in local storytelling and traditional cooking, regardless of formal environmental practices. Thus, these motivations may segregate audiences in terms of what they value most in their travel choices.

4. When travelers try to balance multiple values—authenticity, sustainability, comfort, price—they may experience conflicting goals. Those who feel strongly about one goal (e.g., sustainability) may down-prioritize others (e.g., authenticity) to simplify decisions or reduce cognitive dissonance.

F2 (Rural Immersion) → F3 (Authentic Stay): Estimate = 0.498. This reflects a moderate positive relationship between Rural Immersion and Authentic Stay. Tourists motivated by rural experiences (e.g., local food and farm-based activities) are also more likely to value authentic travel and accommodation experiences. These two constructs appear to be complementary in the tourist decision-making process. Farm Curiosity ← F2: Estimate = 1.011. This is the strongest loading in the model, suggesting that farm-related activities are a central component of the Rural Immersion construct. Culinary Motivation ← F2: Estimate = 0.922. This is also a very high loading, indicating that experiencing local food and wine significantly contributes to rural immersion motivations. Together, these two items confirm that sensory and experiential rural tourism is core to this factor.

Authentic Travel ← F3: Estimate = 1.031. The highest loading for this factor, showing that the pursuit of non-commercialized, culturally rich tourism experiences is fundamental to the construct of Authentic Stay. Rural Stay ← F3: Estimate = 0.785. This also loads strongly on F3, reinforcing the importance of rural accommodations in shaping perceptions of authenticity. These loadings affirm that authenticity in tourism is primarily interpreted through immersion in local culture and staying in traditional settings. Sustainable Preference ← F1: Estimate = 0.209, Sustainable Appeal ← F1: Estimate = 0.164, Nature Bond ← F1: Estimate = 0.153. While all three variables are positively associated with the Sustainable Escape factor, the loadings are relatively low compared to those in the other factors. This may suggest that these indicators, while valid, do not capture the construct as robustly as desired. It could also reflect that environmental motivations are more diffuse or less consistently prioritized among respondents. These findings contribute to a nuanced understanding of tourist motivations, showing that different drivers—such as sustainability, cultural authenticity, and rural immersion—may coexist, complement, or conflict depending on the traveler profile.

Conclusion

The findings from the research conducted in Terlan (Terlano), South Tyrol, Italy, offer valuable insights that can significantly inform the development of agritourism in Fruška Gora. Grounded in the hypothesis that rural tourists are motivated by a combination of environmental values, cultural curiosity, and a desire for authentic experiences, the study provides a comprehensive understanding of the key factors influencing tourist behavior in rural settings. These factors—identified as Sustainable Escape, Rural Immersion, and Authentic Stay—highlight the importance of eco-friendliness, cultural engagement, and genuine hospitality in shaping tourist motivations and destination choices. The results of this study provide a robust foundation for guiding the development of innovative, sustainable, and culturally grounded tourism models in rural regions of Serbia—particularly in Fruška Gora, which holds strong potential due to its natural beauty, agricultural richness, and proximity to urban centers.

Designing Sustainable Escape Experiences (H1): Tourists motivated by environmental values are looking for destinations that align with their eco-conscious lifestyle. To attract this segment, tourism developers in Fruška Gora should focus on: Eco-accommodation: Encourage certification schemes for eco-lodging, support the development of solar-powered rural homes, and promote the reuse of traditional structures with sustainable materials; Nature-based activities: Promote hiking, birdwatching, nature interpretation trails, and forest bathing experiences that create emotional bonds with the environment; Green branding: Develop marketing campaigns that highlight sustainability credentials, including waste reduction, biodiversity protection, and low-carbon tourism options.

Strengthening Rural Immersion through Agritourism (H2): The high motivational value placed on gastronomy and farm activities demonstrates a strong market for authentic, sensory-rich experiences. Key practical steps include: Farm-to-table tourism: Develop networks of local farms and food producers who can offer tasting sessions, cooking classes, and seasonal harvest activities; Agricultural festivals and workshops: Celebrate rural life through themed events (e.g., grape harvest, beekeeping days, organic gardening weekends) that allow tourists to participate and learn; Product development: Encourage the creation of rural tourism packages that combine food, wine, and farm experiences with overnight stays in rural areas.

Cultivating Authentic Stay Experiences (H3): Tourists seeking authentic stays are not merely looking for accommodation—they want to feel immersed in local culture. Strategies to enhance this include: Cultural storytelling: Train hosts to share stories about local traditions, history, and personal experiences, enhancing the emotional and educational value of the stay; Traditional design and lifestyle: Support renovation of village houses using traditional building techniques and interior design that reflects the local cultural identity; Host training and empowerment: Equip local families and rural entrepreneurs with skills in hospitality, communication, and digital marketing while encouraging them to maintain their authenticity rather than adopting commercialized models.

In addition to targeted interventions aligned with specific tourist motivations, several cross-cutting recommendations emerge from the research findings. These offer broader guidance for supporting the long-term sustainability and competitiveness of rural tourism in Serbia. Firstly, policy and funding support from municipalities and national tourism authorities is crucial. Local governments should prioritize incentive programs that encourage the development of green infrastructure, promote experiential forms of tourism, and foster entrepreneurship in rural hospitality. Financial and regulatory support mechanisms can help local actors overcome entry barriers and adopt more sustainable and innovative practices. Secondly, capacity building is essential for equipping rural stakeholders with the skills and knowledge needed to implement quality tourism services. Organizing structured training programs, mentorship schemes, and knowledge exchanges with established agritourism destinations—such as South Tyrol in Italy—can provide valuable models and inspiration. These initiatives would enable Serbian rural entrepreneurs to learn from best practices in combining sustainability, cultural authenticity, and high service standards. Lastly, the formation of integrated rural tourism clusters can significantly enhance the visibility and appeal of rural destinations. By encouraging collaboration between farmers, winemakers, artisans, and accommodation providers, local stakeholders can co-create bundled tourism experiences and establish a unified destination brand. Such collaborative networks not only improve the coherence of the offer but also strengthen local supply chains and promote shared economic benefits within rural communities.

The findings confirm that rural tourism in Fruška Gora should not be developed as a copy-paste product, but rather as an authentic, eco-conscious, and immersive experience rooted in local culture and supported by innovative hospitality practices. By examining the successful example of Terlan, where an innovative and sustainability-driven hospitality model has transformed a rural area into a thriving tourist destination, the study demonstrates how such models can be adapted to similar contexts. Fruška Gora, with its natural beauty, cultural heritage, and potential for wine and farm tourism, is well positioned to implement comparable practices. The emphasis on agritourism as a best-practice hospitality model illustrates how rural destinations can attract visitors seeking meaningful and immersive experiences while simultaneously supporting local economies and preserving cultural landscapes.

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Conflict of interests

The authors declare no conflict of interest.

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ADOPTION OF DIGITAL TECHNOLOGIES AND REDUCTION OF THE DIGITAL DIVIDE AMONG VULNERABLE GROUPS IN THE EUROPEAN UNION

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A B S T R A C T

In the endogenous theory of economic growth, technological progress is viewed as a crucial factor in the economic development of countries. The advancement of digital technologies and ICT innovations underpins sustainable economic growth over the long term. However, the rapid digital development of the population has not been distributed evenly across all social cohorts. The digital divide stems from insufficient adoption of technology by vulnerable groups. The paper assesses internet use, access to digital devices, and digital skill acquisition among vulnerable groups. The methodological approach includes the computation of the Digital Development Index ("IDA Index") and the Digital Divide Index ("DIDIX Index"). The results indicate substantial growth in digital technology adoption and a reduction of the digital divide among vulnerable groups in EU (27) countries. The research demonstrates the emergence of the second-level digital divide, marked by broad access to digital technologies and devices, alongside persistent gaps in the digital competencies required for their effective utilization.

Introduction

The initial theoretical and methodological research on the adoption of digital technologies and the measurement of the digital divide among different population cohorts gained significant attention in scientific studies at the beginning of the 1990s (Compaine, 2001). The concept of the digital divide implies a basic division into the part of the population

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that has access to digital devices and the internet and the part of the population that does not have such access (Van Dijk, 2017; Soomro et al., 2020). The term "digital divide" acquires a completely different meaning, primarily due to the improvement of the social and economic capital of the population of the observed countries (Raggnedda, 2017). In the scientific literature of the 21st century, the digital divide is recognized as a source of poverty and income inequality among certain population groups (Rogers, 2016). Technological progress is a key factor in economic growth, but it does not result in equal adoption of information and communication technologies (ICT) across all social groups, according to Bartikowski et al. (2018). The digital divide is a result of limited access to the internet and modern digital devices, along with uneven development of digital skills within the population (Korovkin et al., 2023). This divide is often linked to social and economic poverty in society (Lin et al., 2017).

At the beginning of the new millennium, three types of digital divide were presented. Norris and Inglehart (2013) define the global digital divide, which implies a different level of adoption of digital technology between different countries. The digital divide refers to the difference in the availability of broadband internet for the adoption of ICT technology by population cohorts (Mitrović, 2015). The third division is the democratic digital division, which involves monitoring the decisions of government administration and institutions through official websites, while promoting democracy via digital communication with citizens' requests. According to Quan-Haase et al., (2018), there are four distinct forms of the digital divide. The first type of digital divide refers to the availability of the internet and modern digital devices. The second type involves developing the population's digital skills for adopting ICT. The third type of digital divide indicates the economic benefits of using digital technologies, i.e. the intensity of the implementation of buying and selling activities. The fourth type of digital divide relates to the population's use of social media and social networks.

A review of scientific research outlines the evolution of the term "digital divide" from the first and second level to the stage of the third level (Aissaoui, 2022):

1. *First-level digital divide* – this refers to the basic access to the internet and the availability of modern digital devices.
2. *Second-level digital divide* – this encompasses not only access to the internet and digital devices but also the development of skills necessary for effectively using information and communication technology.
3. *Third-level digital divide* – this goes further by including access to the internet, digital devices, and digital skills, along with individuals' ability to evaluate and select online content, considering the benefits of utilizing digital technologies.

The first economic growth models acknowledging technological progress as a key factor for advancing economic development emerged in the second half of the 20th century, which is referred to as "endogenous growth theory." There is a disparity in the population's ability to adopt ICT, leading to the digital divide. During the initial phase of adopting new digital technologies, the population was divided into two groups: those who had access to the internet and digital devices and those who did not (Yu et al., 2017). However, in the early years of the new millennium, the definition of the digital divide is being broadened by emphasizing the skills necessary for using digital technologies (Van Dijk, 2006). The second level of the digital divide refers to the quality of human capital necessary for implementing ICT. This division implies differences among individuals based on personal characteristics and their motivation to enhance their skills for adopting digital technologies (Shakina et al., 2021). In recent years, the digital divide at the tertiary level has been addressed. It encompasses improvements in business operations as well as the advantages individuals gain from access to information and the ability to critically evaluate online content (Van Deursen and Van Dijk, 2019). A tertiary level of the digital divide is taking place during the "Covid-19" pandemic (Ionescu et al., 2021), with a significant reduction in the digital divide within population cohorts (Aissaoui, 2022; Kotarac, 2024).

In the 21st century, research has been conducted to identify key factors contributing to the digital divide among countries' populations (Mitrović, 2020). Understanding these factors is essential for recognizing the root causes of the digital divide (Scheerder et al., 2017). The following two groups of digital divide determinants are noteworthy:

1. *Sociodemographic factors*
2. *Socioeconomic factors*

Sociodemographic determinants include age structure, income level, educational structure, degree of urbanization, and ethnicity of the population (Hidalgo et al., 2020). On the other hand, socioeconomic determinants represent digital skills and capacities of individuals, motivation to adopt digital technologies, agility in performing work operations through digital devices, and cultural and personal characteristics of individuals (Venkatesh et al., 2014; Mihajlović, & Todorov, 2024). The precise definition of the drivers of the digital divide within the population of the countries was carried out through the determination of sociodemographic and socioeconomic factors (Lythreatis et al., 2022). This research combines various determinants of the digital divide, which relate to the division of society based on the age structure, level of education, gender structure and employment status of population groups.

Based on the results of various scientific research studies, the following hypothesis will be defined and tested:

Ho: The process of advancing technical and technological progress in countries through the development and implementation of ICT achievements is helping to reduce the digital divide among vulnerable groups within the populations of European Union member states (27).

Materials and methods

The methodological framework for assessing the adoption of information and communication technologies and identifying the digital divide among vulnerable groups within the overall population will be developed using a composite index referred to as the “DIDIX Index.”The digital divide index is calculated as the ratio between the indicator of adoption of information and communication technologies by a vulnerable group and the value of that indicator for the total population. The digital divide index is formed from indicators for four population cohorts, which are classified according to sociodemographic characteristics based on three sub-indices of digital technology development of a country or group of countries (Hüsing & Selhofer, 2004).

For the calculation of the digital divide composite index, the three sub-indices were used as indicators for the adoption of digital technology by the entire population:

1. Individuals – Frequency of internet use.

2. Internet purchases by individuals.

3. Individuals who have basic or above-basic overall digital skills.

The measurement of the value of three sub-indices to form a composite index of the digital divide is conducted for four vulnerable groups:

1. Individuals, 55 to 74 years old.

2. Females, 16 to 74 years old.

3. Individuals with no or low primary education.

4. Unemployed.

The data for calculating the digital divide index is sourced from the Eurostat database (2015-2023) (category – Science, Technology, and Digital Society). Based on these data, three different sub-indices are calculated for all four vulnerable groups. The sample frame of this research consists of the European Union member states, including the latest accessions in 2003, 2007, and 2013. The study covers the period from 2015 to 2023 while avoiding missing data and structural breaks in the time series before the observed period. The calculation of the “DIDIX Index“ is carried out through the value of indicators for the adoption of digital technologies by vulnerable groups to analyze the digital divide within the population of the EU countries.

The calculation of the digital divide index is ensured by defining a predetermined combination of weight values. Logic suggests that each sub-index used in the construction of the composite index should be assigned equal weights. However, a review of the scientific literature confirms that the weights were determined endogenously, i.e., through performance analysis and the harmonization of indicators across countries (Hüsing et al., 2004; Stojković & Kocić, 2024). Namely, the weights for various sub-indices are determined using linear programming methods. Therefore, the values of the composite indices of the digital divide by country are maximized, without any other combination of weights for the sub-indices that would provide a higher value of the composite index of the digital divide (Vehovar et al., 2006).

The analysis of the digital divide among countries involves the calculation of two key indicators: the ICT Development Index (IDI) and the Digital Divide Index (DIDIX). The sampling frame was created using countries in Europe that represent both ends of the digital development spectrum, including those that are least and most digitally advanced.

The IDI index value is calculated using the following formula:

$$\text{IDI Index} = \frac{1}{n}\sum_{i=1}^{n} f_i \quad (1)$$

$$f_i = 100 * \sum_{j=1}^{m} W_j * \frac{S_{ij}}{S_j} \quad (2)$$

, where the symbol (f_i) refers to the value of individual indices or sub-indices for each of the three categories. For the composite index of ICT technology development of countries, the values of a series of sub-indexes $(j = 1,2,3 \ldots 9,10,11)$ were used, for each of the three categories (f_i) $(i = 1, 2, 3)$, W_j indicates the value of the indicator (j) $(j = 1,2,3;\ Sw = 1)$, symbol S_{ij} denotes the value of the indicator (j) within each of the categories $(i)(i = 1, 2, 3)$, the label S_j implies the value of the indicator (j) for all three mentioned categories collectively (ITU Database, 2015-2023).

Results and Discussions

The analysis of the adoption and implementation of ICT is carried out through an insight into the value of digital development indicators, along with the calculation of the digital gap of vulnerable groups within the entire population of countries. Table 2 presents the values of the composite digital divide index (“DIDIX“), which measures the adoption and application of digital technologies by vulnerable groups concerning the entire population of the European Union countries. Based on the change in the value of the digital divide index, the technological development of the observed group of countries will be analyzed in different time units, with a conclusion about the reduction or increase of the digital gap between vulnerable groups within the population of the EU countries (27).

Table 1. Calculation of the digital divide index (“DIDIX“), based on four vulnerable groups within the entire population of EU countries (27)

2015	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	75%	100%	62%	100%	54%	100%	SB1 + SB2 +SB3+SB4
G_1	50%	66.6	50%	80.6	29%	53.7	Sub-Index 1

G_2	72%	96.0	61%	98.3	51%	94.4	Sub-Index 2
G_3	53%	70.0	45%	72.5	31%	54.4	Sub-Index 3
G_4	71%	94.6	47%	75.8	45%	83.3	Sub-Index 4
Sub-index	40.90		20.45		17.86		**79.2**
2017	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	79%	100%	65%	100%	55%	100%	SB1 + SB2 +SB3+SB4
G_1	56%	70.8	51%	78.4	31%	56.3	Sub-Index 1
G_2	78%	98.7	63%	96.9	53%	96.3	Sub-Index 2
G_3	75%	75.9	46%	70.7	31%	56.2	Sub-Index 3
G_4	94%	94.9	50%	76.9	44%	80.0	Sub-Index 4
Sub-index	42.53		20.18		18.05		**80.8**
2019	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	84%	100%	68%	100%	56%	100%	SB1 + SB2 +SB3+SB4
G_1	65%	77.3	53%	77.9	33%	58.9	Sub-Index 1
G_2	83%	98.8	68%	100	54%	96.4	Sub-Index 2
G_3	68%	80.9	50%	73.5	32%	57.1	Sub-Index 3
G_4	79%	94.0	56%	82.3	44%	78.5	Sub-Index 4
Sub-index	43.87		20.85		18.18		**82.9**
2021	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	87%	100%	74%	100%	54%	100%	SB1 + SB2 +SB3+SB4
G_1	72%	82.7	60%	81.0	35%	64.8	Sub-Index 1
G_2	87%	100	74%	100	52%	96.0	Sub-Index 2
G_3	73%	83.0	56%	75.6	32%	61.5	Sub-Index 3
G_4	86%	98.0	65%	87.0	49%	94.0	Sub-Index 4
Sub-index	45.46		21.47		19.76		**86.6**
2023	1 (*0.5)		2 (*0.25)		3 (*0.25)		Didix Index
EU (27)	Frequency of internet use by individuals		Internet purchases by individuals		Digital skills of individuals		
All Indiv.	90%	100%	75%	100%	56%	100%	SB1 + SB2 +SB3+SB4

G_1	82%	91.1	60%	80.0	37%	66.0	Sub-Index 1
G_2	90%	100	75%	100	54%	96.4	Sub-Index 2
G_3	79%	87.7	57%	76.0	34%	60.7	Sub-Index 3
G_4	98.8%	98.8	64%	85.3	48%	85.7	Sub-Index 4
Sub-index	47.22		21.33		19.30		**87.8**

Source: Author's calculation, based on data from the Eurostat database (2015-2023)

The results in Table 1 indicate the share in which the observed vulnerable groups have access to the internet and modern digital devices, information and purchasing activities, as well as possessing digital skills.

The first vulnerable group is made up of the older population, in the age range from 55 to 74. Due to difficulties in acquiring digital skills and aversion to modern digital devices (Matthews et al., 2019), the older population uses the internet significantly less than other population groups (Gallistl et al., 2021), with insufficient information and purchases through available web platforms (Olphert & Damodaran, 2013). The absence of digital skills and the limitation of physical mobility lead to a decrease in social interactions of the older population (Hill et al., 2015). During 2015, the first vulnerable group used the internet network 25% less than the average usage of the internet across the entire population, which was calculated based on the average of the indicator values of the EU countries (27). During the same period, older members of the population received information about products and services available online and made purchases on e-commerce platforms at a rate 12% lower than the average value of the population of EU countries (27). The lag in the digital skills sub-index was evident. In 2015, the first vulnerable group demonstrated digital skills that were 25% lower than the average for the population of the EU (27) countries. However, by 2023, this group saw a 32% increase in internet usage compared to 2015, reducing their lag to only 8% regarding indicators for the entire EU (27) population. Additionally, the older segment of the population increased their online information gathering and purchases through electronic platforms by 10% from 2015 to 2023. This group also experienced an 8% increase in digital skills, which significantly contributes to the adoption of digital technologies.

The formation of the second vulnerable group was based on an analysis of digital development within the gender structure of the population. The research found that women's use of the internet and their development of digital skills related to adopting ICT are significantly lower compared to that of men (Adkins & Sandy, 2020). In rural regions of various countries, the gender digital divide is more pronounced, making women a particularly vulnerable population (Cortelyou-Ward et al., 2020). Another vulnerable group consists of women aged 17 to 74 (Eurostat Database, 2015-2023). In 2015, this age group of women used the internet, consuming content through websites and social networks, at a rate that was only 3% lower than the average for the entire population of the EU (27) countries. In the same period, information about products and services and performance of buying and selling activities via e-commerce platforms by women lagged by a negligible 1% compared to the average values for the entire population of the EU (27) countries. In 2015, the development of digital skills for the use of ICT by this vulnerable group lagged by 3% compared to the average digital skills of the entire population of the EU (27) countries. During 2023, internet use by women aged 17 to 74 amounted to 90%, which is equal to the average value of the indicator for the entire population of the EU (27) countries. In the same year, the information-seeking and purchasing activities of this vulnerable group on e-commerce platforms aligned with the average values for the overall population of the EU (27) countries. However, there was a notable exception in digital skills development, where women aged 17 to 74 were 2% behind the average level of digital skills in the EU (27) countries.

The third vulnerable group is formed based on the educational structure of the population (Kim et al., 2021). The quality of human capital and the economic standard of a country are significantly correlated with the educational system of a country (Winters, 2011; Lythreatis et al., 2022). Adoption of ICT is insufficient among a part of the population with or without lower primary education, which has caused the formation of a third vulnerable group (Helsper & Reisdorf, 2017). Therefore, the third vulnerable group in this research involves the part of the population with or without primary education (Eurostat Database, 2015-2023). In 2015, the population with or without primary education used the Internet 22% less compared to the average values of the internet use of the population of the EU (27) countries. Information and purchasing activities through e-commerce platforms are 17% lower than the average values measured at the level of the entire population of the EU (27) countries. The development of digital skills for the adoption of ICT by this vulnerable group was 23% lower than the average indicator of the total population of the EU (27) countries. Internet use and digital devices by the less educated part of the population increased by 16% in 2023 compared to 2015, representing a lag of 11% compared to the indicators for the entire EU population in 27 countries. During 2023, information and purchasing activities on e-commerce platforms of this vulnerable group increased by 12% compared to 2015, which implies a lag of 18% compared to the average indicators of the EU population. The possession of digital skills related to the application of ICT technologies among the less educated population has seen only a modest increase of 3% since 2015. This growth still leaves a 22% gap when compared to the digital skills levels of the population in the EU (27) countries.

The fourth vulnerable group is linked to per capita income, specifically concerning the low standard of living among the population of these countries. This group is primarily composed of individuals from the unemployed segment of the population. The increased rate of unemployment and low income per capita lead to limitations in the availability of the internet and modern digital devices, with the absence of financial resources for the education of individuals (Ueno et al., 2023). The population that faced low socioeconomic status and standard of living has less ability to adopt and implement digital technologies (Helsper & Reisdorf, 2017). Therefore, the fourth vulnerable group consists of the unemployed part of the population of the EU (27) countries. In 2015, the unemployed population used the internet and consumed the content of websites by 4% less compared to the average values of internet use of the entire population of the EU (27) countries. Information about products and services and purchasing activities via e-commerce platforms was 15% less intense than the number of users of e-commerce platforms in the total population of the EU (27) countries. During 2015, the digital skills of the unemployed population were 9% less developed compared to the average development of skills for using digital devices of the entire population of the EU (27) countries. In 2023, the use of the internet and consumption of online content increased by 27.8% compared to the value measured in 2015. Information about products and services, along with purchasing activities through e-commerce platforms, reached a growth of 17% in 2023 compared to 2015, which also implies a lag of 11% compared to the volume of e-commerce users of the total population of the EU (27) countries. During 2023, the development of digital skills for using digital devices and the adoption of information technologies increased by 3% compared to 2015, with a lag of 8% compared to the measured development of skills of the entire population of the EU countries (27).

Table 2. Values of digital development indicators calculated for the entire population of the 27 countries in the European Union

Countries of EU (27)	Adoption of digital technologies and ICT innovations at the level of total population		
(K_1) - (K_3)	Sub-Index (K_1)	Sub-Index (K_2)	Sub-Index (K_3)
Time Period	Frequency of internet use by individuals	Internet purchases by individuals	Digital skills of individuals
2015-2017	+4%	+13%	+1%
2017-2019	+5%	+3%	+1%
2019-2021	+3%	+6%	-2%
2021-2023	+3%	+1%	+2%
2015-2023	+15%	+13%	+2%

Source: Author’s calculation.

The monitoring of changes in the sub-indices that make up the composite index of the digital divide, known as “DIDIX,” measures the adoption of ICT among vulnerable groups and the overall population of the 27 EU countries.

Between 2015 and 2023, the frequency of internet use among individuals increased by 15%. During the same period, there was also a 13% rise in the value of internet purchases made by individuals. In contrast, the indicator measuring individuals’ digital skills showed only a minimal increase of 2%. Additionally, there was a 13% growth in the value of electronic purchases made by individuals during this time frame. Then, an increase of 2% was measured in the value of the indicator of digital skills. The research results indicate that the growth of digital development is accompanied by improved ICT infrastructure, greater availability of digital devices, and the quality of broadband internet. During the observed period, there was a notable increase in the number of internet users and the use of e-commerce platforms for purchasing activities through digital devices. Human capital has remained relatively stable over time, serving as both a key factor for technological progress and a prerequisite for adopting ICT innovations. However, it was found that the development of digital skills necessary for implementing these technological advancements is still insufficient among the population of the EU (27) countries.

The calculated values of the digital divide index represent the ratio between the indicators of the acceptance of digital technologies by vulnerable groups and the values of the indicators of the entire population of the observed countries. The calculated value of the DIDIX index is approximately 0, indicating that the adoption of digital technologies among vulnerable groups is extremely low. This reflects a significant disparity in digital development compared to the overall population.

The calculated value of the digital divide index, which is approximately equal to the number 100, indicates that the implementation of digital technologies by vulnerable groups is equivalent to the development and implementation of digital technologies of the average value of the entire population (Vehovar et al., 2006). Namely, an increase in the value of the digital divide index indicates a reduction in the digital gap between vulnerable groups and the entire population of a country or group of countries.

The countries aim to develop and implement ICT while reducing the digital divide between different cohorts within the total population. In 2015, the value of the "DIDIX index" was 79.2 units. Therefore, the four vulnerable groups adopted digital technologies at less than 4/5 of the average implementation by the total population. In 2017, the "DIDIX index" was valued at 80.8 units, indicating that the adoption of digital technologies by vulnerable groups was approximately 4/5 compared to the average of the entire population. Improvements in the ICT infrastructure and increased internet use, the availability of digital devices, and the quality of human capital ensure the reduction of the digital divide of the overall population. During 2019, the value of the "DIDIX index" was 82.9 units. Hence, the adoption of digital technologies by vulnerable groups was higher than 4/5 of the average adoption of digital technologies by the total population. The trend continued during the Covid-19 pandemic when the digital divide index was 86.6 (2021) and 87.8 (2023), which is above 4/5 of the average use of ICT by the total population of EU (27) countries.

The analysis of the digital divide among countries involves the calculation of two key indicators: the ICT Development Index (IDI) and the Digital Divide Index (DIDIX).

Table 3. Calculation of digital development and digital divide of vulnerable groups within the most and least digitally developed European countries

Countries	IDI Index		Index Value	DIDIX Index		Index Value
Time frame	2015	2023	(2015-2023)	2015	2023	(2015-2023)
Sweden	86.7	93.9	%ΔIDI=7.2%	89.51	95.56	%ΔDIDIX=6.05
Denmark	88.8	96.9	%ΔIDI=8.1%	95.55	96.64	%ΔDIDIX=1.09
Germany	82.2	87.3	%ΔIDI=5.1%	86.70	88.21	%ΔDIDIX=1.51
Luxembourg	85.9	92.1	%ΔIDI=6.2%	91.36	89.10	%ΔDIDIX=2.26
France	81.2	89.4	%ΔIDI=8.2%	85.20	89.85	%ΔDIDIX=4.65

Countries	IDI Index		Index Value	DIDIX Index		Index Value
Latvia	71.6	93.8	%ΔIDI=22.2%	75.92	86.09	%ΔDIDIX=10.17
Serbia	64.5	85.1	%ΔIDI=20.6%	68.73	82.53	%ΔDIDIX=13.80
Albania	47.3	84.7	%ΔIDI=37.4%	68.02	81.53	%ΔDIDIX=13.51
Montenegro	59.0	87.9	%ΔIDI=28.9%	60.87	80.12	%ΔDIDIX=19.25
Turkey	55.8	85.8	%ΔIDI=30%	69.53	79.73	%ΔDIDIX=10.20
Bosnia and Her.	52.8	78.6	%ΔIDI=25.8%	72.59	74.12	%ΔDIDIX=1.53
North Maced.	60.7	82.0	%ΔIDI=21.3%	68.61	79.66	%ΔDIDIX=11.05

Source: Author's calculation, based on data from the Eurostat database (2015-2023)

Based on the results from Table 3, European Union member states achieved a digital development growth of 9.5% from 2015 to 2023. During the same period, the countries that are candidates for joining the European Union saw a substantial increase of 27.33% in their digital development. According to the digital divide index, the gap of vulnerable groups has been reduced to a level of 90.92, which is above 4/5 of the overall digital development of the entire population. Meanwhile, candidate countries have reduced the digital divide to the level of 79.62, which is below 4/5 of the total population.

The conclusion is provided through a comparison of the calculated values of the digital divide of member countries and candidates for joining the European Union. During 2023, the digital divide in the EU (27) countries was 87.8. Namely, the group of candidate countries for EU membership, i.e., digitally less developed countries, had an 8.2% higher digital gap of vulnerable groups in the total population, compared to the average digital divide of EU (27) countries. On the other hand, the group of EU (27) member states, i.e., highly digitally developed countries, achieved a 3.1% lower level of digital divide of vulnerable groups within the total population, compared to the average digital gap of EU (27) countries. The development of ICT technologies in the candidate countries for EU membership is increasing 2.9 times faster than in the EU member states. European Union member states reduced the digital divide by 11.3% more than candidate countries for EU membership.

Conclusion

The digital divide among the population is a consequence of the rapid development of information and communication technology. This divide highlights the uneven adoption of digital technologies across different groups. Factors contributing to the unequal use of these technologies include an underdeveloped ICT infrastructure and limited availability of digital devices in various regions of the observed countries. Key barriers preventing equal access to digital technologies for all social groups include a lack of digital skills, inadequate education levels, insufficient training and skill development for employees, and lower per capita income among vulnerable populations.

The values of three sub-indices within the composite index of the digital divide were calculated to analyze the digital gap of four vulnerable groups within the population of EU countries. The greatest growth in the use of the internet and consumption of content on websites was measured within the first vulnerable group (Individuals, 55-74). The highest sub-index values were measured in the second and fourth vulnerable groups (Females, 17-74 & Unemployed) in terms of purchasing activities via e-commerce platforms, with information about products and services. Finally, the greatest improvement in the development of digital skills was measured within the first vulnerable group (Individuals, 55-74). The calculation of the DIDIX index confirms the direct negative correlation between the sudden influx of ICT and the reduction of the digital divide within the population of the EU countries.

The most digitally developed EU countries had an almost three times lower growth in ICT technologies, but a double-digit reduction in the digital gap, compared to less digitally developed countries that are candidates for membership in the European Union. Namely, the lack of infrastructure for the implementation of ICT, insufficiently developed e-commerce platforms, and digital skills caused the uneven adoption of ICT technologies in different population cohorts. The first two indicators refer to the use of the internet and the consumption of content on websites, with information about products and services, and the realization of purchasing activities, a double-digit percentage increase was achieved in all four vulnerable population groups in the European Union countries.

The increase in digital skills necessary for implementing digital technologies among the four vulnerable groups is only a single-digit percentage. This research indicates that an effective approach to bridging the digital divide between vulnerable groups and the entire population of the EU (27) countries has not been established. Adopting digital technology successfully requires more than just developing ICT infrastructure and ensuring access to digital devices; it also necessitates enhancing digital skills to effectively utilize technological innovations and ICT solutions.

To reduce the digital divide affecting vulnerable population groups, it is essential to focus on developing human capital and improving the educational system. This includes providing additional training and education for employees and citizens to enhance the overall digital skills of the population.

The recommendation for the creators of national strategies regarding the implementation of information and communication technologies involves raising awareness that overcoming physical barriers to the application of ICT is a necessary but not a single condition for reducing the digital divide within the population. A comprehensive approach implies improving the educational system to develop digital skills and competencies, all to reduce the digital divide and achieve the general social well-being and economic prosperity of countries.

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Conflict of interests

The authors declare no conflict of interest.

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LOCAL VARIETIES AND ECONOMIC ASPECTS OF INVESTMENT IN VINEYARD ESTABLISHMENT: THE CASE OF SERBIA

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A B S T R A C T

Recently, entry into grapevine growing as initial step for wine production has become a wise business decision in Serbian agri-sector. Along promising possibilities for maintaining farm economic sustainability, many new or renewed vineyards have been established. It has become common that, within such vineyards, alongside commercially and internationally recognized grapevine varieties, certain local ones, such as Tamjanika Bela, are also planted. The main goal of the research was to develop the investment analysis towards vineyard establishment as a relevant tool in decision-making process (investment doesn't involve land acquisition). The applied methodological framework included selected dynamic methods for economic assessment of investment (Net Present Value – NPV, Internal Rate of Return – IRR and Dynamic Payback Period – DPP) supported by field data from one grape producer in Trstenik wine-growing subregion. The results, NPV of 2,418.87 EUR, IRR of 8.81%, and DPP of 9 years and 1.46 months, confirmed economic justification of vineyard enlargement.

Introduction

Observing all fruits grown worldwide, the grape (*Vitis vinifera L.)* is not among the most produced fruits as are bananas, citruses or apples (Lado et al., 2018; Scott, 2021),

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but it is surely ranked within the group of top ten fruits, or more closely, it represents globally the most popular fruit species (Mele et al., 2021). Above all, it belongs to the group of the most significant cultivated plant species n modern agriculture. In human consumption grapes could come as fresh or processed mainly as a wine, or other alcoholic beverage (grape spirits, brandy/wine spirits, tsipouro, etc.), as well as juice, jam and jelly, raisins, grape-seed oil, vinegar, etc. (Pappas et al., 2016; Cosme et al., 2017; Venkitasamy et al., 2019).

More than 55% of grapes production is turned to wine production (or in much smaller contents other alcoholic beverages), over the 35% are consumed as fresh (table grapes), while less than 10% are used in raisins production or similar types of processing (Agulheiro Santos et al., 2021). Grape and its by products are commonly used in food and beverage industry, cooking, conventional and alternative medicine, pharmacy, cosmetology and light chemistry industry, animal feeding and feed industry, etc. (Soto et al., 2015; Chowdhary et al., 2021; Sharafan et al., 2023; Quagliardi et al., 2024).

Grapes are mainly made of water, over 80%, carbohydrates, up to 20%, as well as around 1% of proteins, and negligible volume of fats. They are good resource of fiber, energy, certain vitamins (K, B1, B2, B6, C, or E), some macro and micro nutrients (K, Mn, or Cu). Besides, they possess different bioactive substances (phytochemicals), as are phenolic acids, flavonoids, anthocyanins and proanthocyanidins, or stilbenes (Nassiri Asl, Hosseinzadeh, 2009; Georgiev et al., 2014; Chavan, 2020; Tangolar et al., 2022; Chakka, Babu, 2022; Hatterman Valenti et al., 2024). In line to favorable chemical composition and antioxidative activity, grape and grape products consumption strongly benefits human health, preventing the cardiovascular diseases, cancer, diabetes, or dementia and decrease in cognitive functions, as well as it strengthens immune system, or skin and bones health, or it balances the cholesterol level, etc. (Vislocky, Fernandez, 2010; Yang, Xiao, 2013; Hohman, Weaver, 2015; Sabra et al., 2021).

Global trends related to overall production and areas under the vineyards could be observed in Table 1. There could be seen slight decrease in areas under the vineyards in last decade, while there come to stabilization of achieved volume of production, what is mainly the result of slight increase in achieved yields.

Table 1. Global grapes production and areas under vineyards (period 2013-2022, in ha, in t/ha, in t)

Element/year	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Area	7,027,292	7,024,394	7,107,845	6,900,363	6,834,893	6,875,427
Yield	10.89	10.52	10.78	10.80	10.77	11.65
Production	76,507,662	73,906,174	76,593,826	74,517,216	73,600,630	80,096,667
Element/year	**2019**	**2020**	**2021**	**2022**	**Average**	
Area	6,909,210	6,918,656	6,881,764	6,730,179	6,921,002	
Yield	11.15	11.10	11.15	11.14	11.00	
Production	77,054,569	76,828,209	76,750,674	74,942,573	76,079,820	

Source: FAOSTAT, 2024.

Mentioned moves in production worldwide usually derive as the clearing or replacement of old vineyards with new one, that are functioning in line to principles of contemporary production systems, with presence of more productive grapevine varieties resilient to climate changes (primarily to water deficit or draught), or change in set production structure related to further purpose of grown grape (fresh consumption or processing), etc. (Alston, Sambucci, 2019; Santillan et al., 2019; Sgubin et al., 2023). In 2022, the largest areas under vineyards were in Spain (around 13%), France (around 11%) and China (around 11%), (commonly over 2.5 million ha). It is interesting, that those countries (including Italy), contrary to other top grape producers, have showed slight increase in areas under the vineyards. Currently, among the group of the largest grape producers are China, Italy, France, USA, Spain, Turkey, India, Chile, Australia, or Argentina (OIV, 2024).

Despite the mentioned limitations (decrease in areas under vineyards), simultaneously with the growth of agri-food products' prices, there has come to rise in the value of overall grapes production (mainly increase in grapes price at farm gate), (Table 2.).

Table 2. Global value of grapes market (period 2013-2022, in billion USD, in current prices)

Element/year	2013	2014	2015	2016	2017	2018
Value	68.26	71.75	64.46	64.51	69.10	73.66
Element/year	**2019**	**2020**	**2021**	**2022**	**Average**	
Value	75.20	83.33	86.02	85.13	74.14	

Source: FAOSTAT, 2024.

Besides, in last several years towards the climate and energy shocks, COVID 19 crisis, intensification of many local military conflicts, or general disturbance in global economy flows, etc., there has also been a significant increase in pricesof all agro-inputs, restricting the gained profitability in grape production. Nowadays, expectations are focused to further rise in agri-food prices (including grapes) and production costs, but still the huge market issue could be the influence on potential of (dis)similarity in their trends. Of course, it has to be underlined that both, grape prices and thecosts incurred in carrying out winegrowing activities can vary significantly across regions, due to local specificities in established production environment. Besides, it is not so rare that gained grape price is not only the reflection of circumstances at local market, but also represents the ability of grape-grower to properly expose its uniqueness (Nica, 2018; Ben Hassen, El Bilali, 2022; Accetturo, Alpino, 2023; Barakat et al., 2023; Belewu et al., 2024; Cavaliere et al., 2024).

Considering available climate and natural circumstances, Serbia is generally the suitable country for grape production. In this moment, there are roughly less than 20 thousand hectares of vineyards (SORS, 2025). Grape production is exercised in certain level at almost 14% of all farms, with domination of wine grape varieties (Jeločnik et al., 2024). In previous period, not only in Serbia is present the trend that during the renovation of old or establishment of new vineyards, there come to introduction of local varieties, as they have regional recognizability, or they could boost the country image, as well as they have higher level of resistance to occurred pests, diseases and negative side of climate changes. Besides, they usually have stronghold in tradition, while they serve as guards of cultural heritage through the offer of local food products (based on domestic grapevine varieties), or development of wine tourism and entrepreneurial initiatives they include. Thus, a slow change in the structure of vineyards, with an increasing share of local varieties relative to international grapevine varieties, may help ensure the competitiveness and survival of the national viticulture sector (Popović, Živanović Miljković, 2012; Petrović et al., 2024; Tello et al., 2024).

No economic or social activity, nor any territorial unit (local community, region, or the country as a whole), can be established or operated without proper investment. Investments are initiators, levers, or simply the fuel of development, or even precondition for humans' survival (Singer, 1966; Spangenberg, 2001; Alsadat et al., 2017). In essence, investment considers putting certain amount of money into the established financial scheme or mechanism, or any physical property and service, expecting a certain level of profit gaining in close future (investment object exploitation will be based on its usefulness, while gained incomes over the costs may repay initially invested assets). So, they represent financing of any property, rights or interest that will provide income or increase in value of invested asset during the predefined period (Legum, 2006; Cheng, 2011).

In agriculture, they consider purchasing or establishment of capital assets and services such are facilities and plantations, land and livestock, mechanization and equipment, transfer to certain system of production, skip to new form of organization, etc. Investment does not consider momentarily economic consumption to investor (farm, enterprise or rural community), while they initiate accumulation of interests in upcoming period, based on production of different goods and services. They are important in creating the value added in agriculture and rural space, securing adequate life and business conditions at micro (farm or local community) or macro (national or regional) level (Hrytsaienko et al., 2019; Chulkova et al., 2019; Jeločnik, Subić, 2020).

Investments in sector of viticulture could target several things, such as the establishment of vineyard (land purchase, parcel clearing, leveling and reclamation, purchasing and setting the elements required for seedlings planting and further exploitation, as are pillars and wire, etc.), implementation of irrigation systems, including fertigation (irrigation combined with the application of fertilizers) and anti-frost systems, different mechanization, equipment and tools, various facilities (garage, warehouse for inputs, cooler for grapes, or cellar for final products, or processing facilities), various permits, or quality certificates, etc. (Cots Folch et al., 2006; Garcia Garcia et al., 2012; Overton, Murray, 2013; Seyoum Tegegn, Chan, 2013; Bulatović, Milić, 2014). The size of investment could vary due to many reasons, but primarily towards the comprehensiveness and novelty of producer's business idea.

There are no many scientific papers turned to analysis of investments in viticulture, partly caused by the lack of unique solutions, or more often due to general hiding of essential elements of realized project ideas. Considering the grape production and processing as the sectors with significantly growing potential, while the demand for grapes and grape's products is growing intensively, there is assumed reasonable vitality of investments in underlined sector. Besides, investment in grape growing and processing is complex decision, pressed by many risks. Those in the position of investors are usually individual farmsand entrepreneurs, or enterprises and cooperatives. Financing modality could differ from investment of investor own financial assets in certain percent, to investment of assets gained from bank credits, some public incentives, international or national funds oriented to agriculture (IPARD, Wine Investment Fund, FAO, WB, and others), etc. (Cyr et al., 2010; Dutz et al., 2014; Kym, Jensen, 2016; Testa et al., 2018; Prodanović et al., 2020; Assenova et al., 2023).

As the main research goal has been set the reconsideration of results derived from assessment of investment in establishment (or enlargement) of vineyards under the local wine grape variety. It is expected from research to deepen current economic knowledge related to vineyards establishment.

Methods and Materials

In research were used the data gained from the farm oriented to grape production located in Tri Morave winegrowing region (precisely Trstenik wine-growing subregion). Data collection was performed through the in-depth interview with the farm owner. All used data, or made projections are referring to season 2023/24, i.e. all prices and costs within the observed period have been fixed to initial year. So, in order to simplify the investment analysis, it presumes occurrence of quite a similar production circumstances (primarily climate conditions), or after yields stabilization (full yieldingness) fixed volume of gained grapes. As was underlined, the value of all costs and prices (occurred in initial year of vineyard establishment and later during its running) are fixed, while they are in line to exercising good agriculture practice at the farm (used inputs match in the best way the specific requirements of planted grapevine variety), expectation of high yields, and overlapping with current prices of used inputs and obtained grapes at local market. Its assumed that observed farm has enough production capacities (labor, mechanization, facilities and equipment) to cultivate additional hectare of newly established vineyard (investment is turned to vineyard enlargement at farms' unused land that will induce better utilization of current farm's production capacities, i.e. investment does not involve land acquisition). Farm is willing to use the state financial support for vineyard establishment in amount of up to 50% of maximally allowed sum, while other part of investment value will be covered by own capital.

Used methodological framework corresponds to some previous researches focused to establishment of perennial plantations (Subić et al., 2021; Jeločnik et al., 2022; Nastić et al., 2023; Nastić et al., 2024). Investment analysis was based on applying common dynamic methods performed for assessment of investment efficiency, as are Net Present Value (NPV), Internal Rate of Return (IRR), and Dynamic Payback Period (DPP). The investment analysis reconsiders just first 10 years of established vineyard exploitation, as was expected that the investment will be returned within this period. Analysis have not considered appliance of static assessment methods (fixing the representative year), as in conventional grape production the expected effective investment (vineyard) utilization covers longer period (up to 30 years), while certain specificity of vine is that in initial years of vineyard exploitation there is no or quite a limited grape yield under the similar production costs (Carbone et al., 2019; Williams et al., 2020), which could contribute to making the wrong conclusion.

Derived research results are reliable enough for initial decision of grape producer towards to entering the vineyard enlargement process. All used data and obtained research results have been presented in adequate tables, while all values are expressed in EUR (used currency rate - 1 EUR = 117.5 RSD) and correspond to one hectare of production surface, what enables further comparation with results derived from similar researches or entrepreneurial initiatives.

Possible research limitations are underlined using the data just from one locality, as well as the stability in observed prices and costs, or gained incomes and derived costs during the period of vineyard exploitation. Additionally, the farm could or could not apply to certain level of state financial support. Besides, gained research results may variate due to difference in used technological approach, grapevine variety, production ambitions and goals of the farm, way of investment financing (used of own assets or loan of commercial bank), etc. So, as was previously mentioned, there are no unique (or similar) solutions and production preconditions in grape production.

Results and Discussion

Farm wants to enlarge existing vineyard (currently 3 ha) for one hectare. As the dominant wine variety in vineyard is Tamjanika Bela, this promising local variety (without delving in this paper into the issue of genetic origin whether it is truly a local, regional, or international grapevine variety) will be also planted at vineyard extension. Farm is located in Trstenik wine-growing subregion. Parcel that will be used for vineyard expansion has a regular shape and it is owned by the farm (1 ha), so vineyard enlargement does not include land acquisition, while it will be the extension of current vineyard at the holding. It relies to existing vineyard along its entire length (soil and climate preconditions are the same). The owned terrain intended for the vineyard expansion has a moderate slope. As was previously mentioned, farm owns all necessary mechanization and equipment used in grape production, that can be also applied for parcel preparing and further vine planting. Farm has already implemented irrigation (drip) system, while it possesses required facilities for storing inputs, machinery, and additional part of grape yield. The farm applies adequate grape production technology, guaranteeing maximal grape yields of very good quality. Produced grape will be sold locally. It is planned that for certain production operations, or during the production peaks, farm will hire external labor.

New investment covers (Table 3.) just costs of activities (used mechanization and labor) and necessary inputs for parcel (1 ha) preparing for the vineyard establishment, planting of certified seedlings (Tamjanika Bela), and implementation of seedling stands (vineyard support), as well as the costs of Permanent Working Capital (PWC), (standardized at 10% of overall investment value).

Costs of parcel preparing for vineyard establishment involve costs of external labor (payment of 12 per diems, while daily wage accounts to 25 EUR) mainly engaged for parcel leveling, extermination and clearing from wooden plants, correction of deep plowing, manual support to transport and deposition of manure and mineral fertilizers, etc. Mentioned activity was supported by tractor aggregates (different power) with adequate equipment. Working day of mechanization (tractor) considers costs of spent energy (fuel) and part of wage of operator engaged in performing of certain activity at 1 ha. Besides, it also considers depreciation of used mechanization, and other costs linked to exploitation of tractor unit. Mechanization is used for terrain leveling and clearing, manure and mineral fertilizers transportation and spreading, heavy tillage, direct activities linked to land preparation for planting vines seedlings, etc. Costs of used inputs manly involves costs of applied volume of manure (50 t of mature cow manure) and mineral fertilizers (superphosphate, potassium salt and limestone). It has to be underlined again that maid investment does not involve land acquisition.

Table 3. Investment in vineyard establishment (1 ha, in EUR)

Description	**Value (in EUR)**	**Share (in %)**
Costs of soil preparing for vineyard establishment (surface leveling and cleaning)	5,960.0	26.1
Costs of planting	7,075.0	31.0
Costs of seedlings stands implementing	7,700.0	33.8
PWC	2,073.5	9.1
Total	**22,808.5**	**100.0**

Source: IAE, 2024.

Costs of vine seedlings' planting (with hydro-drill) involve 17 per diems for external workers engaged in markers preparing, marking roads, paths, and rows, as well as places for planting vines, preparing seedlings for planting and their further planting with hydro-drill, etc. Used mechanization mainly involves tractor with trailer and water-tank. It was engaged for transportation of markers, seedlings, or water for planting, as well as for planting with hydro-drill, etc. Costs of inputs used for this segment of vineyard establishment considers the value of certified vine seedlings (variety Tamjanika Bela, planting density 4,000 seedlings/ha), etc.

Costs of setting seedlings stands involve 52 per diems paid for engaged external labor at activities of handling with stands, stakes, anchors and wire during their transportation, deployment and installation, etc. For that purposes (transport of inputs) were used tractor with trailer. Costs of inputs considers the price of external and inner stands (wooden), stakes (wooden), anchors (concrete), galvanized wire (5 mm, 3.1 mm, and 2.4 mm).

In grape production, full income or return on investment (full yielding of the vineyard) usually starts after fourth year, expecting that the farmers labor will be fully compensated at the market at that moment (Williams et al., 1994). For vineyard establishment and further grape production, farm is planned to apply for state support (Table 4.).

Table 4. Used subsidies for vineyard establishment and running (in EUR)

Description	Maximally allowed subsidies (in EUR per ha or seedlings)	Used subsidies (in EUR)
Direct payment (plant production)	acc. 150 EUR/ha	Fully used
Subsidies for soil preparing	acc. 4,250 EUR/ha	2,125
Subsidies for certified seedlings	acc. 1.1 EUR/seedling	2,000
Subsidies for stands	acc. 5,960 EUR/ha	2,980

Source: OGRS, 2023; IAE, 2024.

Expected incomes in first ten years of vineyard exploitation (after the moment of its establishment) are given in next table (Table 5.). Annual incomes differ due the achieved grape yields, obtained wholesale market price of grape and level of gained state support.

Table 5. Income forming in vineyard running (in EUR, for 1 ha, production year 2023/24)

Year	Yield (kg/ha)	Price (EUR/kg)	Selling revenues (EUR)	Direct payments (EUR/ha)	Other subsidies (EUR)	Total incomes (EUR)
I	-	-	-	150	7,105	7,255
II	1,500	1	1,500	150	-	1,650
III	5,500	1	5,500	150	-	5,650
IV	9,000	1	9,000	150	-	9,150
V	10,000	1	10,000	150	-	10,150
VI	12,000	1	12,000	150	-	12,150
VII	12,000	1	12,000	150	-	12,150
VIII	12,000	1	12,000	150	-	12,150
IX	12,000	1	12,000	150	-	12,150
X	12,000	1	12,000	150	-	12,150

Source: IAE, 2024.

There should be underlined that the wholesale price for the fresh grapes of Tamjanika Bela, as rising star at national market in last several years, is much higher (for 50% to 100%) than the price of some commercial globally recognized white wine varieties. Price difference is also supported by the fact that mentioned variety has limited share within the overall vineyards' structure in Serbia, while it cannot fully respond to the growing market demand.

During the vineyard exploitation there comes to forming of certain expenses (Table 6.). Level of annual expenses mainly depends on volume of required inputs and services, and their market price. Farm has a practice to insure its production, while the costs of insurance of established production are 10% of the planed value of production. As was underlined, vineyard maintaining generates a certain level of costs, regardless of whether any grape yields are obtained.of . Type of used inputs, applied services of mechanization, or activities done by engaged labor are generally the same in any year of vineyard exploitation. Their volume and intensity gradually increase from initial year along with the emergence and further growth of gained grape yields until they reach the maximum. After that moment they could be considered constant.

Table 6. Costs of vineyard running (in EUR, for 1 ha, production year 2023/24)

Year	Labor (EUR)	Mechanization (EUR)	Inputs (EUR)	Insurance (EUR)	Total costs (EUR)
I	800	500	1,230	-	2,530
II	1,050	800	930	150	2,930
III	1,100	800	1,092	550	3,542
IV	2,275	1,350	1,306	900	5,831
V	2,275	1,350	1,306	1,000	5,931
VI	2,275	1,350	1,306	1,200	6,131
VII	2,275	1,350	1,306	1,200	6,131
VIII	2,275	1,350	1,306	1,200	6,131
IX	2,275	1,350	1,306	1,200	6,131
X	2,275	1,350	1,306	1,200	6,131

Source: IAE, 2024.

So, in first three years, care of vineyard initiates expenses that are not followed by adequate incomes, i.e. grape yields, while in later stages of vineyard exploitation it shows its full economic potential. Production costs could be roughly grouped in three clusters, i.e. costs of used mechanization, required labor and applied inputs. For production activities there are mainly used tractors equipped by adequate side machines, trailer, water tank, or sprayer, etc. These group of costs are usually expressed for performed activity per hectare, while mechanized activities involve autumn or spring deep plowing (with vine (un)covering), corrective shallow plowing few times per vegetative season, transportation and spreading of mineral fertilizers, transportation of water and pesticides and spraying, land preparation for grassing, and grass sowing and mowing, transportation of grapes, green pruning, etc.

External labor is mainly seasonally engaged as support to farm members, for exercising specific labor-intensive activities in short period (season peaks). Engaged workers are usually locals, while their per diem represents sum usually paid for same or similar activities within the local community (generally 25 EUR/day). Workers are basically employed for activities such assoil cultivation in the row (after the seedlings planting, or seasonally as corrective measure to improve soil regime and facilitate plant growth), tying the shoots and trunks, shoots shortening, or redundant and barren shoots cutting, as well as preparing adequate solution and spraying the pesticides, manipulation under agro-chemicals, pruning (including green pruning) and disposal of pruned vine, substitution of weak or damaged seedlings, corrections after mechanized (un) covering of seedlings, maintenance of field roads and trails, broken stands repair, grape harvesting, manipulation under the fresh grapes, etc.

Considering applied inputs, they mainly involve used vine seedlings for annual substitution of weak or damaged seedlings (generally 5-10% of planted seedlings are changed in first two years), various pesticides, mineral fertilizers, banding, etc. Within the costs structure, in initial years costs of used inputs and engaged labor are at similar level but much higher than costs of mechanization, while in period of full vineyard exploitation costs of labor dominate (mainly affected by the level of costs of harvesting). In order to simplify the analysis, depreciation costs are not considered.

Observing the economic flow of investment (Table 7.), the investment generally does not generate positive cash flow in initial two years of vineyard exploitation, as in both years there is no, or there is so limited yield (income) that could cover the incurred production costs (a negative financial outcome in the first observed year was avoided as result of applied subsidies). Setting the economic flow of investment utilization (vineyard exploitation through the annual cycles in grape production) is a precondition for development of dynamic indicators used in assessing the investment economic effectiveness (Tables 8. and 9.). Indicators are calculated upon the discounted values of the net cash flow for all observed years.

According to gained indicators' values (Table 8. and Table 9.), establishment of vineyard under assumed natural, business, and administrative circumstances could be considered as economically justified business decision (in circumstances when investment does not involve land acquisition). More precisely, after 10 years of vineyard exploitation, generated NPV (2,418.87 EUR) gives strong assurance to grape producer that there could be expected significant cumulative profit over the entire lifespan of established vineyard (at least 25 to 30 years).

Table 7. Economic flow (in EUR)

No.	Element	Zero moment	Year									
			1	2	3	4	5	6	7	8	9	10
I	**Total revenue**	**0**	**7,255.0**	**1,650.0**	**5,650.0**	**9,150.0**	**10,150.0**	**12,150.0**	**12,150.0**	**12,150.0**	**12,150.0**	**12,150.0**
1.	Total income	0	7,255.0	1,650.0	5,650.0	9,150.0	10,150.0	12,150.0	12,150.0	12,150.0	12,150.0	12,150.0
II	**Total expenditures**	**22,808.5**	**3,002.5**	**2,930.0**	**3,752.8**	**6,162.9**	**6,352.9**	**6,732.9**	**6,732.9**	**6,732.9**	**6,732.9**	**6,732.9**
2.	Investment value	22,808.5	-	-	-	-	-	-	-	-	-	-
	2.1. Fixed assets	20,735.0	-	-	-	-	-	-	-	-	-	-
	2.2. PWC	2,073.5	-	-	-	-	-	-	-	-	-	-
3.	Costs without depreciation and interest	0	2,530.0	2,930.0	3,542.0	5,831.0	5,931.0	6,131.0	6,131.0	6,131.0	6,131.0	6,131.0
4.	Income tax	0	472.5	0.0	210.8	331.9	421.9	601.9	601.9	601.9	601.9	601.9
III	**Net cash flow**	**-22,808.5**	**4,252.5**	**-1,280.0**	**1,897.2**	**2,987.1**	**3,797.1**	**5,417.1**	**5,417.1**	**5,417.1**	**5,417.1**	**5,417.1**

Source: IAE, 2024.

Table 8. Derived values for Net Present Value and Internal Rate of Return (in EUR)

No.	Element	Zero moment	Year										Cumulative
			I	II	III	IV	V	VI	VII	VIII	IX	X	
0	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	Net cash flow – economic flow (columns 3-12)	-22,808.5	4,252.5	-1,280.0	1,897.2	2,987.1	3,797.1	5,417.1	5,417.1	5,417.1	5,417.1	5,417.1	**38,739.4**
2.	Discount rate (%)	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	
3.	Discount factor $(1+i)^{-n}$ while i = discount rate, n = lifespan of investment	1.0000	0.93	0.87	0.82	0.76	0.71	0.67	0.62	0.58	0.54	0.51	
4.	Present value of net cash flow (column 3-12)	-22,808.5	3,974.3	-1,118.0	1,548.68	2,278.84	2,707.28	3,609.64	3,373.50	3,152.80	2,946.54	2,753.78	**25,227.37**
5.	**NPV (columns 2-12)**	**2,418.87**											
6.	**Relative NPV [(columns 2-12) / |column 2|] > i**	**0.11 (11%)**											
7.	**IRR > i**	**8.81%**											

Source: IAE, 2024.

In addition, gained value for IRR (8.81%) is above the applied, quite conservative discount rate (7%), (used discount rate represents the rate suggested by the National Bank of Serbia (NBS, 2019)). This represents strong argument that the increase in generated accumulation of farm assets through the grape production (exploitation of vineyard just in first ten years after its establishment) will be over the calculative price of external assets at the local capital market.

In line to supposed production circumstances, gained value for the Dynamic Payback Period (Table 9.) expects that the invested financial assets in vineyard establishment will be repaid to producer through the grape production in 9 years and 1.46 months. So, within the expected productive lifespan of vineyard (up to 30 years) less than 1/3 of observed period will be used for investment covering.

Table 9. Payback period of investment in vineyard establishment (in EUR)

Years	Present value of net cash flow	Cumulative net cash flow
0	-22,809	-22,809
I	3,974	-18,834
II	-1,118	-19,952
III	1,549	-18,404
IV	2,279	-16,125
V	2,707	-13,417
VI	3,610	-9,808
VII	3,373	-6,434
VIII	3,153	-3,281
IX	2,947	-335
X	2,754	2,419

Source: IAE, 2024.

Generally, there is no uniform solution in vineyard establishment, while it could come to certain deviations in required level of investments, or differences in profitability potential per established hectare of vineyard. Although, the investment object is vineyard of wine grape variety (local variety of Tamjanika Bela) that currently shows economic advantages over the commonly grown commercial wine grape varieties at local level, some previous researches focused to vineyards establishment (basically in different geographic context, or under unlike investment circumstances) have also showed that expected payback period could be around nine years (Szabo et al., 2022), or even less, i.e. around 8.2 years (Koprivlenski, 2016), or less than five years (Naveen et al., 2010). On other hand, under specific production circumstances (level of used subsidies, achieved yields and grape prices, used grape type (for fresh consumption or processing) and variety, occurred input prices, demand intensity, etc.) payback period could be prolonged up to 12 years (Eubanks et al., 2020).

Conclusion

Observed globally, there is a constant rise in market demand for grapes and grape products (mainly wine and dried grapes), with adequate response on production side.

General trends turned to slight expansion of existing vineyards, both in a way of their modernization (renewal) or enlargement, have been also occurred in Serbia. According to mentioned, grape producers, especially those involved in wine production, are facing the dilemma which way to go, to establish the vineyards under the commercial, globally recognized grape varieties, or under the local ones. Both ways have certain benefits and disadvantages, while final decision is very difficult, especially in accordance to the fact that vineyard establishment is long-lasting investment, which does not undergo significant changes after several years.

In economic sense, no matter to chosen vine variety, planned investment (vineyard exploitation) has to show long-term sustainability. As the value of overall investment in vineyard establishment is usually significant for the producer, he is forced to exercise detail market and supply analysis (both input and final products market), to consider whether he is able to handle planed enlargement of growing areas with existing production resources (e.g. mechanization, labor, or facilities), to perceive suitability of available natural conditions (e.g. water, soil, or climate elements), to analyze all investment scenarios due to model of financing, level of used subsidies, level of vineyard equipping and quality of implemented elements, etc.

It has to be underlined, that different state subsidies for supporting grape production sector are available to producers. As very sensitive sector of agriculture that could involve several suppliers and intermediaries, level of diversity and value of offered subsidies usually have one of major roles in process of defining expected direction and level of overall sector development. Although the part of support turned to vineyards and processing facilities establishment could be considered as satisfactory, segment that has to support annual grape production at the micro level, unfortunately sounds as relatively small. So, level of subsidies assumes to be certain reflection of official recognition of the viticulture sector, or verification of its strategic importance at national or even regional level.

In accordance to gained results of investment analysis (appliance of dynamic methods for assessment of economic effectiveness of investment), and under the assumed natural, administrative and production preconditions, grape producers would make economically right decision if they invest in enlargement of vineyard under white vine variety Tamjanika Bela (investment does not involve land acquisition). Derived values for NPV (2,418.87 EUR), IRR (8.81%), and DPP (9 years and 1.46 months) are convincing enough to justify further viability of grape production at observed farm.

Further research steps could imply sensitivity of investment in vineyard establishment due to the structure and level of used subsidies, or comparing effects of investment in vineyard establishment under commercial and local vine varieties, or enlarging the investment with land acquisition, or assessing the investment in entire process of wine making.

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Conflict of interests

The authors declare no conflict of interest.

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THE IMPACT OF EDUCATION AND ENTREPRENEURIAL SKILLS ON THE FINANCIAL PERFORMANCE OF AGRICULTURAL ENTREPRENEURS

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A B S T R A C T

In today's business environment, the agricultural sector faces numerous challenges, including climate change, market fluctuations, and the need for innovation. Education and entrepreneurial skills are key factors for improving the business performance of agricultural entrepreneurs. The aim of this research is to examine the impact of education and entrepreneurial skills on the financial success of agricultural entrepreneurs. The study was conducted on a sample of 567 entrepreneurs from the agribusiness sector, using three key variables: entrepreneurial education, entrepreneurial skills, and financial performance. The results showed that both education and skills have a statistically significant and positive impact on the financial performance of entrepreneurs, with the influence of skills being more pronounced. Strategic decision-making, resource management, and the ability to make quick decisions in complex situations proved to be especially important competencies.

Introduction

Agriculture represents one of the most important sectors in the economies of developing countries. Agriculture as a complementary activity represents a particular

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potential for the growth of the surrounding rural areas and the improvement of the living standard of the domicile population. (Milićević et al., 2022). The role of small and medium-sized entrepreneurs in agribusiness is becoming increasingly significant, both due to their flexibility and their ability to respond more quickly to changes in the market and technological environment. However, many of them face challenges in the areas of management, financial planning, and innovation. According to the OECD (2020), education and entrepreneurial skills are key determinants of business success in agriculture.

Vujičić et al. (2019), analyzing the level of awareness about healthy eating and the consumption of organic products among the student population in Serbia, concluded that education plays a crucial role in shaping consumer behavior and can potentially stimulate entrepreneurship in the organic agriculture sector.

Many authors (Agrawal, 2016; Zakić, Bugarčić, Milovanović, 2017; Pavić, 2019; Milanović, 2020; Šormaz, 2021; Vemić, Hrechyshkina, Samakhavets, 2022; Puška, Štilić, 2022; Stojković Hadži Kastratović, Stanković, 2022; Šćepanović, Stevanović, Šćepanović, 2023) emphasize the importance of technological advancement, innovation, and education across all areas of business activity.Krmpot, Krmpot, and Janković (2025) note that, at the global level, technological progress has reached an exceptionally high level with further improvement potential, and that continuous training is essential even though the workforce has reached the highest level of education ever recorded.Cindrić, Anđelković, and Chiro (2024) state that lifelong learning is evolving into lifelong education, and that the skills required by employees are shifting toward the development of both professional and soft skills, along with their enhancement and transformation. Numerous studies have shown a strong correlation between the level of education and the ability of entrepreneurs to manage their businesses and risks (Becker, 1993; Van der Sluis et al., 2008). In the agricultural sector, both formal and informal education enable entrepreneurs to acquire knowledge about new technologies, market trends, and regulatory frameworks. According to FAO (2021), farmers with higher education levels are more likely to adopt innovations and successfully diversify their production. According to Milanović, Nikitović, and Vujičić (2020), the sustainable success of agricultural holdings largely depends on the development of knowledge, product quality, financial management, and the application of innovations, which underscores the key role of education and entrepreneurial skills in modern agriculture.In addition to education, entrepreneurial skills such as leadership, decision-making, team and financial management are crucial for the success of agricultural businesses (Man et al., 2002). In the dynamic environment of agribusiness, the ability to recognize opportunities, solve problems, and adapt to the market directly influences the competitiveness and financial performance of enterprises.

.Literature review

The theoretical foundation of this research is based on the human capital theory (Becker, 1964) and the resource-based view of the firm (Barney, 1991).

Education and skills are regarded as intangible resources that contribute to competitive advantage and financial success. Education and entrepreneurial skills represent key components of human capital and are the subject of numerous studies in the fields of economics, management, and rural development. Understanding the impact of education on economic outcomes is grounded in the concept of human capital developed by Becker (1964), who argued that investment in individuals' education and training leads to increased productivity and economic growth. This theory emphasizes that educated individuals possess more knowledge, skills, and the ability to make better business decisions, manage risks, and implement innovations, all of which directly contribute to their financial performance.Numerous studies have confirmed that education has a positive impact on entrepreneurial performance. Van der Sluis, Van Praag, and Vijverberg (2008) concluded that there is a statistically significant, albeit moderate, positive effect of education on entrepreneurial success. Similarly, Davidsson and Honig (2003) emphasize the importance of formal education during the early stages of a business venture, while informal education and prior experience play a greater role in later phases of the business. In rural and agricultural environments, education can play an even more important role as it contributes to the modernization of production, better application of agronomic measures, and more efficient use of resources (OECD, 2020). Simonović (2016), analyzing the role of public advisory services in Serbian agriculture, emphasizes the importance of education and professional training of farmers for improving production and financial success.The specificity of the agricultural sector lies in the complexity of managing production cycles, the dependence on external factors such as weather conditions and market fluctuations, and the need for multifunctional knowledge. According to a study conducted by the FAO (2017), there is a clear link between the education of farmers and their ability to diversify production, adopt innovative technologies, and gain better market access. Likewise, farmers with higher education levels are more likely to use information and communication technologies and access funding and subsidies.

In addition to education, entrepreneurial skills are gaining increasing attention in the literature. These include competencies such as leadership, strategic decision-making, communication, negotiation, innovation, and team management. Man, Lau, and Chan (2002) developed a model of entrepreneurial competencies that highlights the importance of skill-based functional attributes for the competitiveness of small and medium-sized enterprises. These competencies not only support better business decision-making but also enable entrepreneurs to recognize opportunities, manage resources more efficiently, and adapt to market changes.In the agricultural sector, skills are particularly important due to the need to combine technical knowledge with managerial and business abilities. Research conducted by Mishra, El-Osta, and Shaik (2010) in the United States showed that farmers with more advanced business skills are more likely to achieve positive financial outcomes, regardless of farm size. Similarly, Njoku and Odii (1991) in their study emphasize that financial literacy and planning ability are key factors for the profitability of small agricultural holdings. Research conducted by EIP-

AGRI (2016) highlights the importance of training farmers in business management, innovation, and digital tools as a prerequisite for the sustainable development of rural areas. Planning is a key factor in the development of innovation in small and medium-sized enterprises, as it allows for efficient resource use and timely decision-making that fosters innovative activities (Vujičić, Ravić & Nikolić, 2021).A combination of formal education and practical skills has proven to be the most effective model for achieving financial stability among entrepreneurs. This is confirmed by research conducted by Martin, McNally, and Kay (2013), which found that training programs combining theoretical knowledge and practical skills have a significant positive effect on revenue growth and the long-term survival of businesses. Additionally, Kreft and Sobel (2005) in their study emphasize that regions with a higher number of highly educated entrepreneurs experience faster economic growth and greater resilience to crises, further highlighting the importance of human capital.From a policy perspective, the European Union and FAO promote the development of entrepreneurial education in rural areas as part of a strategy to increase competitiveness and employment. According to a European Commission report (2016), the introduction of specialized educational programs within rural development, along with support for incubators and training centers, significantly contributes to strengthening the capacities of the local population to start and sustain successful agribusinesses. In Serbia, similar initiatives have been recognized through IPARD program measures, but their effectiveness depends on the integration of education and mentorship into local development strategies.

It should also be noted that psychological aspects, such as self-confidence, motivation, and risk readiness, can influence business success. Zhao, Seibert, and Lumpkin (2010) point out that entrepreneurs with high levels of self-confidence and intrinsic motivation are more successful in applying acquired knowledge and skills. In rural environments, where support systems are often limited, the internal resources of individuals become even more important.

Materials and methods

In order to examine the impact of education and entrepreneurial skills on the financial performance of entrepreneurs, an empirical study was conducted on a sample of 567 respondents in the Republic of Serbia, during the period from September 10, 2024, to March 15, 2025.The research was conducted using a structured questionnaire. A five-point Likert scale was used to measure respondents’ attitudes across all variables.

In today’s business environment, particularly in the agricultural sector, education and the development of entrepreneurial skills have become key factors of competitiveness and financial sustainability. The main problem addressed in this research lies in analyzing the impact that formal education and acquired entrepreneurial skills have on the financial performance of agricultural entrepreneurs.

The following research objectives were set:

- To determine whether entrepreneurial education has no impact or has an impact on entrepreneurial finances.
- To determine whether entrepreneurial skills have no impact or have an impact on entrepreneurial finances.

The ultimate research objective is:

- To determine whether entrepreneurial education and skills, together or separately, have an impact on entrepreneurial finances.

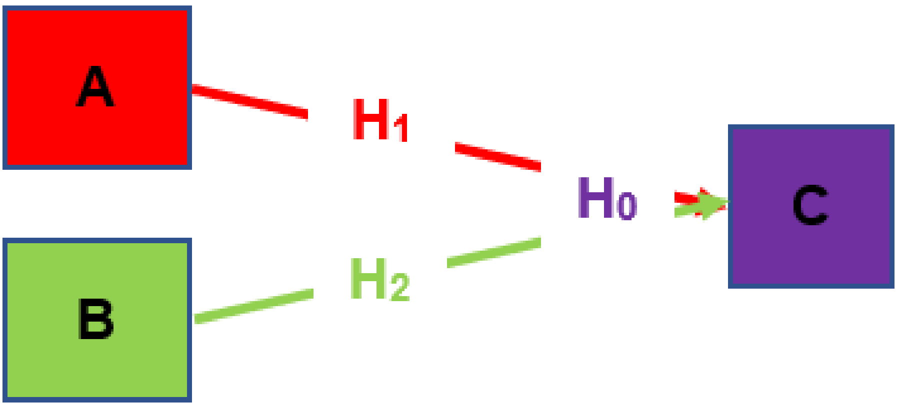
The auxiliary hypotheses of the research are as follows:

- H01: Entrepreneurial education does not influence entrepreneurial finances.
- H11: Entrepreneurial education influences entrepreneurial finances.
- H02: Entrepreneurial skills do not influence entrepreneurial finances.
- H21: Entrepreneurial skills influence entrepreneurial finances.

The main hypotheses of the research are:

- H0: Entrepreneurial education and skills do not influence entrepreneurial finances.
- H1: Entrepreneurial education and skills influence entrepreneurial finances.

Figure 1. Theoretical research model



Source: Authors

Variable A – Entrepreneur's education
Variable B – Entrepreneur's skills
Variable C – Entrepreneur's finances

According to the descriptive data in Table 1, the following conclusions can be drawn:

- The sample is almost evenly divided by gender, with a slightly higher proportion of male respondents. The gender structure is relatively balanced: males – 296 (52.21%) and females – 271 (47.79%).

Table 1. Descriptive statistics

Respondent's gender	**N**	**% of Total**
male	296	52,21
female	271	47,79
Respondent's age	**N**	**% of Total**
(18-35)	91	16,05
(36-55)	329	58,03
(>55)	147	25,93
Respondent's education	**N**	**% of Total**
primary / secondary school	371	65,43
college/ faculty	196	34,57
Total	567	100,00%

Source: Authors

The largest number of respondents falls within the age group of 36–55 years, which accounts for more than half of the sample. This indicates that the majority are individuals in their mature working age, which may influence their attitudes, habits, and priorities: ages 18–35: 91 (16.05%), 36–55: 329 (58.03%), and over 55: 147 (25.93%).

The majority of the sample consists of respondents with a lower level of formal education (primary or secondary school). Therefore, the research results reflect the views of the general population rather than academically educated individuals: primary/secondary school: 371 (65.43%), college/faculty: 196 (34.57%).

The structure of the sample suggests that the research covered a broad population, with an emphasis on middle-aged and less formally educated individuals.

Results

The number of statements defined for each variable in the proposed research model is six. A five-point Likert scale of attitudes was applied to each statement for all variables. The number of respondents in the study was 567. Based on these data, the significance of factor loadings for each defined variable is 0.35. In *Table 2*, the values of Cronbach's alpha coefficient are provided for all statements of each variable and for each sub-variable. The conclusions are as follows:

- All sub-variables (A1–A6) have α values between 0.82 and 0.86, indicating high internal consistency. The total α for Entrepreneur's Education (A) is 0.9306, which is considered excellent consistency. The scale for this variable is highly reliable.
- Sub-variables (B1–B6) range between 0.86 and 0.91, also demonstrating good stability and interrelation. The total α for Entrepreneurial Skills (B) is 0.8727,

which qualifies as good internal consistency. This variable has a high degree of reliability, although slightly lower than that of Entrepreneur's Education (A).

- Sub-variables (C1–C6) range from 0.82 to 0.90, all within a strong reliability range. The total α for Entrepreneur's Finances (C) is 0.8495, which also falls under the category of good consistency. This variable is also reliable, though not as highly as Entrepreneur's Education (A).

All three variables—Entrepreneur's Education (A), Entrepreneurial Skills (B), and Entrepreneur's Finances (C)—have high Cronbach's alpha values, indicating that the instruments used to measure these variables are highly reliable.

Table 2. Sizes of Cronbach's alpha coefficient

Variable	**Sub variable**	**Cronbach`s (α)**	**Internal consistency**
A - Entrepreneur's education	A1 - Entrepreneurship education is key to achieving business success	0.8379	
	A2 - Entrepreneurs with higher education better manage the finances of their companies	0.8634	
	A3 - Education of entrepreneurs has a positive effect on making strategic decisions in entrepreneurship	0.8201	
	A4 - Education of entrepreneurs contributes to their ability to adapt to market changes	0.8237	
	A5 - A higher level of education of entrepreneurs increases their competitiveness on the market	0.8245	
	A6 - The education of entrepreneurs has a significant impact on the ability to implement new business strategies	0.8275	
Total variable A - Entrepreneur's education		0.9306	excellent
B - Entrepreneurial skills	B1 - An entrepreneur's team management skills directly affect the company's financial results	0.8826	
	B2 - Developed entrepreneurial skills enable entrepreneurs to better manage resources	0.8693	
	B3 - Entrepreneur's problem-solving skills improve business performance	0.8696	
	B4 - Entrepreneurs with better communication skills make business contacts and cooperation more easily	0.9129	
	B5 - Developed skills of entrepreneurs in strategic planning contribute to better business organization	0.8908	
	B6 - Skills in making quick and efficient decisions improve the financial stability of entrepreneurs	0.8747	
Total variable B - Entrepreneurial skills		0.8727	good

Variable	Sub variable	Cronbach`s (α)	Internal consistency
C - Entrepreneur's finances	C1 - The state of the entrepreneur's finances depends on their ability to properly manage costs	0.8470	
	C2 - Good financial management of entrepreneurs allows them greater stability and profitability	0.8342	
	C3 - Entrepreneurs with better financial planning have better chances for long-term business sustainability	0.9010	
	C4 - The financial stability of an entrepreneur is crucial for the growth and development of the company	0.8572	
	C5 - Entrepreneurs with better financial strategies attract investments more easily	0.8314	
	C6 - Entrepreneurs' highly developed financial skills contribute to their ability to effectively manage business risks	0.8247	
Total variable C- Entrepreneur's finances		0.8495	good

Source: Authors

Descriptive statistics of respondents for all proposed statements are presented in Table 3.

Table 3. Descriptive statistics for all claims

Claim	Mean	Std Dev	Std Err	Variance
$\mathbf{A_1}$	4.2874779541	0.8302 380491	0.0348667207	0.6892952182
$\mathbf{A_2}$	4.2169312169	0.8779970986	0.0368724123	0.7708789052
$\mathbf{A_3}$	4.0705467372	0.9239435095	0.0388019802	0.8536716087
$\mathbf{A_4}$	4.2698412698	0.8834103986	0.0370997495	0.7804139324
$\mathbf{A_5}$	4.1746031746	0.8814081707	0.0370156639	0.7768803635
$\mathbf{A_6}$	4.2151675485	0.9582721117	0.0402436460	0.9182854401
$\mathbf{B_1}$	4.4038800705	0.8495597112	0.0356781543	0.7217517029
$\mathbf{B_2}$	4.4162257496	0.8082729517	0.0339442734	0.6533051645
$\mathbf{B_3}$	4.4126984127	0.8078989146	0.0339285653	0.6527006562
$\mathbf{B_4}$	3.8342151675	1.0752731806	0.0451572290	1.1562124130
$\mathbf{B_5}$	2.5449735450	0.7115940085	0.0298841394	0.5063660329
$\mathbf{B_6}$	4.3209876543	0.9394948712	0.0394550760	0.8826506129
$\mathbf{C_1}$	4.2804232804	0.8861046473	0.0372128973	0.7851814460
$\mathbf{C_2}$	4.2151675485	1.0120733705	0.0425030865	1.0242925072
$\mathbf{C_3}$	3.7178130511	1.2057357681	0.0506361427	1.4537987424
$\mathbf{C_4}$	4.1481481481	1.0343530058	0.0434387432	1.0698861406

Claim	Mean	Std Dev	Std Err	Variance
C_5	4.3209876543	0.8912414882	0.0374286244	0.7943113903
C_6	4.2045855379	0.9494912880	0.0398748860	0.9015337060

Source: Authors

The following conclusions can be drawn:

- For the variable Entrepreneur's Education (A): Average scores (Mean): All range between 4.07 and 4.29, indicating that participants generally rated the statements within this variable highly.Highest mean: A1 (4.29).Lowest mean: A3 (4.07).Variances and standard deviations are moderate, which means that responses are not widely dispersed.Statements in group A were rated highly and consistently—with lower variability.The results are consistent with the excellent Cronbach's alpha coefficient (0.9306).
- For the variable Entrepreneurial Skills (B):Average scores: Most are above 4.3, indicating that participants generally rated the statements positively—except for statement B5, which stands out significantly with an average score of 2.54.B5 – Outlier: The low score and smaller standard deviation suggest that participants agree the statement is either negative or not applicable.B4 has a slightly lower score (3.83), but it is not as drastic as B5.Overall, the scores are high, but statement B5 represents an exception that requires further analysis—it may refer to a problematic issue or be interpreted differently.
- For the variable Entrepreneur's Finances (C):Average scores range from 3.72 to 4.32, indicating moderate to high agreement with the statements.The lowest average score: C3 (3.72) – also has the highest standard deviation (1.21), showing considerable disagreement among respondents.The highest average score: C5 (4.32).Although the statements were generally rated well, C3 reflects differing opinions among respondents, which may suggest the topic is particularly specific or the statement was ambiguously worded.

The variable Entrepreneur's Education (A) shows a high level of agreement with the statements and low variability—indicating a reliable and consistent variable.The variable Entrepreneurial Skills (B) reflects a generally positive perception, but statement B5 significantly deviates, representing a potential point for further interpretation or revision. The variable Entrepreneur's Finances (C) demonstrates moderate to high agreement, but statement C3 shows high variance, possibly due to different understandings of the statement or divided opinions.

Table 4 presents the summary descriptive statistics for all statements of the variables. The analysis of the aggregate descriptive indicators suggests that respondents generally rated all three groups of statements positively(Entrepreneur's Education**,** Entrepreneurial Skills**,** and Entrepreneur's Finances**)**.The variable Entrepreneur's

Education (A) recorded the highest average score and the lowest variability among responses, indicating a high level of agreement and consistency in attitudes. The variable Entrepreneurial Skills (B**)** has the lowest average value, partly due to one particularly low-rated statement (B5), while the group Entrepreneur's Finances (C) shows solid agreement but somewhat greater dispersion in opinions.These results support the previous findings from the Cronbach's alpha analysis and contribute to the validation of the instrument's reliability.

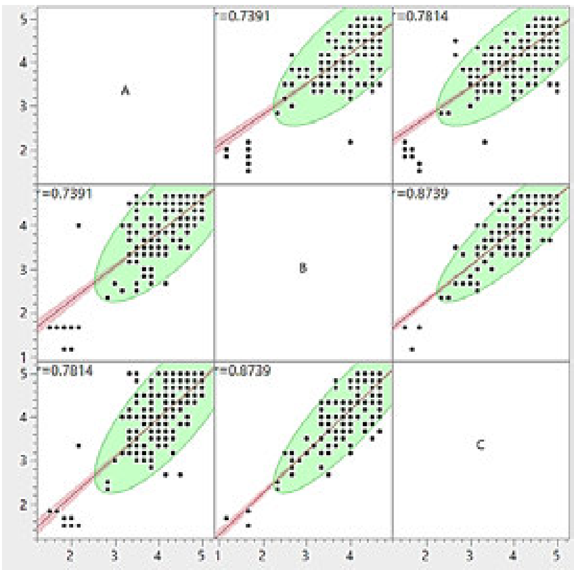
Table 4. Descriptive statistics for variables

Claim	Mean	Std Dev	Std Err	Variance
A	4.2057613169	0.6825192107	0.0286631126	0.4658324730
B	3.9888300999	0.7139261041	0.0299820782	0.5096904821
C	4.1478542034	0.7823878467	0.0328572011	0.6121307427

Source: Authors

Figure 2 shows the Pearson correlation values. All correlations are high and positive (all > 0.7), indicating that the variables are strongly related to each other. The strongest correlation is between **Entrepreneurial Skills** and **Entrepreneur's Finances** (0.874), suggesting that responses to the statements in these variables are very similar or that they measure similar constructs. The variables **Entrepreneur's Education** and **Entrepreneurial Skills** are somewhat less strongly correlated (0.739), but still exhibit a strong relationship.

Figure 2. Correlation of the formed model



Source: Authors

Multivariate analysis confirms that the statements for all three variables are highly correlated, with the strongest relationship observed between the variables entrepreneurial skills and entrepreneur's finances. The overall Cronbach's alpha (0.9218) indicates excellent reliability of the questionnaire as a whole. Although all three variables contribute to internal consistency, the exclusion of the variable entrepreneur's education results in a slight increase in overall reliability, suggesting that the statements from the entrepreneur's education variable may be somewhat less correlated with the rest of the scale. Nevertheless, all alpha values remain high, confirming that this is a highly reliable instrument. These results are further supported by descriptive statistics, which show stable and positive responses with relatively small deviations.

Correlation and regression analysis of variables A and C

The regression model that includes the variable entrepreneur's education (table 5) successfully explains 61.06% of the variance in the dependent variable entrepreneur's finances, which can be considered a very satisfactory result. The adjusted coefficient of determination (0.6099) further confirms the model's stability, while the low RMSE (0.49) indicates a high degree of accuracy in predicting the dependent variable entrepreneur's finances.

Table 5. Model evaluation for variables A and C

RSquare	0.610565
RSquare Adj	0.609875
Root Mean Square Error	0.488679
Mean of Response	4.147854
Observations (or Sum Wgts)	567

Source: Authors

The results of the ANOVA test (table 6) confirm that the model is statistically significant (P<0.0001), which means that the predictor variable Entrepreneur's education explains a significant amount of variance in the dependent variable Entrepreneur's finances. The high F Ratio (885.8184) suggests that the model is very effective in explaining the variance, while the low p-value (<0.0001) indicates that these results are unlikely to be due to chance. The statistical significance is reported as [F(1,565)=885.8184, p<0.0001].

Table 6. ANOVA for variables A and C

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	211.53989	211.540	885.8184
Error	565	134.92611	0.239	**Prob > F**
C. Total	566	346.46600		<.0001

Source: Authors

The regression results (table 7) indicate that the variable Entrepreneur's education (A) has a statistically significant impact on the dependent variable. The coefficient of 0.8957 means that an increase of one unit in Entrepreneur's education leads to an increase of approximately 0.90 units in the dependent variable Entrepreneur's finances (C). The high standardized Beta (0.7814) shows that variable A is a key component of the model, while VIF=1 confirms that there are no multicollinearity issues among the predictors. The results further support the validity and reliability of the model. Based on this data, the auxiliary alternative hypothesis **H11: Entrepreneur's education affects Entrepreneur's finances can be confirmed**.

Table 7. Contribution coefficients for variables A and C

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Intercept	0.380663	0.128227	2.97	0.0031	0	.
A	0.8957216	0.030095	29.76	<.0001	0.781386	1

Source: Authors

Based on the data from the previous table, a regression equation can be formed (formulas 1 and 2), as follows:

$y = 0.380663 + 0.8957216 \cdot x_1$ (1)
or
$C = 0.380663 + 0.8957216 \cdot A$ (2)

In the appendix (figure 3), the regression equation diagram is presented for the variables Entrepreneur's education (A) and Entrepreneur's finances (C).

Correlation and Regression Analysis of Variables B and C

The model with the independent variable Entrepreneurial skills (B) (table 8) explains 76.36% of the variance in the dependent variable Entrepreneur's finances (C), which is a very high result. An RMSE of 0.38 indicates that the model's predictions are highly accurate, and the adjusted R^2 confirms that the model is not overfitted. Overall, this model provides a good balance between explaining variance and prediction precision of the dependent variable Entrepreneur's finances (C).

Table 8. Evaluating the model for variables B and C

RSquare	0.76363
RSquare Adj	0.763212
Root Mean Square Error	0.380717
Mean of Response	4.147854
Observations (or Sum Wgts)	567

Source: Authors

The results of the ANOVA test (Table 9) confirm that the model with the variables Entrepreneurial skills (B) *and* Entrepreneur's finances (C) is statistically significant ($P<0.0001$), indicating that the variable Entrepreneurial skills explains a significant portion of the variance in the dependent variable Entrepreneur's finances. The high F-ratio (1825.322) suggests that the model is highly effective in explaining the variance, while the p-value of less than 0.0001 confirms that these results are not due to chance. The statistical significance is reported as [$F(1,565)=1825.322$, $p<0.0001$].

Table 9. ANOVA for variables B and C

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	264.57189	264.572	1825.322
Error	565	81.89411	0.145	**Prob > F**
C. Total	566	346.46600		<.0001

Source: Authors

The variable Entrepreneurial skills (B) is statistically significant (Table 10) with a coefficient of 0.9577, which means that an increase of one unit in the variable Entrepreneurial skills (B) leads to an increase of 0.9577 units in the dependent variable Entrepreneur's finances (C). The standardized Beta coefficient of 0.8739 indicates that the variable Entrepreneurial skills (B) has a very strong positive impact on the dependent variable Entrepreneur's finances (C), while VIF=1 confirms that there is no multicollinearity with other predictors. Based on these data, the auxiliary alternative hypothesis **H21: Entrepreneurial skills (B) affects Entrepreneur's finances (C) can be confirmed.**

Table 10. Contribution coefficients for variables B and C

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Intercept	0.3279198	0.090828	3.61	0.0003	0	.
B	0.9576578	0.022415	42.72	<.0001	0.873859	1

Source: Authors

Based on the data from the previous table, the regression equation can be formed as follows (formulas 3 and 4):

$y = 0.3279198 + 0.9576578 \cdot x_2$ (3)
or
$C = 0.3279198 + 0.9576578 \cdot B$ (4)

In the appendix, Figure 4 presents the regression equation diagram for the variables Entrepreneurial skills (B) and Entrepreneur's finances (C).

Multiple correlation and regression analysis for the variable Entrepreneur's finances (C)

The model with the independent variables Entrepreneur's education (A) and Entrepreneurial skills (B) (Table 11) explains 80.41% of the variance in the dependent variable Entrepreneur's finances (C), which is a very high result. The RMSE of 0.35 indicates that the model's predictions are very precise, and the adjusted R^2 confirms that the model is not overfitted. The results suggest that the model with the independent variables Entrepreneur's education (A) and Entrepreneurial skills (B) provides excellent predictions and has strong predictive power for the dependent variable Entrepreneur's finances (C).

Table 11. Evaluating the model

Rsquare	0.804117
RSquare Adj	0.803422
Root Mean Square Error	0.346888
Mean of Response	4.147854
Observations (or Sum Wgts)	567

Source: Authors

The results of the ANOVA test (Table 12) confirm that the model with the variables Entrepreneur's education (A), Entrepreneurial skills (B), and Entrepreneur's finances (C) is statistically significant ($P<0.0001$), with a high F Ratio of 1157.635, indicating that the model explains the variance in the dependent variable Entrepreneur's finances (C) very well. The model with the independent variables Entrepreneur's education (A) and Entrepreneurial skills (B), and the dependent variable Entrepreneur's finances (C), is much better at explaining the variance compared to the error, which means that these variables have a significant influence on the dependent variable Entrepreneur's finances (C). The statistical significance rating is provided in Table 12 and is [$F(2,564)= 1157.635$, $p<0.0001$].

Table 12. ANOVA

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	2	278.59921	139.300	1157.635
Error	564	67.86679	0.120	**Prob > F**
C. Total	566	346.46600		<.0001

Source: Authors

In the model with the independent variables Entrepreneur's education (A) and Entrepreneurial skills (B) (Table 13), both have a statistically significant impact on the dependent variable Entrepreneur's finances. However, the independent variable Entrepreneurial skills (B) ($\beta = 0.6531$) has twice the standardized impact compared to the independent variable Entrepreneur's education (A) ($\beta = 0.2987$), indicating that Entrepreneurial skills (B) is the dominant predictor. There are no significant issues with multicollinearity ($VIF \approx 2.2$). The model clearly shows that both independent variables, Entrepreneur's education (A) and Entrepreneurial skills (B), are relevant, but the influence of Entrepreneurial skills (B) is significantly stronger. Based on this data, the main alternative hypothesis **H1: Entrepreneur's education (A) and Entrepreneurial skills (B) influence Entrepreneur's finances (C) can be confirmed**

Table 13. Contribution coefficients

Term	Estimate	Std Error	t Ratio	Prob>|t|	Std Beta	VIF
Intercept	-0.147146	0.093728	-1.57	0.1170	0	.
A	0.3424079	0.031714	10.80	<.0001	0.298701	2.2037321
B	0.7157272	0.030318	23.61	<.0001	0.653098	2.2037321

Source: Authors

Based on the data from the previous table, a multiple regression equation can be formulated (formulas 5 and 6), as follows:

$$y = -0.147146 + 0.3424079 \cdot x_1 + 0.7157272 \cdot x_2 \quad (5)$$

or

$$C = -0.147146 + 0.3424079 \cdot A + 0.7157272 \cdot B \quad (6)$$

In the appendix, Figure 5 presents the diagram of the multiple regression equation for the variable C.

Discussions

Based on the provided tables, which represent the results of three linear regression models, a detailed discussion of the findings can be conducted. Each table shows the impact of the independent variables Entrepreneur's education (A) and Entrepreneurial skills (B) on the dependent variable Entrepreneur's finances (C), as follows:

- The variable Entrepreneur's education (A) has a strong and statistically significant positive effect on the dependent variable ($p<0.0001$). A high t-ratio and a high standardized coefficient indicate that Entrepreneur's education (A) is one of the key predictors. A VIF of 1 shows that there is no multicollinearity.
- The variable Entrepreneurial skills (B) has an even stronger and statistically significant positive effect on the dependent variable than A (compared to the first model). The values of both the coefficient and the standardized beta are higher, indicating that Entrepreneurial skills (B) may be a more important predictor. A VIF of 1 also rules out multicollinearity.
- When both variables, Entrepreneur's education (A) and Entrepreneurial skills (B), are included in the same model, both remain statistically significant, but the influence of Entrepreneur's education (A) decreases in terms of both the coefficient value and the standardized beta. This suggests that B has a dominant effect in this model. The VIF slightly increases (2.2), but remains within acceptable limits (<5), indicating moderate but not problematic collinearity.

Both variables, Entrepreneur's education (A) and Entrepreneurial skills (B), have a positive and statistically significant impact on the dependent variable. Entrepreneurial skills (B) has a stronger influence than Entrepreneur's education (A), both in individual models and in the combined model. In the joint model, the effect of Entrepreneur's education (A) diminishes, which may suggest that Entrepreneur's education (A) and Entrepreneurial skills (B) share some variance, though not to a degree that would cause problems in the model. The intercept in the joint model is not statistically significant ($p=0.117$), which is not uncommon in models with multiple predictors.

Conclusions

Based on the first obtained regression equation, it can be concluded that the education of entrepreneurs has a strong and positive impact on their financial position. In other words, the more educated the entrepreneurs are, the more successful they tend to be in managing the finances of their businesses. This confirms the importance of investing in education and professional development of entrepreneurs as a strategy to improve their business performance and financial health.

Based on the second obtained regression equation, it can be concluded that entrepreneurial skills are a key factor for improving the financial condition of entrepreneurs. Although education can also play an important role (as shown in the previous equation related to education), entrepreneurial skills have an even stronger and more direct influence on their finances. This means that the development and enhancement of these skills should be a priority for every entrepreneur seeking to improve business performance.

Based on the third obtained regression equation, it can be concluded that the education of entrepreneurs has a positive but smaller impact on their finances. Each additional level of education increases the financial performance of entrepreneurs by 0.3424 units, indicating that education contributes to financial success, but not as significantly as skills. Entrepreneurial skills have a substantially stronger influence on finances—each improvement in skills increases finances by 0.7157 units. Therefore, developing and enhancing entrepreneurial skills (e.g., business management, strategic decision-making, team leadership) has a strong impact on financial success. Together, education and skills can significantly improve the financial status of entrepreneurs, but skills have a greater influence. This suggests that entrepreneurs with well-developed managerial and business skills, combined with education, have better chances of achieving improved financial outcomes. Entrepreneurs should focus their efforts on further developing their skills, as this has the greatest impact on their business success.

Conflict of interests

The authors declare no conflict of interest.

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APPENDIX

Figure 3. Diagrams of regression equations AC

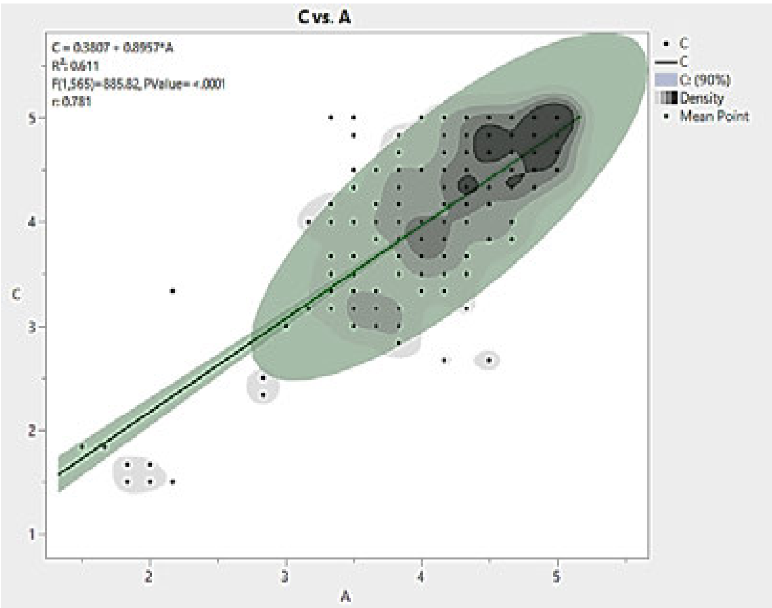

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Figure 4. Diagrams of regression equations BC

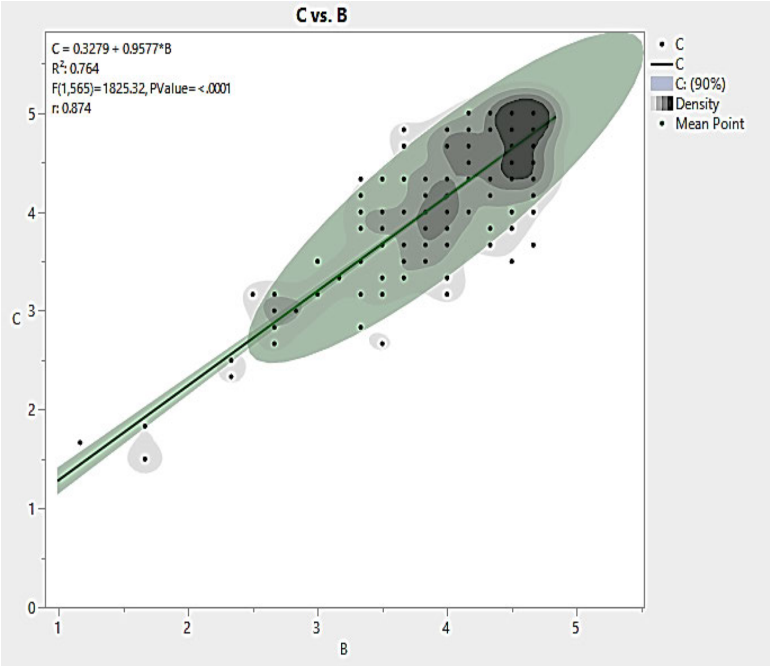

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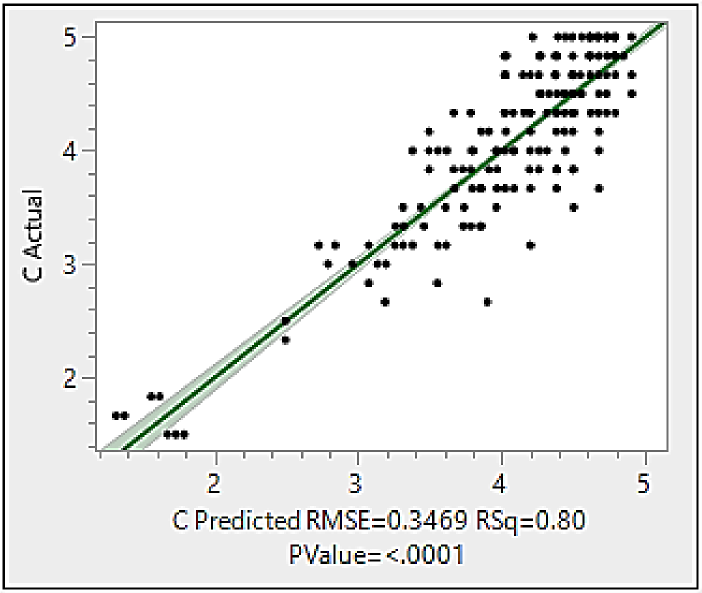
Figure 5. Multiple regression equation plot for variables AB & C



Source: Authors

RESEARCH ON THE MEDIATING EFFECTS OF RURAL ROADS ON AGRICULTURAL DEVELOPMENT

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ABSTRACT

Rural roads, regarded as the "entrepreneurial capital" of agricultural modernization, serve as critical infrastructure for connecting urban and rural resources and ensuring the smooth circulation of agricultural products. Their level of development profoundly influences rural economic vitality and farmers' well-being. However, financial constraints in rural areas necessitate the strategic optimization of investment to maximize both the direct benefits and indirect impacts of roads. Based on a composite multiple mediating effect model, this study reveals that rural roads drive agricultural growth through dual pathways of "direct empowerment" and "indirect catalysis." The results indicate that rural roads directly break the "honeycomb" spatial lock of farmland by promoting land consolidation (e.g., returning farmland to cultivation, merging small plots into larger fields), thereby optimizing spatial layout and establishing a core pathway of "road construction → land transfer → output growth." Simultaneously, rural roads significantly enhance agricultural mechanization, accelerating the transition toward large-scale and intensive production, while jointly with land optimization, reshaping the rural employment structure.

Introduction

Rural roads serve as a critical link for agricultural production and market circulation. Beyond their fundamental role in facilitating the transport of agricultural products, they play a pivotal role in high-quality farmland development, agricultural modernization, rural revitalization, and urban-rural integration. From a multidimensional perspective, the impact of rural roads on agricultural development can be categorized into direct and indirect effects, operating through multiple transmission pathways to ultimately

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support high-quality agricultural growth. This study aims to systematically investigate the causal mechanisms by which rural road development affects agricultural growth.

Rural roads have a significant direct impact on the economic development of agricultural regions (Banerjee and Duflo et al., 2020). They enhance the efficiency of agricultural product transportation(Lu and Li, 2022), enabling faster market access(Aggarwal, 2018; Zhou and Duan et al., 2021), reducing losses, and increasing agricultural output value and farmers' income(Donaldson, 2018; Lu and Zhao et al., 2022). Enhanced transportation conditions also help lower transport and labor costs, promote the optimization of industrial structures, improve production efficiency, and strengthen market competitiveness. Furthermore, rural roads facilitate the flow of agricultural capital, promote modernization, and activate rural labor markets. These dynamics contribute to technological spillover effects, foster the coordinated development of related industries, and create a virtuous cycle that supports sustained regional economic growth.

Rural roads also exert important indirect effects on agricultural modernization and regional economic development. Improved transportation infrastructure enhances the operational efficiency of agricultural machinery(Sotelo, 2019; Teng and Han, 2020) and supports the upgrading of farmland facilities(Bacior and Prus, 2018), thereby boosting productivity and income. It also facilitates land transfer and consolidation, contributing to the optimization of land use and the development of modern agricultural systems. Moreover, improved road networks expand employment opportunities, promote labor mobility, narrow the urban–rural income gap, and attract both capital and talent to rural areas(Zhang and Xu, 2024). These factors accelerate the dissemination of agricultural technology and support economic upgrading. Rural roads also promote the growth of rural tourism and related industries, thereby enhancing rural economic vitality. In parallel, they improve access to public services such as education and healthcare, contributing to poverty reduction. Rural roads serve as key drivers of balanced regional economic development by fostering industrial clustering and strengthening urban–rural linkages(Arbués and Baños et al., 2015).

However, existing research has predominantly focused on higher-grade highways, while rural roads have received comparatively less attention due to their limited service scope, difficulty in quantifying economic benefits, and heavy reliance on government investment. This research gap has left rural roads relatively disadvantaged in resource allocation, preventing the full realization of their potential value. Therefore, scientifically evaluating the role of rural road construction in stimulating regional economic development along their corridors can provide a critical basis for designing more efficient investment strategies and development plans.

Based on the above studies, this research proposes the following working hypotheses: first, rural road construction can significantly enhance agricultural output; second, rural roads exert significant indirect effects on regional economic and social development through the mobilization of capital, technology diffusion, land optimization, and labor mobility; third, rural road development generates a chain-mediated mechanism, producing continuous indirect impacts on agricultural development and regional economic growth.

Using Shaoguan City, Guangdong Province, as a case study, this research employs a composite multiple mediating effects approach to analyze how rural roads improve public service systems, promote rural revitalization, reduce poverty, and foster coordinated urban–rural development. The findings provide both theoretical insights and practical guidance for sustainable agricultural development and regional economic growth.

Literature Review

Rural roads, as critical infrastructure in rural areas, address transportation deficiencies, connect dispersed agricultural populations, and promote the optimization and upgrading of industrial structures, thereby enhancing regional agricultural economic development and serving as a key means to narrow the urban-rural gap(Aggarwal, 2018; Asher and Novosad, 2020; Li and Wang et al., 2020). For developing countries, where most people live in rural areas with low living standards and high trade costs, governments worldwide have prioritized the construction and study of rural roads. In recent years, countries like China, India, Iran, and Ethiopia have made significant progress in rural road development. Notably, in 2023, China invested 484.3 billion yuan in rural road infrastructure, adding 188,000 kilometers of roads, which facilitated employment for 200,000 rural workers and provided robust transportation support for the rural revitalization strategy(Han, 2024).

Numerous studies have explored the impact of rural roads on agricultural economic growth. (Asomani-Boateng and Fricano et al., 2015)noted that rural road construction increases per capita income for agricultural households, expands agricultural markets, reduces working hours, and lowers transportation costs(Zhang et al, 2018), significantly contributing to poverty alleviation in many developing countries. Kebede (2024), using the Ricardian trade model, demonstrated that rural road development reduces price disparities for agricultural products across regions, lowering trade costs. Donaldson (2018) found that transportation infrastructure in India enhances commodity circulation, significantly increasing the income of agricultural workers. Additionally, (Li and Wang et al., 2020), using a nonlinear time-varying factor model, empirically showed that road infrastructure reduces the urban-rural gap. Hu and Liu (2022) highlighted that transportation infrastructure facilitates human resource mobility, serving as a key driver of China’s rapid economic growth over recent decades, expanding inter-regional trade, and promoting economic integration.

Recent empirical evidence further highlights the role of rural roads in poverty alleviation and social welfare. Yang (2025) found that rural road construction significantly alleviates poverty and facilitates farmers’ transition to non-agricultural sectors, thereby increasing their access to broader social welfare benefits. Similarly, Wiegand and Koomen et al. (2023) applied a random effects model in Papua New Guinea and demonstrated that rural road upgrades improve household welfare, housing quality, and school enrollment while encouraging a shift from subsistence to market-oriented farming. In Nigeria, Jimoh and Araromi (2024) emphasized that investment in additional rural road branch lines strengthens the link between farmland and markets, facilitating more efficient transportation of agricultural products.

Further, Maphela and Adanlawo (2025), through a comprehensive literature review, highlighted that inadequate rural transport infrastructure constrains residents, exacerbating poverty, hunger, and food insecurity. Rikhotso et al. (2025) argued that enhancing the quality and connectivity of rural roads is essential for promoting rural economic growth, expanding development opportunities, and improving access to public services. Adamopoulos (2025) empirically demonstrated in Ethiopia that rural road expansion shapes the spatial distribution of agricultural production and inputs, lowers transportation costs, and increases overall productivity.

Du et al. (2023) analyzed data from 285 cities between 2017 and 2022 in China, showing that rural infrastructure development not only directly promotes economic growth but also indirectly supports it by improving rural living environments, thus underscoring the necessity of rural roads for balanced regional development. Kaiser et al. (2022) further highlighted the contribution of rural roads to welfare in low- and middle-income countries, advocating for stronger integration with education to maximize the poverty alleviation effects of transportation infrastructure. Zeng and Wang (2025) confirmed that transport infrastructure positively influences the gross output of both agricultural and industrial sectors, reinforcing its central role in fostering rural economic development.

However, some studies suggest that rural road construction has a stronger positive impact in poorer areas, enabling resource accumulation (e.g., financial and educational resources), but has less effect on wealthier groups. Chatterjee and Turnovsky (2012) indicated that infrastructure investment may, in the long term, widen regional income disparities, affect labor efficiency, and have a moderate positive causal effect on per capita GDP for industries near transportation networks, though per capita GDP growth shows no clear correlation with road development. Zhou et al. (2021) analyzed panel data from 31 Chinese provinces spanning 2002–2018 and found that while rural road construction significantly enhances agricultural sustainability, it has a negative and delayed impact on environmental sustainability.

Despite extensive research on the relationship between rural roads and agricultural economic growth, the clarity of their causal relationship remains limited. Moreover, the combined effects of confounding factors and the insufficient consideration of variable interactions often undermine the reliability of research conclusions. Therefore, further in-depth studies are necessary to comprehensively reveal the mechanisms by which rural roads impact agricultural economies and their potential variable influences.

The mediating effect of rural roads on agricultural development

To thoroughly investigate the mechanisms by which rural roads influence agricultural development and address underlying rural agricultural issues, this study employs mediation effect theory to comprehensively explore and expand the added value of rural road services.

2.1 Mediation Effect

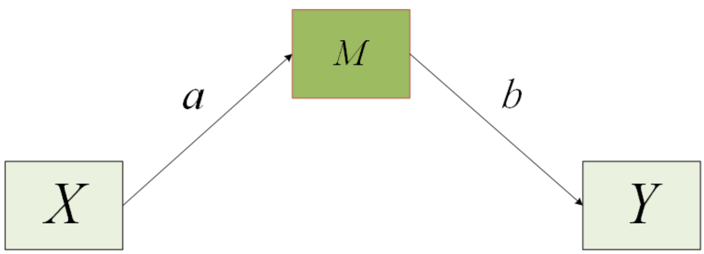
The theoretical evolution of the mediation effect model originates from Woodworth's (1928) Stimulus-Organism-Response (*S-O-R*) framework, which broke away from the unidirectional logic of the traditional Stimulus-Response (*S-R*) paradigm. The S-O-R framework emphasizes that external stimuli (e.g., rural road construction) indirectly influence outcome variables (e.g., agricultural development) through internal transformation processes within the organism (e.g., resource reorganization, technological diffusion). However, the empirical application of this theoretical advancement lagged for decades until the 1980s, when Baron and Kenny (1986) and Judd and Kenny (1981) introduced the Causal Steps Approach. This approach provided a standardized procedure for quantifying simple mediation effect models (single independent variable $X \rightarrow$ mediator $M \rightarrow$ dependent variable Y)(WEN et al., 2022).

Notably, while mediation effect models have been widely applied in psychology and management, their use in studying the relationship between rural infrastructure and agricultural economies remains limited. Existing literature primarily focuses on the direct impact of road construction on agricultural output, often overlooking the mediating mechanisms, such as land transfer and technological diffusion. This research gap may lead to policy designs overly reliant on "hard inputs" (e.g., inter-regional highways) while neglecting "soft connections" (e.g., the added value of rural road networks and their synergistic effects with rural development factors).

(1) Mediation Effect

The mediation effect is a mechanism analysis method used to explain how an independent variable (X) influences a dependent variable (Y) through a mediator variable (M). Its core principle is that changes in the independent variable X affect the mediator variable M, which then transmits the effect to the dependent variable Y, forming an indirect effect ($X \rightarrow M \rightarrow Y$). This process is illustrated in Figure 1.

Figure 1. Schematic diagram of the mediating effect



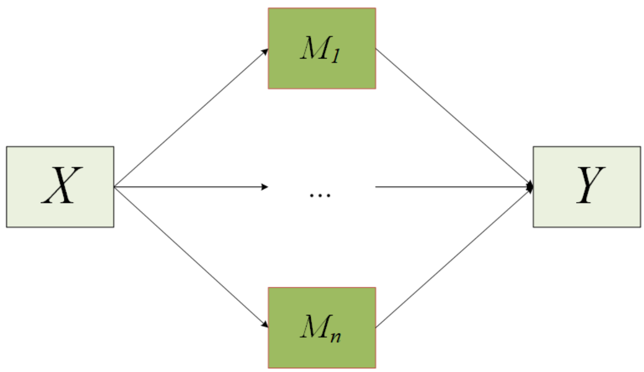
(2) Multiple Mediation Effects

The mediation effect model, due to its simple structure and clear explanatory power, is widely used to effectively reveal the direct influence of an independent variable on a dependent variable, as well as the bridging role of a mediator variable (*M*). However, in complex scenarios, relying solely on a simple mediation model may be insufficient to fully explain the mechanisms by which the independent variable affects the dependent variable. In such cases, multiple mediating variables need to be introduced to construct a multiple mediation effect model. Based on the mechanisms of the mediating variables, multiple mediation effects are classified into three types: parallel multiple mediation effect, sequential multiple mediation effect, and composite multiple mediation effect.

1) Parallel Multiple Mediation Effect

The parallel multiple mediation effect model incorporates multiple independent mediating variables into the analytical framework to explore the mechanisms through which the independent variable influences the dependent variable via multiple pathways. Its core characteristics are manifested in three key dimensions: The mediating variables do not influence each other and independently receive the effect of the independent variable; Each mediating variable is driven separately by the independent variable, forming distinct pathways, with the effects of these pathways being additive; The influence of each mediating variable is homogeneous, meaning different pathways consistently transmit the effect from the independent variable (*X*) through the mediators to the dependent variable (*Y*). This structure is illustrated in Figure 2.

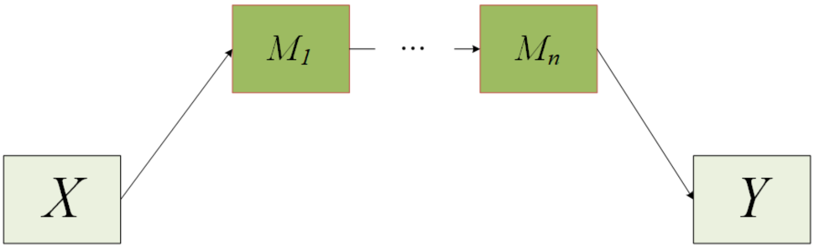
Figure 2. Parallel multiple mediating effects



2) Sequential Multiple Mediation Effect

In the real world, causal relationships are often far more complex. Relying solely on the parallel multiple mediation effect, which assumes that mediating variables independently influence the relationship between the independent variable and the dependent variable, fails to account for interactions and dependencies among mediators. As a result, it is insufficient to fully explain the causal relationships in the data. The sequential multiple mediation effect model overcomes the independence assumption of the parallel model by addressing the interactive nature of real-world causal relationships, constructing a sequential transmission mechanism. The core characteristics of this model are reflected in three key attributes: Mediating variables are interdependent, and the effect from the independent variable to the dependent variable is realized only through their mutual interactions; The indirect effect of the independent variable on the dependent variable is transmitted through multiple mediators in a sequential manner, with the mediation effect calculated as the product of the path coefficients, rather than the simple additive effects seen in parallel mediation; The model exhibits a strong sequential causal relationship, where the effect of earlier mediators on subsequent mediators is necessary for the model to be computed step-by-step. This structure is illustrated in Figure 3.

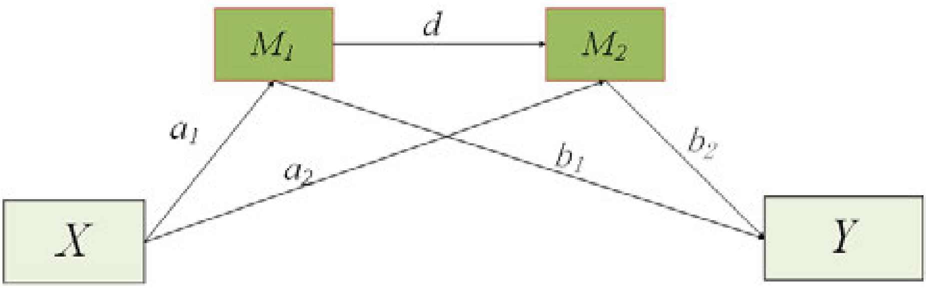
Figure 3. Chained multiple mediating effects



3) Composite Multiple Mediation Effect

The composite multiple mediation effect integrates the dual mechanisms of parallel multiple mediation and sequential multiple mediation, constructing a multidimensional network of transmission relationships. At the level of mediation effect analysis, it can be decomposed into the linear additive effects of parallel mediation and the multiplicative effects of sequential mediation, thereby quantifying the heterogeneous contributions of multiple pathways. This integrated design not only identifies the independent effects of mediating variables but also captures their interdependencies, providing a more accurate analytical tool for elucidating the multi-level causal relationships between rural roads and agricultural development. The structure is illustrated in Figure 4.

Figure 4. Compound multiple mediating effects



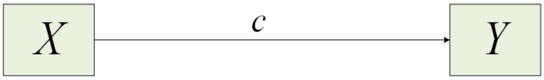
2.2 Mediating Effect Model of Rural Roads on Agricultural Development

When analyzing the mediating effect model, the first step is to determine the total effect of the independent variable on the dependent variable, which serves as the foundational step in model construction. Specifically, regression analysis is required to test whether the independent variable has a significant direct impact on the dependent variable.

The direct impact of the independent variable on the dependent variable yields the total effect (denoted as *c*), with no mediating variables considered at this stage. The corresponding formula is as follows:

Figure 5. Direct impact

$$Y = cX + \varepsilon \qquad (1)$$



The multiple mediating effect refers to the indirect impact of the independent variable on the dependent variable after considering multiple mediating variables. The corresponding formula is as follows:

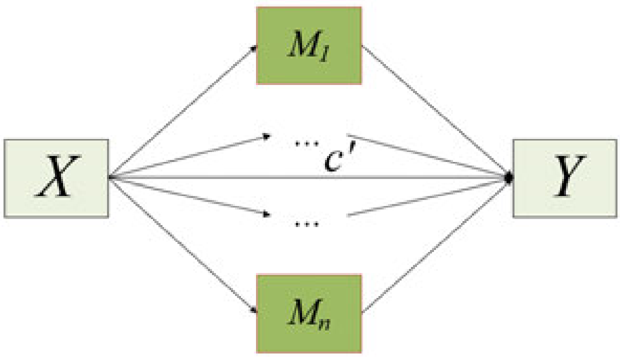
$$Y = c'X + \sum_{j=1}^{n} b_j M_j + \varepsilon, \; j = 1, \cdots n \qquad (2)$$

(1) Parallel Multiple Mediating Effect Model

The relationship between the independent variable X and multiple mediating variables M_j indicates how changes in X affect M_j, with the coefficient denoted as a_j. The corresponding formula is as follows:

Figure 6. Schematic diagram of parallel multiple mediating effects

$$M_j = a_j X + \varepsilon \;, \; j = 1, \cdots n \qquad (3)$$



(2) Construction of the Chain Multiple Mediating Effect Model

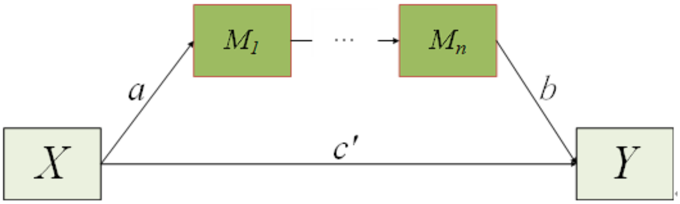
The relationship between the independent variable X and the first mediating variable M_1 indicates how changes in X affect M_1, with the coefficient denoted as a_1. The corresponding formula is as follows:

$$M_1 = a_1 X + \varepsilon \qquad (4)$$

The relationships among multiple mediating variables M_j are represented by coefficients denoted as d_j. The corresponding formula is as follows:

$$M_j = \sum d_j M_{j-1} + \varepsilon,\ j = 2,\cdots n \qquad (5)$$

Figure 7. Chained multiple mediating effects



(3) Construction of the Composite Multiple Mediating Effect Model

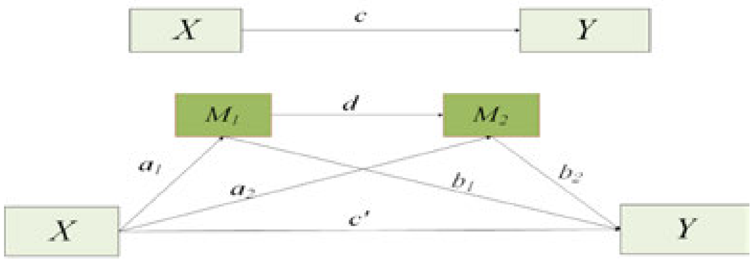
The relationship between the independent variable X and multiple mediating variables M_j illustrates how changes in X affect M_j, with the coefficients denoted as a_j. The corresponding formula is as follows:

$$M_j = a_j X + \varepsilon,\ j = 1,\cdots n \qquad (6)$$

The relationships among multiple mediating variables M_j are represented by coefficients denoted as d_j. The corresponding formula is as follows:

Figure 8. Compound multiple mediating effects

$$M_j = \sum d_j M_{j-1} + \varepsilon,\ j = 2,\cdots n \qquad (7)$$



2.3 Selection of Mediation Effect Models for the Impact of Rural Roads on Agricultural Development

When considering multiple variables mediating the relationship between the independent variable and the dependent variable, selecting an appropriate multiple mediation model involves the following operational steps and methods:

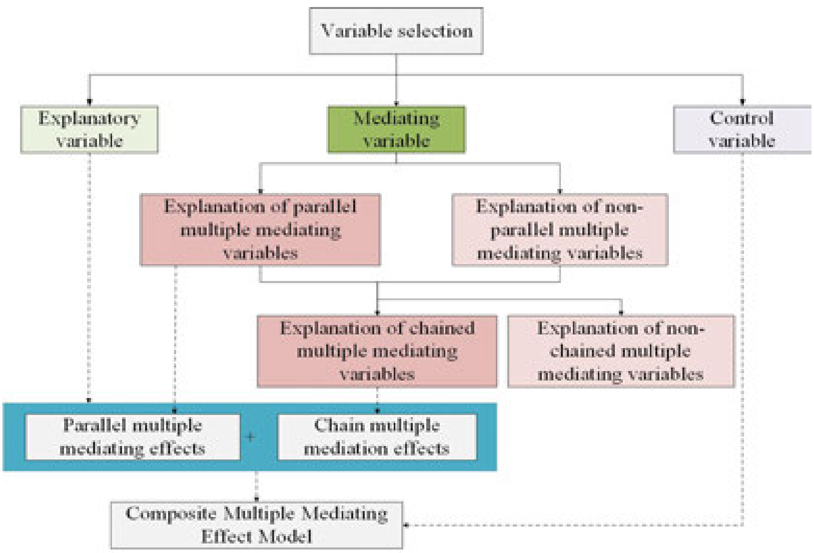
Step 1: Variable Selection and Classification: First, identify the explanatory variable (independent variable), mediating variables, dependent variable, and control variables. This requires a literature review and theoretical analysis to screen for mediating variables that are correlated with both the independent variable and the dependent variable. Ensure that the role of each variable is clearly defined for subsequent analysis.

Step 2: Identification of Parallel Mediating Variables: After determining the mediating variables, assess whether these variables independently influence the dependent variable. If multiple mediators operate independently, are driven by the independent variable, and directly affect the dependent variable, they are classified as parallel multiple mediating variables.

Step 3: Identification of Sequential Mediating Variables: Following the identification of parallel mediators, further examine whether there are causal dependencies among the mediating variables. If the effect of one mediator depends on another and forms a sequential pathway, these are classified as sequential multiple mediating variables.

Step 4: Model Determination: If both parallel and sequential mediating variables coexist, a composite multiple mediation effect model should be applied. Otherwise, based on the type of mediators identified, select either the parallel multiple mediation effect or the sequential multiple mediation effect for analysis.

Figure 9. Flowchart for determining the composite multiple mediating effect model



Testing the Mediation Effect Model of Rural Roads on Agricultural Development

This study employs the Bootstrap sampling method to test the significance and accuracy of the mediation effect model, with the core approach being the coefficient product test method, assuming $H_0: ab = 0$. This method uses the principle of resampling with replacement to extract multiple samples from the original data, approximating the variability of statistical estimates and their confidence intervals (Xie, 2021; Xiao and Kim et al., 2024). It establishes the relationship between the dependent variable and the independent variable, making it particularly suitable for scenarios with limited sample sizes or unknown data distributions. The specific steps are as follows:

Step 1: Total Effect Test: Test the total effect coefficient c. If the total effect coefficient c is significant, it indicates that the independent variable (*X*) has a significant impact on the dependent variable (*Y*), and the analysis proceeds to the next step for mediation effect analysis. If *c* is not significant, analyze the masking effect to explore which variables may be suppressing the effect.

Step 2: Testing Parallel Multiple Mediation Effects: Conduct a Bootstrap test for parallel mediation effects, with the null hypothesis $H_0: ab = 0$ for each mediator. If the null hypothesis is rejected, the variable is confirmed as a parallel mediating variable. Otherwise, the mediator does not participate in the parallel mediation effect.

Step 3: Testing Sequential Multiple Mediation Effects: Apply the Bootstrap test for sequential mediation effects, where the coefficient product test examines the product of path coefficients. The null hypothesis is $H_0: adb = 0$. If the null hypothesis is rejected (i.e., the confidence interval of the sequential indirect effect does not include zero), a significant sequential mediation effect exists. Otherwise, no sequential mediation effect is present.

Step 4: If *ab* or *abd* has the same sign as *c'*, it indicates the existence of a partial mediating effect. The parallel mediating effect value is ab/c, and the chain mediating effect value is *abd/c*. The opposite sign is the masking effect. The parallel masking effect value is |*ab/c'*|, and the chain masking effect value is |*abd/c'* |.

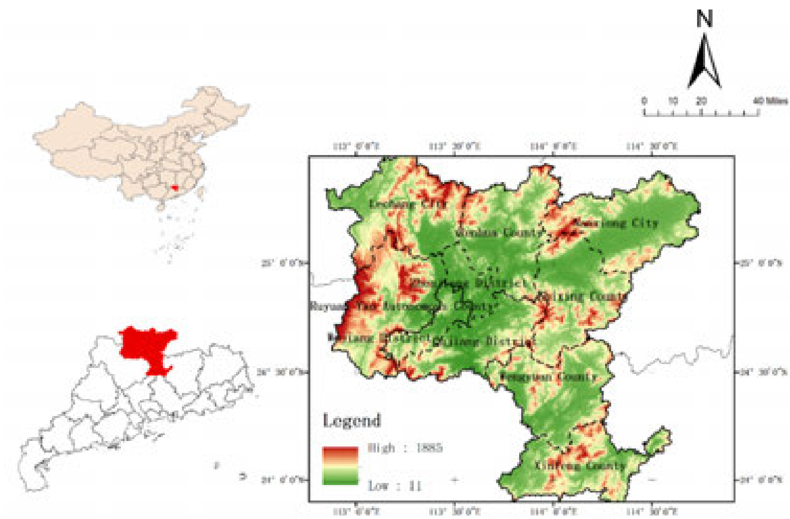
Case Study on the Mediation Effects of Rural Roads on Agricultural Development

Study Area

Shaoguan City is located in northern Guangdong Province, bordering Hunan to the north and Jiangxi to the east. The terrain is higher in the north and lower in the south, with the Nanling Mountains running through the region. Mountainous and hilly areas account for approximately 80% of the total land, earning Shaoguan the nickname "eight parts mountains, one part water, one part farmland." The city covers a total area of 1.8413 million hectares, of which 1.4553 million hectares are forested, making it a key forestry city in Guangdong. Shaoguan enjoys a warm and humid climate, with synchronized rainy and warm seasons, where March to August serves as the primary rainy season, providing favorable natural conditions for agricultural development. Leveraging its abundant agricultural resources, Shaoguan has become a significant agricultural development base in Guangdong, with per capita arable land ranking among the highest in the province. In 2023, the total output value of agriculture, forestry, animal husbandry, and fisheries reached 39.29 billion yuan, forming a distinctive “6+6” agricultural industry system, laying a solid foundation for regional economic development.

In terms of transportation, Shaoguan’s total road mileage reaches 17,200 kilometers, with rural roads accounting for 77.9%. However, a high proportion of these are fourth-grade roads, indicating limited traffic capacity that requires further improvement. The city has a permanent population of 2.8577 million, with 40.3% residing in rural areas and an urbanization rate of 59.7%. The pronounced urban-rural dual structure provides a broad research and practical space for rural revitalization and modern agricultural development.

Figure 10. Topographic map of Shaoguan City



Research Variables and Data

Research Variables

This study selects the total output value of agriculture, forestry, and fisheries (AGDP) as the dependent variable to more accurately assess the impact of rural transportation infrastructure on agricultural development. The core independent variable is rural transportation infrastructure, specifically measured by the total mileage of rural roads in a given year to ensure the reliability of results(Guo et al., 2011). Based on the study’s objectives and the characteristics of the study area (Shaoguan City), agricultural labor (AP), agricultural land area (AL), and agricultural machinery (AM) are selected as mediating variables(Xie, 2021). To reduce errors due to omitted variables and enhance the rigor of the study, control variables are included. The specific definitions of the variables are as follows:

(1) Dependent Variable

Total value of farm output (AGDP): This variable captures the comprehensive output value of agriculture, forestry, animal husbandry, and fisheries. It reflects the overall level of agricultural and rural development. To ensure comparability over time and control for inflation effects, all data are adjusted to constant 2010 prices.

(2) Core Independent Variable

Rural Transportation Infrastructure Level (Road): Measured by the total mileage of rural roads in each district or county, serving as an indicator of transportation infrastructure.

(3) Mediating Variables

Agricultural Practitioners (AP): Represented by the number of individuals engaged in agriculture, forestry, animal husbandry, and fisheries. This reflects the availability of rural labor and its potential contribution to agricultural productivity.

Agricultural Machinery (AM): Measured by the total power of agricultural machinery. This indicator captures the level of technological advancement in agriculture, which plays a critical role in improving productivity and promoting labor substitution and transfer (Rahman and Ali et al., 2021).

Agricultural Land (AL): Defined as the total area of agricultural land, including arable land, garden plots, forest land, grassland, and fishponds. It provides a comprehensive measure of land resources available for agricultural production.

(4) Control Variables

Industrial Structure (IS): Measured by the ratio of primary industry GDP (agriculture) to total regional GDP. This reflects the extent to which the regional economy depends on the agricultural sector (Wei, 2019; Cheng, 2021) .

Urbanization Rate (RU): Calculated as the proportion of the urban registered population to the total population. This variable captures the influence of urbanization on the rural and agricultural economy(Zhang, 2018).

3.2.2 Data Sources and Processing

Since 2011, the Ministry of Transport of China has introduced a series of policies aimed at advancing rural road construction. The *"Twelfth Five-Year Plan" Guidelines for Rural Road Construction* laid the policy foundation. In 2015, the *Opinions on the Construction of "Four Good Rural Roads"* proposed building a safe and green rural road network by 2025. In 2018, the *Measures for the Quality Management of Rural Road Construction* established a lifelong responsibility system for quality. Based on these policies, this study uses data from Shaoguan City spanning 2010 to 2020. To ensure stationarity and eliminate heteroscedasticity, the data were transformed using natural logarithms. Relevant data are presented in Table 1.

Table 1. Descriptive statistics of each variable

Abbreviation	Sample	Units	Mean value	Standard deviation	Minimum value	Maximum value
Road	100	km	7.22	0.53	6.09	7.22
AGDP	100	w	11.97	0.53	11.06	12.97
AL	100	km^2	3.53	0.61	2.28	4.61
AP	100	p	2.33	0.47	1.59	5.08
AM	100	kw	8.61	0.60	7.61	10.16
RU	100	%	2.59	0.83	0.90	2.59
IS	100	%	3.90	0.30	3.44	4.45

Study on the Multiple Mediating Effects of Rural Roads on Agricultural Development

Construction of the Multiple Mediating Effect Model of Rural Roads on Agricultural Development in Shaoguan City

Based on the selection of the mediating effect models described above, the composite multiple mediating effect consists of both parallel and chain multiple mediating effect models. Therefore, in this chapter, the impact of rural roads on agricultural economic development is analyzed using only the parallel and chain multiple mediating effect models. Control variables are introduced to reduce errors caused by omitted variables, thereby forming a complete causal chain and making the analysis results more accurate and reasonable. The corresponding formula is as follows:

The direct effect of rural roads on the total output value of agriculture without considering any mediating factors.

$$AGDP = cRoad + \sum \gamma_i Control_i + \varepsilon \qquad (8)$$

After considering the mediating variables, the multiple mediating effects of rural roads on the total output value of agriculture.

$$AGDP = c'Road + b_1 AL + b_2 AM + b_3 AP + \sum \gamma_i Control_i + \varepsilon \qquad (9)$$

(1) Parallel Multiple Mediating Effects

The impact of rural roads on agricultural land use.

$$AL = a_1 Road + \sum \gamma_i Control_i + \varepsilon \qquad (10)$$

The impact of rural roads on agricultural mechanization.

$$AM = a_2 Road + \sum \gamma_i Control_i + \varepsilon \qquad (11)$$

The impact of rural roads on agricultural labor.

$$AP = a_3 Road + \sum \gamma_i Control_i + \varepsilon \qquad (12)$$

(2) Chain Multiple Mediating Effects

Building on the parallel multiple mediating effects, this section studies the correlations among the mediating variables.

The relationship between agricultural mechanization and agricultural land use.

$$AL = d_1 AM + \sum \gamma_i Control_i + \varepsilon \qquad (13)$$

The effect of agricultural labor on agricultural mechanization.

$$AM = d_2 AP + \sum \gamma_i Control_i + \varepsilon \qquad (14)$$

The effect of agricultural labor on agricultural land use.

$$AL = d_3 AP + \sum \gamma_i Control_i + \varepsilon \qquad (15)$$

3.3.2 Study on the Mediating Effect of Rural Roads on Agricultural Development

This study decomposes the composite mediating effect model into two parts: parallel multiple mediating effects and chain multiple mediating effects. The processes for testing and model determination are constructed for each part to simplify their complexity. The relevant results are as follows:

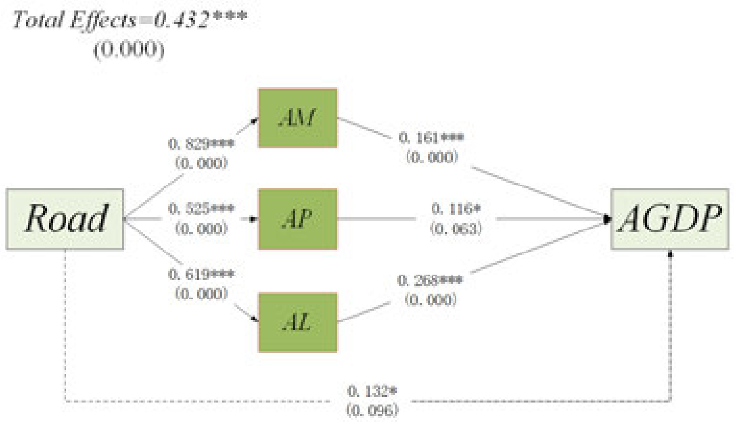
(1) Parallel Mediating Effects of Rural Roads on Agricultural Development

The parallel mediating effect of rural transportation infrastructure on the total output value of agriculture is illustrated in Figure 11. The findings demonstrate that the development of rural roads exerts a significant direct positive effect on agricultural output. Without including any mediating variables, rural road development shows a direct and significant impact on total agricultural output value (c=0.492, p=0.000), indicating that increased rural road mileage directly fosters agricultural growth.

Additionally, rural transportation infrastructure is significantly positively correlated with all mediating variables, particularly with agricultural mechanization (b=0.829, p=0.000), followed by agricultural land area (b=0.619, p=0.000), and finally agricultural employment (b=0.525, p=0.000). These relationships suggest that the expansion of rural roads facilitates improvements in agricultural inputs and production conditions. In the second stage of mediation, all three mediators exert positive effects on agricultural output: Agricultural land area has the strongest effect (b = 0.268, p = 0.000), followed by agricultural mechanization ($b = 0.161$, $p = 0.000$), and agricultural labor ($b = 0.116$, $p = 0.063$), which is marginally significant.

When all mediating variables are included in the model, the direct effect of rural roads on agricultural output remains positive but is reduced in magnitude (c'=0.132, p=0.096), indicating a partial mediating effect. This result confirms that rural road development contributes to agricultural growth not only through direct infrastructural benefits but also indirectly by improving the allocation and efficiency of agricultural production factors—notably through the enhancement of mechanization, more effective land utilization, and labor optimization.

Figure 11. Parallel mediating effects of mediating variables on agriculture, forestry and fishery



Note: Control variables include industrial structure and urbanization rate. Values represent standardized coefficients. The dashed line indicates the direct effect of rural roads on the total output value of agriculture, forestry, and fisheries. *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.

Table 2. Test of the Parallel mediating Effects of mediating Variables on agriculture, forestry and fishery

Class	c	a	b	$a \times b$	c'	Mediating effect
Road->AM->AGDP	0.492***	0.829***	0.161***	0.133**	0.132*	27.03%
Road->AP->AGDP	0.492***	0.525***	0.116*	0.061	0.132*	0.00%
Road->AL->AGDP	0.492***	0.619***	0.268***	0.166***	0.132*	33.74%

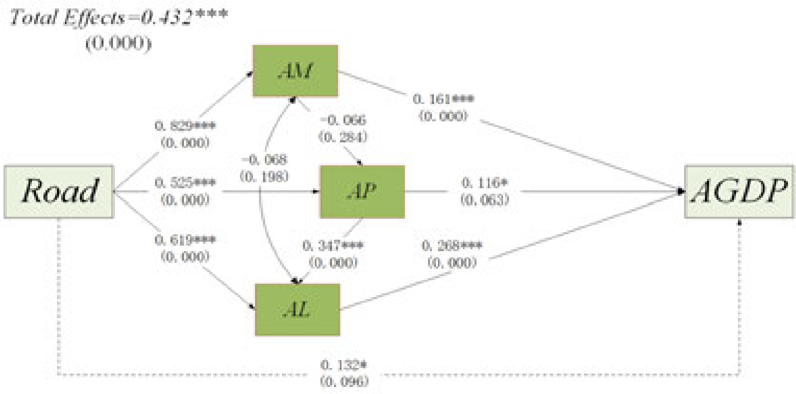
Note: * indicates p < 0.10, ** indicates p < 0.05, and *** indicates p < 0.001.

Using the Bootstrap method, the results presented in Table 2 reveal that the mediating effects of agricultural technological progress and agricultural land area are statistically significant in the relationship between rural roads and agricultural development. Specifically, the indirect effect via agricultural technological progress is *ab*=0.133 (*p*=0.015), accounting for 27.03% of the total effect, while the effect through agricultural land area is ab=0.166 (*p*=0.003), with a mediation proportion of 33.74%. In contrast, the mediating effect of agricultural employment (*ab*=0.061, *p*=0.385) does not reach statistical significance, indicating that this pathway does not constitute a valid mediating mechanism in the parallel mediation model. These results suggest that the positive impact of rural roads on agricultural economic growth is primarily realized through technological advancement and the optimized allocation of land resources, rather than by increasing the number of agricultural workers. This finding reflects a broader trend in the context of agricultural modernization: as mechanization and technology adoption deepen, the direct labor intensity of agricultural production is diminishing, and efficiency gains from land and technology are emerging as the dominant drivers of agricultural development.

(2) Chain Mediating Effects of Rural Roads on Agricultural Development

The potential interactions among mediating variables are shown in Figure 12. Under the influence of rural transportation infrastructure, only a significant positive correlation exists between agricultural employment and agricultural land area (*d*=0.347, *p*=0.000). Agricultural mechanization may have a negative effect on agricultural employment (*d*=-0.066, *p*=0.284) and agricultural land area (*d*=-0.068, *p*=0.198), but these effects did not pass the significance test. This indicates that among the three mediating variables—agricultural technological progress, agricultural employment, and agricultural land area—only agricultural employment and agricultural land area exhibit a potential correlation.

Figure 12. Mediating effects of mediating variables on the chain of agriculture, forestry and fishery



Note: Control variables include industrial structure and urbanization rate. Values are standardized coefficients. The dashed line represents the direct effect of rural roads on the total output value of agriculture, forestry, and fisheries. Values in parentheses indicate significance levels. **p* < 0.10, ***p* < 0.05, ****p* < 0.001.

Table 3. Test of the chain mediating Effect of Mediating variables on agriculture, forestry and fishery

S.N.	Class	*abd*	*z*	*p*	Mediating effect
1	Road->AM->AP->AGDP	-0.006	-0.534	0.595	0
2	Road->AM->AL->AGDP	-0.015	-1.163	0.248	0
3	Road->AP->AL->AGDP	0.054	2.271	0.025**	10.98%
4	Road->AP->AM->AL->AGDP	0.002	0.800	0.424	0

Note: *$p < 0.10$, **$p < 0.05$, ***$p < 0.001$.

Simultaneously, the Bootstrap method was used to test the chain multiple mediating effects, as shown in Table 3.3, confirming that only one chain mediating effect exists between rural transportation infrastructure and the total output value of agriculture, forestry, and fisheries. Specifically, the development of rural transportation infrastructure increases agricultural employment, which further expands the development of agricultural land, thereby increasing the total output value of agriculture, forestry, and fisheries. This pathway (*abd*=0.054, *p*=0.025) passed the significance test, with a chain mediating effect value of 10.98%. Since pathways 1, 2, and 4 did not pass the significance test, the hypothesized effects of rural roads influencing agricultural economic development through interactions among mediating variables in these three pathways are not supported. Therefore, rural transportation infrastructure effectively promotes the growth of the total output value of agriculture, forestry, and fisheries only through the chain mediating effect of increasing agricultural employment and expanding agricultural land development.

Discussion

The findings of this study indicate that the enhancement of rural road infrastructure exerts a significant positive effect on agricultural economic development. This effect is primarily mediated through several key pathways, including the advancement of agricultural mechanization, the optimization of land use for farming, and the mobility of agricultural labor. These results not only confirm prior research on the facilitating role of transportation infrastructure in rural and agricultural development(Asher and Novosad, 2020), but also provide new insights into the differentiated mechanisms of multiple mediating effects, thereby enriching the theoretical understanding of how rural roads influence agricultural growth.

Agricultural land is a key parallel mediating pathway through which rural road improvements promote agricultural economic development. Enhanced road infrastructure reduces transaction costs in land transfers, enabling consolidation of fragmented plots through measures such as merging small fields, converting drylands to paddy fields, and reclaiming wastelands. These interventions improve the spatial configuration and overall quality of farmland, thereby increasing agricultural productivity.(Yusheng and Zhaofa et al., 2023; Chen and Peng et al., 2024; Feng and Robinson et al., 2025) Moreover, road improvements interact synergistically with high-standard farmland policies, ensuring more efficient land utilization and further boosting agricultural output. This evidence confirms that rural road enhancement disrupts the "honeycomb-like" spatial constraints of traditional small-scale farming(Liu and Jin et al., 2022), facilitating large-scale, intensive allocation of land resources and substantiating the transmission mechanism of "road improvement → land transfer → agricultural economic growth," consistent with prior research on farmland fragmentation and its driving forces(Liu and Li et al., 2025; Gandidzanwa and Verschoor et al., 2021).

Agricultural mechanization constitutes another key parallel mediating pathway through which rural road improvements foster agricultural economic development. Enhanced transportation infrastructure facilitates the accessibility of large-scale agricultural machinery to farmland, effectively reducing operational costs and time input while significantly increasing the scale and intensity of agricultural production. As a result, farmers can complete more tasks in a shorter period, leading to a marked improvement in labor productivity. This efficiency gain not only optimizes the allocation of production factors but also creates favorable conditions for the adoption of advanced agricultural technologies and modern management practices, driving a gradual transition from traditional extensive farming to high-efficiency, intensive, and modernized agriculture(Ma and Sun, 2024). Additionally, improved roads accelerate the circulation of agricultural machinery and related services, enhancing the coverage of equipment sales, maintenance, and support systems in rural areas, thereby further lowering the costs associated with mechanization(Lu and Yang et al., 2025; Xu and Ma et al., 2025). This virtuous cycle promotes the widespread adoption and deepening of mechanization, which, by increasing land productivity and reducing production risks, provides sustained impetus for agricultural economic growth (Wang and Zhang et al., 2024; Geng and Yan et al., 2025).

Although the agricultural employment does not serve as a direct parallel mediating variable, it indirectly promotes agricultural economic development through a chain mediating pathway. Compared with agricultural mechanization and land optimization, its effect is relatively weaker, likely reflecting the increasing reliance of modern agriculture on technological innovation and efficient resource allocation. The chain mediation analysis reveals a significant linkage between agricultural labor and land use, indicating a nonlinear mechanism through which labor influences agricultural development(Zhang and Chen et al., 2025). Consistent with previous studies, improvements in rural road infrastructure, particularly in areas with poor transportation conditions. It not only enhance land use efficiency but also attract labor back to rural areas, mitigating labor outflow and providing critical support for agricultural growth. Furthermore, the formation of this chain mediating effect is closely associated with industrial restructuring and the optimization of regional development patterns(Pei and Zhao et al., 2024). Road enhancements facilitate the orderly transfer of industries and deeper functional specialization while promoting more equitable provision of public services, thereby alleviating the excessive concentration of urban-rural resources and fostering a multi-centered, balanced development model(Yan and Hu et al., 2025).

Conclusion

Main finding

Based on agricultural data from Shaoguan City from 2010 to 2020, this study constructed a composite multiple effect model, which was decomposed into direct effects, parallel multiple mediating effects, and chain multiple mediating effects.

Corresponding selection processes were established to reduce the complexity of the study. The research findings are as follows:

(1) Rural road infrastructure affects agricultural development through multiple dimensions. Its influence is not limited to a direct positive effect on productivity, but also operates via complex mediating pathways that integrate several interrelated mechanisms.

(2) Improvements in rural roads facilitate agricultural mechanization and optimize land use, which together directly enhance agricultural economic performance. These pathways enable more efficient production processes, higher output, and better allocation of agricultural resources.

(3) Rural roads also indirectly promote economic growth through a sequential interaction between agricultural labor and land use. By improving accessibility and connectivity, roads influence labor distribution and retention, which in turn enhances land productivity and overall agricultural output.

Policy implications

The research results show that rural roads not only have a significant direct impact on agricultural development, but also the economic benefits related to transportation infrastructure are considerable. In the new stage of development, efforts must continue to be made to build rural roads and promote local economic growth related to roads. Through the “transportation +” model, the resources along the transportation routes can be effectively utilized to promote agricultural modernization and economic development. The following suggestions are hereby put forward:

(1) The establishment of the “Transport Plus Land Optimization” model will facilitate the integration of rural road construction with land circulation, land reclamation, and irrigation improvement. This model will promote the intensive development of cultivated land in the region, enhancing land utilization efficiency.

(2) Link the construction and renovation of rural roads with policies on agricultural machinery subsidies and the building of service systems. Strengthen infrastructure support for large-scale mechanized operations and accelerate the transition to modern agricultural production methods.

(3) In rural areas with insufficient transportation networks and large-scale labor mobility, priority should be given to improving connectivity with urban centers. Strengthening the rural road network will enhance the connection between agricultural production areas and markets, improve access to social services, and ultimately help increase rural incomes, reduce poverty, and promote broader economic and social development in rural areas.

Limitations and further research

The influence path of rural roads on agricultural development may have nonlinear characteristics. Therefore, future research can further introduce multiple variables and combine nonlinear modeling techniques (such as structural equation models, machine learning methods, etc.) to systematically analyze the multi-level and nonlinear influence mechanism of rural roads on agricultural development, so as to improve the accuracy and applicability of the research.

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Conflict of interests

The authors declare no conflict of interest.

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THE INFLUENCE OF REPORTING ON SUSTAINABLE DEVELOPMENT ON THE AUDITOR'S OPINION ON BUSINESS OPERATIONS OF AGRICULTURAL COMPANIES IN THE REPUBLIC OF SERBIA

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ABSTRACT

The auditor's opinion on the operations of agricultural companies in the Republic of Serbia, conditional on reporting on sustainable development, is the topic of this paper. Although reporting on sustainable development is a legal obligation, its absence does not affect the audit opinion. The aim of this paper is to confirm the independence of the audit opinion on sustainable development reporting. The research was conducted on a sample of agricultural enterprises in a three-year period. The audit opinions of those companies and "Annual business reports", were analyzed. The reports lack quantitative indicators of sustainability and they are primarily descriptive. The Fisher test confirmed the independence of the audit opinion and reporting on sustainable development. The research confirmed that the transparency of investment in sustainable development still does not significantly influence the audit opinion. A proposal was made on how reporting on sustainable development can be improved, within the institutional framework that will impose reporting obligations, and within the reporting of agricultural enterprises.

Introduction

Reporting on sustainable development is of great importance for agricultural enterprises due to the growth of environmental and social demands imposed by regulators, as well as by consumers, investors and partners. This process allows businesses to demonstrate their contribution to environmental protection, responsible resource management and social sustainability. By combining these proposals, agricultural companies in Serbia

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can improve reporting on sustainable development, which contributes, not only to better environmental protection, but they can also increase their competitiveness in domestic and international markets, as well. Due to that two additional hypothesis of the paper would be to indicate that a greater presence of quantitative indicators in sustainable development reports positively correlates with the transparency of financial statements and that mandatory reporting on sustainable development leads to greater consistency of audit opinions.

Reporting on sustainable development is still not mandatory for all agricultural companies in Serbia, but it is mandatory for large companies subject to the Accounting Law ("Official Gazette of RS", no. 73/2019 and no 44/2021) and companies participating in the IPARD program. Large companies must submit reports on non-financial information (including environmental data) if they participate in the IPARD program and use EU subsidies for agriculture. Many companies in Serbia voluntarily report on environmental standards in order to meet the demands of the market and investors.

Sustainability reporting can be linked to an audit opinion if companies have legislative and regulatory obligations. The auditor's duty could be to confirm that the company reports are in accordance with those rules. In some cases, sustainability reports may include aspects related to resource management, emissions and other environmental aspects that have a direct impact on accounting reports (e.g. environmental costs or subsidies for sustainable production). An auditor may be engaged to verify that these factors are properly presented in financial statements.

Literature review

The importance of this topic is also indicated by the fact that in 1998 the authors Nitkin and Brooks dealt with the connection between reporting on sustainable development and its revision (Nitkin and Brooks, 1998). They indicated their importance on a sample of 174 largest Canadian companies at that time, out of a total sample of 1,500. In that period, this type of reporting was voluntary, and they also questioned the degree of audit independence in this matter.

The statistic significant association between quality reporting on environmental protection and its audit in a six-year period on a sample of 81 legal entities proved to be significant. Also, a positive and statistic significant relationship was discovered in the same paper (Moalla, Bassem and Anis, 2020) on voluntary environmental reporting and environmental audit committees.

Also, the involvement of supreme audit institutions in the implementation of the SDGs, resource mobilization and monitoring and evaluation frameworks can be a powerful tool to help governments to realize the SDGs (Montero and Le Blanc, 2019). So far, this innovation has proven to be rare, but the conclusions are that it can be very useful. In this way, the connection between sustainable development, reporting on sustainable development and auditing can be seen from another angle.

The motive for researching this topic arose from the lack of comparison and assessment of the impact of non-financial reporting, especially on sustainable development and environmental protection, on the auditor's opinion. Many authors have dealt with related topics. What we encounter in our work is qualitative data. Non-financial reporting has always been the target of criticism for its objectivity and quality in analysis (Michelon et al., 2015). It is Baalouch, Ayadi and Hussainey (2019) who deal with the issue of the quality of publishing data on environmental protection and they, following Bramer and Pavelin (2008), challenge the assumptions that a large volume of disclosed qualitative information contributes to their high quality.

Akpan and Oluwagbade (2023) study underscores the transformative role of accountants in addressing social and environmental responsibility. It contributes to the field by emphasizing ethical considerations, sustainability reporting, and the integration of non-financial metrics. Organizations are recommended to prioritize transparency, accountability, and continuous education for their accountants to adapt to this evolving landscape. Petricica and Buboi (2024) deal with the topic of including accountants and auditors in sustainable development. They indicate that the traditional role of the auditor should move towards a more comprehensive spectrum that also includes sustainability. It is concluded that auditors should be included in the part of reporting on sustainable development, where they will check currently applied methods, advise on the application of working methods so that production procedures are as efficient as possible. They are also responsible for transparent and appropriate reporting on sustainable development.

The aim of this study is to evaluate whether there is a positive relationship between qualitative reporting on sustainable development and audit opinion.

The institutional framework that regulates the corporate sustainability reporting of agricultural enterprises

The institutional framework that regulates environmental protection and sustainable development of agricultural enterprises in the Republic of Serbia includes the Law on Environmental Protection ("Official Gazette of RS", No. 135/2004, 36/2009, 72/2009, 43/2011, etc.), the Law on Environmental Impact Assessment (Official Gazette of RS, No. 135/2004, etc.), the Law on Integrated Prevention and Control of Environmental Pollution (IPPC), Law on Agriculture and Rural Development. The Law on Environmental Protection prescribes obligations related to pollution, waste management and sustainable use of resources. The Law on Environmental Impact Assessment prescribes the obligation according to which larger agricultural companies must obtain an "Environmental Impact Assessment Study", while the Law on Integrated Prevention and Control of Environmental Pollution applies to large plants that use intensive production methods (farms, industrial plants). The Law on Agriculture and Rural Development - encourages sustainable agriculture and the use of ecological practices.

ESG reporting is the process of creating and publishing reports by a company on the impact that it has on the environment (environmental), social environment (social), as well as on the way it manages the organization (governance). ESG reporting includes qualitative disclosures related to these three elements, but also quantitative measurements, as well as a comparison of the company's achieved performance with previously defined ESG risks, opportunities and strategies. Creating an ESG report can often be challenging, given that companies must first determine how, what ESG information and what indicators they will measure and communicate. ESG reporting, which is not yet a legal obligation, is a good tool for business improvement. ESG rating disagreement can indicates significantly increases the probability of auditors issuing modified audit opinions, shown by (Cheng et al., 2024). It can help agricultural enterprises to position themselves better in the market, to attract investors and to reduce environmental risks. The authors (Wang et al., 2023) point out that good environmental and social responsibility (ESG performance) can reduce perceived business risk, which, according to the information asymmetry theory, can encourage auditors to issue an unqualified opinion. Agricultural companies in Serbia will have to report on sustainability, especially those that plan to export their products to the European Union and other countries.

The National Strategy for Sustainable Development in the Republic of Serbia contains guidelines for sustainable agriculture and environmental protection. The Law on Incentives in Agriculture and Rural Development defines provisions related to agricultural production practices and negative impacts on the environment. The Law on Environmental Protection provides environmental protection standards for all production sectors, including agriculture, as well as local self-government contributes to the implementation of all laws and prescribed regulations by measures of stimulation, supervision and control of the application of environmental protection measures. Pearson's linear correlation coefficient shows that there was no statistically significant correlation between indicators of solvency and environmental protection in 2020, 2021 and 2022. (Stojic and Pejovic, 2024)

In Serbia and the EU, regulations such as EU Directive 2014/95, which relates to sustainability reporting for large companies, may impose obligations to publish certain data related to sustainable practices. If an agricultural enterprise chooses to report on sustainable development, an auditor can be engaged to verify the accuracy and reliability of that information, just as he will verify financial statements. Inadequate reporting or unrealistic data on sustainable practices can lead to a negative auditor's opinion.

If the company regularly reports on sustainable development and uses recognized benchmarks and indicators (e.g. GRI standards), the audit opinion can become a positive factor for investors, partners and regulators. Auditing these reports can increase confidence in the accuracy and reliability of data, which can be critical to making investment or business cooperation decisions. If a company does not report on sustainable development, or does not implement sustainable practices, it can lead to business risks such as regulatory fines, loss of market or reputation damage. These factors can affect the financial result of the company, which could be noticeable in the audit opinion.

Research methodology

At the time of the research conducted in the Republic of Serbia, according to the data from the Serbian Business Registers Agency, 708 agricultural enterprises were active. 298 were selected using the random sample method, and of that number, only 40 met the conditions necessary for the research. Only 40 companies from the sample belong to the medium and large category, because only these enterprises are obliged to have an independent auditor's opinion about their operations. Since 2021, companies have been required to prepare an additional financial report Annual Business Report which only contains relevant data related to sustainable development and socially responsible behaviour of companies.

The analysis was conducted with the aim of determining whether the audit opinion was influenced by reporting on sustainable development. For each analysed company, the auditor's opinion was recorded, as well as whether the Annual Business Report stated how much and to what extent it was invested in sustainable development. Coding of variables was carried out and belonging to a certain category was marked with numerical codes. For all analysed companies, a score of 0 to 3 was used for the three-year research period. Agricultural companies that did not attach an Annual Business Report to their financial statements, even though it is legally required, were quantified with "0". The number "1" was assigned to companies that had an annual business report, but without qualitative information on sustainable development actions. Companies that had an annual report on business operations and a brief record of sustainable development were rated "2" in the research, and all companies that had an Annual Report on Business and a more detailed record of sustainable development were rated "3".

In the Annual Reports of companies, related to sustainable development, it was generaly stated textually that they respect the agenda of sustainable development, recycle waste, use renewable energy sources, avoid using artificial fertilizers and pesticides to destroy pests, use filters for purifying waste water and exhaust gases, collect rainwater to save water, use irrigation systems and protection against hail and weather disasters, but concrete quantitative indicators that would document these claims were not in the reports.

Audit opinions related to Annual reports on operations are mainly based on the fact that the management is responsible for the preparation of other information in accordance with the regulations of the Republic of Serbia. They usually state that the opinion on the financial statements does not refer to other information. They feel it is their responsibility to read the rest of the information and consider whether there is a materially significant inconsistency between the other information contained in the Annual reports on operations and the financial statements and their findings obtained during the audit, or otherwise appear to be materially misstated. In connection with the Annual Report on Business, they carried out the procedures prescribed by the Law on

Accounting of the Republic of Serbia. Those procedures included checking whether the Annual Business Report in the formal sense was compiled in accordance with the Law on Accounting of the Republic of Serbia.

Based on the procedures performed during the audit, to the extent that they were able to assess, other information presented in the annual reports on operations is, according to all materially significant issues, aligned with the information presented in the financial statements. On the basis of the knowledge and understanding of the Company and its environment acquired during the audit, the auditor's responsibility was only to report whether the other information in the Annual Business Report contained materially significant misstatements. According to the procedures carried out, they only determined whether there were materially significant misstatements in the Annual Business Report.

The analysis of financial reports and available data largely depends on the activities and sub-activities of the selected sample, and therefore, the structure of the used sample is shown (*Table 1*). In the analysed sample, there is the largest number of companies from the field of livestock and poultry farming and companies that deal with mercantile goods. The sample is diversified.

Table 1. Characteristics of the sample

Serial number	Sub-activities	Number	Percentage share
1.	Livestock, poultry farming	9	22.50%
2.	Artificial fertilizers, seed products and protective agents	3	7.50%
3.	Vegetable growing	1	2.50%
4.	Fruit growing	2	5.00%
5.	Farming	7	17.50%
6.	Animal feed and components	3	7.50%
7.	Mercantile goods	9	22.50%
8.	Services in agriculture and animal husbandry	3	7.50%
9.	Agricultural machinery and equipment	2	5.00%
10.	Consulting, engineering	1	2.50%
Total:		**40**	

Source: Authors' calculations

Results and discussion

Due to the specificity of the sample and nominal variables, the Fisher test was used to determine the statistical significance of the connection between the auditor's opinion and the annual report and whether the auditor's opinion is conditioned by reporting on sustainable development. Also, in all contingency tables there is at least one frequency that is less than 5 and the table is larger than 2x2 (both variables contain more than 2 categories).

As we came to at the amount for statistical analysis by quantifying the qualitative data, it must be noted that this aspect cannot be taken for a more detailed investigation due to the existence of the inevitable subjective influence of the assessment of the given information. Also, the absence of quantitative data provided by the company raises the question of their veracity and assessment of which activities were actually undertaken and to what extent. It indicates that the additional hypothesis about the importance of quantitative data is confirmed. The research would be more relevant if there was an obligation of quantitative reporting.

Fisher's test was used to determine the relationship between the auditor's opinion in 2021 and the comprehensiveness of the annual report in 2021. Given that the p value was p=0.120, it can be concluded that there is no statistical significant relationship between these variables. (p>0.05) (*Table 2.*) Therefore, we can conclude that there is no influence of Annual business report on audit opinion and report.

Table 2. Contingency table and Fisher's test for 2021

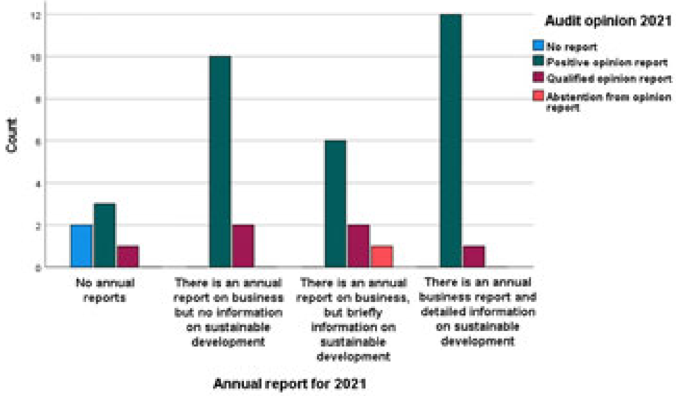
Auditor's opinion 2021.	**No Annual Report**	**There is an AR, no environmental inf.**	**There is an AR, with brief environmental inf.**	**There is an AR with detailed environmental inf.**	**Total**	**Fisher's test(p)**
No reports	2 (5.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	2 (5.0%)	**11.074 (p=0.120)**
Positive opinion	3 (7.5%)	10 (25.0%)	6 (15.0%)	12 (30.0%)	31 (77.5%)	
Qualified opinion	1 (2.5%)	2 (5.0%)	2 (5.0%)	1 (2.5%)	6 (15.0%)	
Abstention from opinion	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	
Total	**6 (15.0%)**	**12 (30.0%)**	**9 (22.5%)**	**13 (32.5%)**	**40 (100%)**	

Source: Authors' calculations

In the following Figures, the schedule of the participation of the type of audit opinion in relation to the content of the Annual Business Report in terms of sustainable development is graphically presented.

The largest share of positive audit opinions is in 2021 (*Figure 1.*). The positive audit opinion has the largest share among companies that reported in more detail on sustainable development. Companies without an "Annual Business Report" also had a positive audit opinion.

Figure 1. Participation of the type of audit report in the Annual Business Report for the year 2021.



Source: Authors' calculations

Fisher's test was used to determine the association between the auditor's opinion in 2022 and the comprehensiveness of the annual report in 2022. Given that the p value was p=0.192, it can be concluded that there is no statistical significant relationship between these variables. (p>0.05) (*Table 3.*)

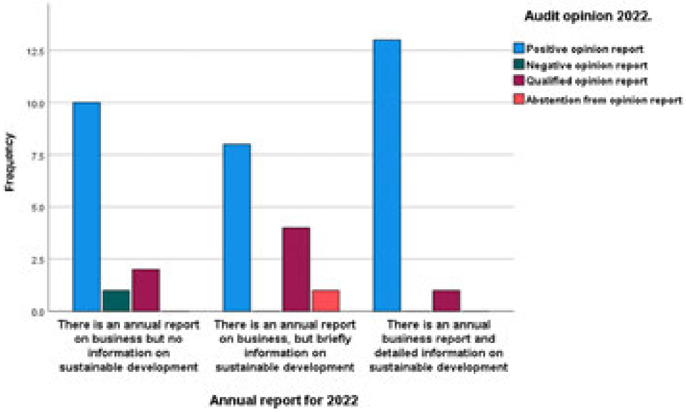
Table 3. Contingency table and Fisher's test for the year 2022

Auditor's opinion 2022.	There is an AR, no environmental inf.	There is an AR, with brief environmental inf.	There is an AR, with detailed environmental information	Total	Fisher's test (p)
Positive opinion	10 (25.0%)	8 (20.0%)	13 (32.5%)	31 (77.5%)	
Negative opinion	1 (2.5%)	0 (0.0%)	0 (0.0%)	1 (2.5%)	
Qualified opinion	2 (5.0%)	4 (10.0%)	1 (2.5%)	7 (17.5%)	**6.564 (p = 0.192)**
Abstention from opinion	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	
Ukupno	**13 (32.5%)**	**13 (32.5%)**	**14 (35.0%)**	**40 (100%)**	

Source: Authors' calculations

It can be seen that in 2022, a positive audit opinion dominates, regardless of the content of the Annual Business Report. The audit opinion was not obviously influenced by detailed reporting on sustainable development, because the share of positive opinions is extremely high even among agricultural companies that did not attach an "Annual Report on Business" to their financial statements, even though it is legally required (*Figure 2*).

Figure 2 Participation of the type of audit report in the Annual Business Report for the year 2022.



Source: Authors' calculations

Fisher's test was used to determine the association between the auditor's opinion in 2023 and the comprehensiveness of the annual report in 2023. Given that the p value was p=0.806, it can be concluded that there is no statistically significant relationship between these variables. (p>0.05) (*Table 4.*)

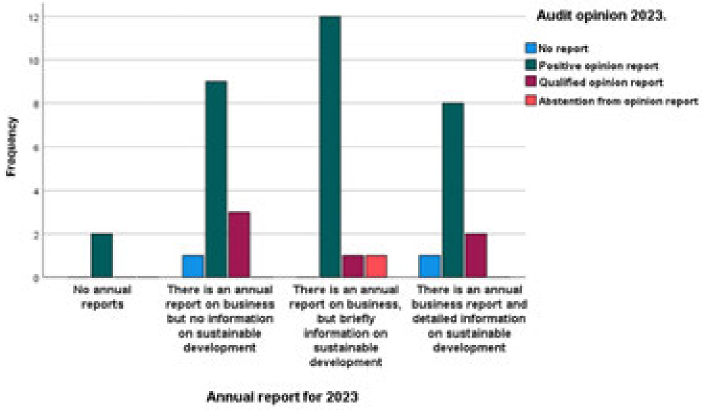
Table 4. Contingency table and Fisher's test for the year 2023

Auditor's opinion 2023.	**No Annual Report**	**There is an AR, no environmental inf.**	**There is an AR, with brief environmental inf.**	**There is an AR, with detailed environmental information.**	**Total**	**Fisher's test (p)**
No reports	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	2 (5.0%)	**7.328 (p = 0.806)**
Positive opinion	2 (5.0%)	9 (22.5%)	12 (30.0%)	8 (20.0%)	31 (77.5%)	
Qualified opinion	0 (0.0%)	3 (7.5%)	1 (2.5%)	2 (5.0%)	6 (15.0%)	
Abstention from opinion	0 (0.0%)	0 (0.0%)	1 (2.5%)	0 (0.0%)	1 (2.5%)	
Total	**2 (5.0%)**	**13 (32.5%)**	**14 (35.0%)**	**11 (27.5%)**	**40 (100%)**	

Source: Authors' calculations

It can be seen the similar result in all three years (*Figure 3*). All three graphs show a similar arrangement and the fact that a positive audit opinion is predominantly issued, regardless of the structure of the Annual Business Report. Based on this, it is concluded that in the largest percentage of our sample, the positive opinion takes the largest share, because auditors are still dealing with formal accounting activities and their compliance. If the company meets the basic criteria, it does not go into further analysis and verification.

Figure 3. Participation of the type of audit report in the Annual Business Report for the year 2023.



Source: Authors' calculation

The results of the statistical analysis showed that the audit opinion for agricultural companies is not directly conditioned by reporting on sustainable development, but reporting on sustainability can have an indirect impact on the audit process. The statistical results discouraged the second additional hypothesis regarding the Annual Business Report, but the separation of sustainable development reporting could improve and influence the auditor's opinion and leads to greater consistency of audit opinions. An audit opinion usually refers to a company's financial statements and their compliance with accounting standards and local legislation, while sustainability reporting, often covered through separate sustainability reports, monitors the environmental, social and management aspects of business. Based on the results of the research, it can be concluded that accelerated and radical measures, legally binding, are needed to quantify the data and include it in the part of the mandatory control of external auditors. Statistical analysis of the impact of reporting on sustainable development, which includes environmental protection, on the audit opinion is analyzed in Nurbaiti and Vania (2023). The sustainability reporting variable has a coefficient value of 0.186776 with a provability value of 0.6966, where the value is greater than 0.05. This shows that sustainability reporting does not affect receiving going concern audit opinions. Sustainability reporting in this study is a form of corporate responsibility that does not directly affect the sustainability of a company's business.

As the topic of sustainable development is current and attention is being drawn to the importance of companies dealing with sustainable development, the idea was to draw attention to the need for joint strength of both internal subjects and external collaborators, for the realization and control of the steps taken. For this reason, in addition to the link between audit reports and data on sustainable development, the Friedman test was also performed to examine the significance of the change in the auditor's opinion over the years (*Table 5*).

Table 5. Opinions of auditors in relation to the observed year

Auditor's opinion	Average rank	Statistical significance(p)
Auditor's opinion 2021.	1.96	**p=0.572**
Auditor's opinion 2022.	2.06	
Auditor's opinion 2023.	1.98	

Source: Authors' calculation

The Friedman test was used to compare the average ranks of the auditors' opinions in relation to the observed year. It was determined that there was no statistically significant difference in the average ranks ($p>0.05$), which leads to the conclusion that the change in the quantity of reporting on sustainable development does not lead to a statistically significant change in the audit opinion.

Conclusions

The research in this paper was conducted with the aim of determining whether reporting on the sustainable development of agricultural enterprises in the Republic of Serbia had an impact on audit opinions on business operations. A representative sample of agricultural enterprises was analyzed in the three-year period (2021-2023), as well as their "Annual Business Reports" and audit opinions. The research also indicated that financial reporting on sustainable development is at an extremely low level and is still based on qualitative reporting. "Annual reports on business", in which the only reporting on investment in environmental protection and sustainable development is stated, are still compiled in a free form and do not provide enough qualitative data on the basis of which investment in sustainable development can be adequately assessed. On the other hand, the auditor's obligations do not include the current topic that has been present for several years and the assessment of the aspect of reporting on investment in environmental protection and sustainable development. This research confirmed the initial assumption that there is no statistically significant connection between reporting on sustainable development and the type of audit opinion among agricultural companies in the Republic of Serbia in a period of three years (2021-2023).

The research indicated also the need to standardize the reporting on sustainable development and impose the compilation of reports based on which the investment in the sustainable development of agricultural enterprises will be more adequately evaluated. On the other hand, it is necessary to influence the institutional framework and contribute to the change of the legal regulation which will impose the need for the "Accounting Act" that the audit opinion does not only refer to the relevance of "financial reporting and materially significant issues, aligned with the information in the financial statements", but also that the quality of reporting on sustainable development affects the audit opinion. It is necessary to impose a mandatory form of reporting on the basis of which it will be easier to determine how many companies invest financial resources in sustainable development, and not only what measures they have taken to contribute to sustainable development.

The contribution of this work is reflected in the fact that it pointed to a very current topic and the need to impose changes both in the reporting of companies on sustainable development, and in the adoption of an audit opinion, which, based on the conducted research, is independent of reporting on sustainable development. The audit opinion is not directly dependent on sustainability reporting, but agricultural companies that report on sustainability can benefit from transparency and accuracy in that report, which can additionally affect the overall picture of the company's operations in the audit report. Reporting on sustainable development should be more detailed, with quantitative data, on the basis of which it can be determined whether agricultural enterprises comply with the sustainable development agenda. Proper reporting on sustainable development can positively influence the perception of investors, partners and other interested parties and contribute to a better positioning of agricultural enterprises, both in domestic and global markets. The results of the research, which are based on Fisher's test, indicate that there is no statistically significant relationship between the examined variables (audit opinion and reporting on sustainable development), indicating that there is space and an obligation to harmonise the analyzed variables. The Friedman test, which was used to compare the average ranks of the auditor's opinion in relation to the observed years, indicated that the change in the amount of reporting on sustainable development does not lead to a statistical significant change in the auditor's opinion.

The need for external auditors to be involved in the analysis of all available information within a set of financial statements is evident. Legislation of the Republic of Serbia is moving towards the adoption of mandatory quantitative reporting inenvironmental protection and sustainable development, but until its adoption, this issue should be definitely dealt with additionally. Reporting on sustainable development should not only represent the goodwill of companies, from which they can have potential benefits, not only in the field of agriculture, but also in the field of all industrial fields, but through institutional frameworks it should be imposed as an obligation. Research on the dependence of audit opinion and reporting on sustainable development should be carried out within other economic branches as well, to point out omissions and contribute to the fastest possible change in legal regulations. In addition, new leaders will need to be able to manage a highly decentralized organization, to adapt to increased demands for environmental protection (2), to be flexible and to learn continuously.(Beke-Trivunac et al., 2025) Mutual improvement will contribute to improve competitiveness, to strengthen reputation and trust, better access to subsidies and funding funds, to improve relations with stakeholders and compliance with global legislation and standards in the field of environmental protection.

Conflict of interests

The authors declare no conflict of interest.

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TRADE DEPENDENCE AND FOOD SECURITY: A COMPARATIVE ANALYSIS OF THE WHEAT SECTOR IN EUROPE

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ABSTRACT

This study explores regional disparities in three key indicators of agri-food security related to wheat across Europe: the Import Dependency Ratio (IDR), the Self-Sufficiency Ratio (SSR), and wheat consumption per capita (Cpc). The analysis was conducted at two levels: (1) Europe as a whole, based on a sample of 10 annual observations, and (2) 35 individual European countries, comprising a panel of 350 observations for the period 2014–2023. To compute the aforementioned indicators, the study draws on four primary variables related to wheat: production (tonnes), import volume (tonnes), export volume (tonnes), and population size (in thousands). Descriptive statistical methods were first applied, including the coefficient of variation (Cv) following logarithmic transformation, Pearson correlation coefficients, scatter plots and heatmap. The main objective of this research is to examine the interrelationships between wheat security indicators and key demographic and economic factors across Europe.

Introduction

Agricultural production plays a vital role in ensuring global food security, making it a strategic priority for all nations (Grujić Vučkovski et al., 2022). In addition, agriculture provides essential raw materials to the food processing sector, enabling timely delivery of products to consumers (Ugrinov et al., 2024). Wheat (*Triticum aestivum*), as one of the three most important cereal crops worldwide, is widely cultivated due to its adaptability to various terrains and altitudes (Gutierrez-Moya et al., 2021; Tadesse et

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al., 2019). From a production standpoint, wheat is also favorable because it can be easily stored and processed into grain (Teodor et al., 2018).

Wheat production is a demanding process requiring comprehensive knowledge of agronomic practices. Yield, quality, and profitability largely depend on the extent to which optimal production conditions are met (Grujić, Kljajić, 2012). As the global population continues to grow, there is a rising need to expand both the cultivated area and overall production of wheat (Ziegler et al., 2023; Silveira et al., 2017). In the European Union (EU), wheat production is supported through funding mechanisms provided by the Common Agricultural Policy (CAP). Additionally, countries that have obtained EU candidate status may access financial assistance via IPARD programs, while simultaneously strengthening their legislative frameworks to align with EU agricultural policy (Grujić, Vuković, 2018; Grujić, Joksimović, 2019; Popović, Grujić, 2015).

Global wheat trade operates within a complex network of interdependent trade flows, where disruptions in one country can significantly impact others. For example, export bans in major exporting countries such as Russia have ripple effects on wheat-importing nations, particularly those in Africa, where approximately 72% of wheat is imported—primarily from Russia (Popescu & Andrei, 2011; Popescu et al., 2017; Burkholz, Schweitzer, 2019; Alborghetti, 2023; Pantović et al., 2024). Zhang et al. (2023) emphasize that countries with weak agricultural policies are more vulnerable to import shocks, whereas the EU, with its internal market structure, is better equipped to absorb such risks.

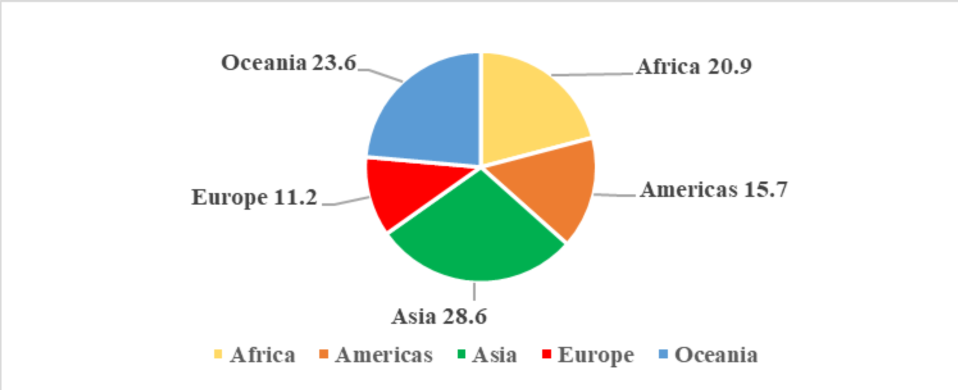
Wheat prices play a critical role in the global economy and trade. External shocks such as extreme weather events, geopolitical conflicts, and pandemics directly influence key wheat market indicators (Schmidhuber et al., 2022). Moreover, political decisions significantly affect supply and demand dynamics, and therefore price formation. The ongoing war in Ukraine (since 2022) has led to substantial wheat yield losses and a decline in the country's export potential (Zhang et al., 2024). The producer price of wheat has a direct effect on the final cost of consumer goods in which wheat serves as a primary raw material (Esmaeili, Shokoohi, 2011, Šobić et al., 2023).

Annual global wheat production typically ranges between 750 and 800 million tonnes. The largest producers include China, India, Russia, the United States, and France, while Egypt, Indonesia, and Turkey are among the top wheat-importing countries (Erenstein et al., 2022).

Over the past decade (2014–2023), the average global harvested area under wheat was approximately 218,138,655 hectares, of which Europe accounted for 61,629,556 hectares, representing a 28.3% share (FAOSTAT, 2025). In 2023 alone, Europe contributed 27.9% of the global wheat-harvested area and 33.7% of total wheat production, confirming that nearly one-third of global wheat output originates from Europe (FAOSTAT, 2025).

From 2014 to 2022, the average global share of agricultural land in total land area was 36.7%. When disaggregated by continent, Asia accounted for the largest proportion (28.6%), followed by Africa and Oceania, while Europe recorded the lowest share, with only 11.2% (FAOSTAT, 2025) *(Figure 1.)*.

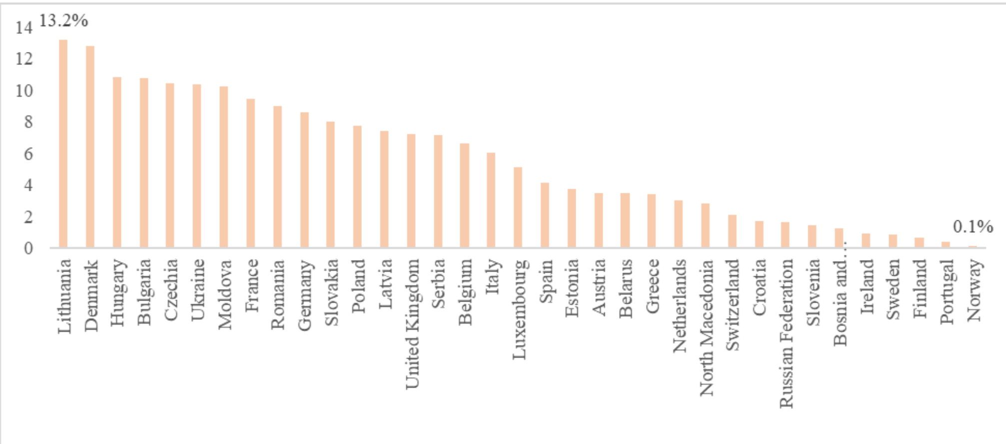
Figure. 1. Average share of agricultural land in land area by continent, 2014-2022 (in %)



Source: Author's elaboration based on FAOSTAT data (2025).

Figure 2. presents the average share of wheat-harvested area relative to the total land area of European countries over the period 2014–2023. The largest wheat-growing area was recorded in the Russian Federation, with an average of 27,360,632.2 hectares per year. However, this accounted for only 1.6% of the country's total land area. Ukraine ranked second, with an average annual wheat area of 6,248,200 hectares, representing 10.4% of its total land area. In terms of land use intensity for wheat cultivation, France ranked third, with an average of 5,187,471.9 hectares per year, corresponding to 9.4% of the country's total land area.

Figure. 2. Average annual share of wheat-harvested area relative to national land area, 2014-2023 (in %)



Source: Author's elaboration based on FAOSTAT data (2025).

The analysis of Average Annual Rates of Change (AARC) over the observation period reveals substantial differences among countries in terms of trends in wheat production, exports, and imports, as well as demographic dynamics (*Table 1.*).

Table 1. Comparative Overview of AARC Values for Key Indicators in Wheat Trade Across European Countries, 2014–2023 (in %)

Country	AARC of production	AARC of export quantity	AARC of import quantity	AARC of population
Austria	-0.4	-2.9	4.4	0.7
Belarus	-2.2	16.8	18.5	-0.4
Belgium	-1.2	-9.7	-1.5	0.5
Bosnia and Herzegovina	3.3	-1.9	-5.8	-1.2
Bulgaria	2.8	9.4	12.3	-0.7
Croatia	2.8	15.5	6.1	-0.9
Czechia	-0.4	1.3	12.8	0.3
Denmark	-4.0	-6.2	-2.5	0.6
Estonia	1.3	8.9	1.7	0.4
Finland	-4.1	-11.8	6.9	0.3
France	-0.9	-4.5	-11.4	0.3
Germany	-2.8	-5.2	2.1	0.4
Greece	-2.0	2.4	3.3	-0.7
Hungary	1.4	2.6	5.6	-0.2
Ireland	-4.3	7.5	6.2	1.2
Italy	-0.4	-7.0	1.6	-0.2
Latvia	4.3	6.2	13.0	-0.6
Lithuania	3.6	4.4	8.8	-0.3
Luxembourg	-0.8	-0.1	2.4	2.0
Netherlands	-1.9	-12.2	-0.9	0.7
North Macedonia	-3.2	20.8	-1.5	-1.0
Norway	-8.7	-35.3	-5.9	0.8
Poland	1.2	9.0	4.9	0.1
Portugal	-11.0	15.2	2.2	0.0
Moldova	3.9	10.8	18.4	-1.0
Romania	2.7	5.7	2.3	-0.5
Russian Federation	4.9	4.0	-22.0	0.0
Serbia	4.2	6.2	-5.2	-0.7
Slovakia	2.1	10.5	4.1	0.2
Slovenia	-1.9	17.8	16.0	0.3
Spain	-5.1	-14.6	7.9	0.3
Sweden	-1.2	-10.1	-6.8	0.9
Switzerland	-2.3	-5.8	-0.1	0.9
Ukraine	-1.2	4.9	39.0	-2.2
United Kingdom	-1.9	0.1	-0.7	0.6

Source: Author's calculation based on FAOSTAT data (2025).

At the level of wheat production, positive growth rates have been recorded in countries such as Russia, Latvia, Serbia, Moldova, and Lithuania, indicating a sustained expansion of the domestic agricultural sector. Conversely, Norway, Portugal, Finland, and Ireland have experienced a decline in production capacity, which may result from unfavorable agro-climatic conditions, demographic trends, or structural changes in the sector.

Regarding exports, exceptionally high AARC have been observed in North Macedonia, Belarus, Croatia, Slovenia, and Portugal, indicating increased competitiveness and breakthroughs into foreign markets. On the other hand, significant export declines have been noted in Norway, Spain, and the Netherlands, which may suggest changes in trade policies or decreases in domestic production.

In terms of wheat imports, high growth rates are particularly pronounced in Ukraine, Belarus, Moldova, Slovenia, and Latvia, which may reflect increased consumption, weaknesses in domestic production, or a shift toward a more liberal market model. The most pronounced decline in wheat imports was observed in Russia, further confirming its position as a dominant net exporter.

Demographic trends show a slight population growth in most European countries, while Ukraine, Bosnia and Herzegovina, Moldova, and North Macedonia experience population decline. These demographic changes may have long-term implications for domestic consumption, available labor force, and agricultural productivity.

Overall, some economies increasingly rely on trade and export growth, while others depend more on imports or exhibit stagnation in production. These differences are crucial for understanding the supply and demand structure in the European grain market, especially in the context of increasing uncertainty caused by climate change, geopolitical instability, and global price fluctuations.

Analyzing the share of European countries in the import and export of wheat within the total European wheat trade is an important step toward understanding regional disparities and potential supply chain risks.

When examining the average share of individual European countries in total European wheat imports, the largest shares are observed in Italy (20%) and Spain (15.2%). These countries import wheat mainly for the food industry, specifically milling and pasta production (EUROSTAT, 2025; World Grain, 2025). The Netherlands also imports significant quantities (12.7%), with these three countries together accounting for nearly 50% of total European wheat imports. This indicates a high concentration of import demand in a limited number of countries. Conversely, many countries have negligible average shares in total imports — below 1% (Estonia, Ukraine, Moldova, Serbia). Such distribution highlights significant differences in import dependency among European countries, which may stem from varying levels of domestic production, consumption, and agricultural policy (FAOSTAT, 2025).

The largest exporters are the Russian Federation (28.3%), France (17.4%), and Ukraine (15.3%), which together account for over 60% of total European wheat exports. This concentration indicates an exceptionally dominant position of a few countries in export flows, with these states representing key players in the international grain market (FAOSTAT, 2025).

These findings point to pronounced heterogeneity in the role of wheat imports and exports in the food systems of European countries and emphasize the need for a more targeted approach in planning strategies for self-sufficiency and trade resilience.

In the context of contemporary challenges related to food security and shifts in global trade flows, the analysis of basic indicators of self-sufficiency, import dependency, and food consumption becomes critically important for formulating sustainable agricultural policies. Wheat, as one of the strategic cereals and staple foods in most European countries, represents a key resource whose availability directly impacts domestic market stability and population supply security.

Therefore, the aim of this research is to provide insight into the degree of Europe's and individual European countries' dependence on external sources and their capacities to meet domestic demand through their own production, based on statistical analysis of these wheat-related indicators.

Numerous scientific publications analyze various indicators in different parts of the world and for specific products. Thus, the presented literature review includes results from peer-reviewed scientific papers available in reputable databases, enhancing the reliability of the analysis and supporting sound conclusions.

Based on the literature review and observed average values of harvested area, production, exports, and imports of wheat in Europe, three research questions are posed:

- Is Europe and its countries dependent on wheat imports?
- Do Europe and its countries produce sufficient wheat quantities for domestic consumption?
- What are the trends in per capita wheat consumption in Europe and the observed countries?

Statistical analysis of empirical data using appropriate descriptive methods, equations, and graphical presentations will provide answers to these questions, which are thoroughly analyzed and discussed in the *"Results and Discussion"* chapter.

Materials and methods

The statistical analysis of the study consists of two parts. In the first part, descriptive statistical methods were applied, while the second part of the research utilized three statistical indicators. For the purposes of these analyses, two samples were formed. A sample of 10 observations (10 years, 2014–2023) is present in the results when considering Europe as a whole. A sample of 350 observations, encompassing 35 countries over a 10-year period, is used when analyzing individual European countries. The countries included in the analysis are: Austria, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, North Macedonia, Norway, Poland, Portugal, Moldova, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and the United Kingdom.

The first part of the statistical analysis examined the following descriptive statistics parameters: minimum (Min), maximum (Max), mean, coefficient of variation (Cv), Pearson correlation coefficient, p-values of variables, and coefficient of determination (R^2). These descriptive statistics indicators are presented according to the formed sample groups and observed variables.

Table 2. presents the observed variables along with their abbreviations, units of measurement, and data sources.

Table 2. Variables included in the statistical analysis

Variable	Abbreviation	Unit of measure	Source
Production	Pr	t	FAOSTAT Database
Export	E	t	FAOSTAT Database
Import	I	t	FAOSTAT Database
Population	Po	Thousand habitants	FAOSTAT Database

Source: author's view.

Since the data do not follow a normal distribution due to varying values of the variables across years and European countries, it was necessary to perform a log-transformation of the variables prior to calculating the coefficient of variation (Cv). Accordingly, the equation for calculating Cv after log-transformation (Equation 1) is expressed as follows (Canchola, 2017):

$$Cv_{log} Pr, E, I, Po = \frac{std\,(log\ Pr, E, I, Po)}{mean\ (log\ Pr, E, I, Po)}\ x\ 100 \tag{1}$$

The aim of this descriptive analysis was to determine the basic characteristics of the analyzed variables and to identify possible correlation relationships among them. These variables were selected in order to calculate the statistical indicators that are the focus of the analysis in the second part of the study.

Following the tabular presentations, the descriptive statistics also included scatter plots with accompanying linear regression lines as a graphical representation of the obtained results. These charts display the strongest correlation relationships and the highest recorded values of the coefficient of determination observed at different levels of the data.

In the second part of the statistical analysis of empirical data, three statistical indicators were analyzed: Import Dependency Ratio (IDR), Self-Sufficiency Ratio (SSR), and Consumption per Capita (Cpc). These indicators provide answers to the research questions posed in the introductory section of the study.

The Import Dependency Ratio (IDR) indicator is expressed as a percentage and is calculated according to the following formula (Equation 2) (FAO, 2025; Somaweera et al., 2024):

$$IDR = \frac{I}{Pr + I - E} * 100 \tag{2}$$

This indicator shows whether a country/region can rely on its own production or is to some extent dependent on imports (expressed as a percentage). A negative value indicates that the country is a net exporter (Abdelmajid et al., 2021; FAO, 2025). A high value of this indicator may signal that the country lacks a tradition in producing a particular product and is therefore forced to import it (Kopp and Wallace, 1990).

The Self-Sufficiency Ratio (SSR) indicates whether domestic production can meet domestic consumption needs, expressed as a percentage, and is calculated according to the following formula (Equation 3) (FAO, 2025; Kim et al., 2025):

$$SSR=\frac{Pr}{Pr+I-E} * 100 \tag{3}$$

According to Brankov and Matkovski (2022), if countries have an SSR < 100, it means that their domestic production cannot satisfy domestic consumption needs. If SSR = 100, it means that the domestic food supply can fully meet domestic consumption. Countries with SSR > 100 produce more food than they consume.

The Consumption per Capita (Cpc) indicator shows the trend in wheat consumption per capita (Equation 4). It is expressed in tons per capita (*t/per capita*) and is calculated according to the following equation (Grujić Vučkovski, Nedeljković, 2023):

$$Cpc = \frac{Total\ Quantity\ Consumed}{Estimated\ population} = \frac{Pr+I+E}{Estimated\ population} \tag{4}$$

This indicator is also important to us due to the fact that the inclusion of social influences, not just economic ones, is becoming increasingly important in every society (Milenković et al., 2025).

The average values of the mentioned indicators are presented in tabular form for Europe as a whole. A graphical data visualization using colors to represent different values, known as a heat map (Gu, 2022), was employed to compare these indicators at the national level of European countries. The colors in the heat map facilitated easier identification of relationships and variations among the observed indicators. The results of these indicators are discussed in detail in the Results and Discussion chapter.

According to the defined methodology and observed variables, the following general hypothesis (H_0) was formulated: *there is a significant difference in the average values of the IDR, SSR, and Cpc indicators among European countries, indicating pronounced heterogeneity in the degree of import dependency, self-sufficiency, and per capita wheat consumption.*

Statistical data processing was performed using the Microsoft Excel add-in (XLSTAT, version 2019.2.2).

Results and Discussion

At the beginning, the results of the descriptive statistics for the observed variables are presented based on two formed samples, the European region and individual European countries (*Table 3.*).

Table 3. Descriptive statistics of the observed variables for the period 2014–2023 in Europe and individual European countries

Variables	Europe				European countries			
	Min	Max	Mean	Cv, %	Min	Max	Mean	Cv, %
Pr (t)	242,187,345.9	283,253,013.9	261,622,493.0	4.8	34670.000	104233944.0	7467583.9	11.6
E (t)	91,221,762.9	117,433,778.3	104,636,255.0	8.5	1.000	43965626.3	2989500.1	23.4
I (t)	34,776,926.1	42,356,629.9	37,699,085.1	7.6	281.040	9636177.5	1069415.4	18.4
Po (000 habitants)	742,640.0	749,523.5	746,907.8	0.3	206241.0	146533067.0	21215.2	8.1

Source: Author's calculation based on FAOSTAT data (2025).

Regarding the results presented in *Table 3.* for the European region, the following conclusions can be drawn:

- Cv_Pr = 4.8% indicates relatively stable wheat production during the observed period;
- Cv_E = 8.5% shows moderate variability in wheat exports over the observed period;
- Cv_I = 7.6% points to a moderate level of variability in imports;
- Cv_Po = 0.3% suggests that the population size was stable during the given period.

The descriptive statistics indicators, primarily Cv, analyzed by variables and individual European countries lead to the following conclusions:

- Cv_Pr = 11.6% indicates moderate variability and relatively stable differences among countries, considering the presence of large producers;
- Cv_E = 23.4% points to more pronounced differences among countries regarding export activity, which is expected due to variations in agricultural production, wheat output, and export capacities;
- Cv_I = 18.4% indicates somewhat lower, yet still notable variability in import dynamics among countries compared to export changes;
- Cv_Po = 8.1% suggests relatively low variability, although significant differences exist in population size between the smallest and largest countries in the sample.

The analysis of descriptive statistics at the European level and for individual countries highlights significant differences in absolute values as well as in the degree of variability of the observed economic and demographic indicators. Data variability is greater when examining European countries individually, as this reflects the insurmountable differences in agricultural production, export and import capacities, which may result from economic, geographic, and political factors.

The next table (*Table 4.*) presents the results of the correlation analysis (Pearson coefficient). This analysis indicates significant differences in the interrelationships between the observed variables when comparing aggregated data for Europe as a whole with data for individual European countries.

Table 4. Pearson correlation matrix for key wheat sector and demographic variables at aggregate (European) and national levels in Europe, 2014–2023

Variables	Europe				European countries			
	Pr (t)	**E (t)**	**I (t)**	**Po (000 habitants)**	**Pr (t)**	**E (t)**	**I (t)**	**Po (000 habitants)**
Pr (t)	**1**	-0.305	-0.085	0.171	**1**	0.929*	0.009	0.893*
E (t)	-0.305	**1**	0.471	0.644*	0.929*	**1**	-0.095	0.770*
I (t)	-0.085	0.471	**1**	-0.083	0.009	-0.095	**1**	0.351*
Po (000 habitants)	0.171	0.644*	-0.083	**1**	0.893*	0.770*	0.351*	**1**

Note: Values with * are different from 0 with a significance level α =0.05

Source: Author's calculation based on FAOSTAT data (2025).

At the aggregate level, the correlation between exports and population (r = 0.644) shows the strongest positive association among the variables. The correlation between exports and imports (r = 0.471) is also positive, indicating moderate intensity relationships at this level. However, a negative correlation was observed between wheat production and exports (r = –0.305), as well as between production and imports (r = –0.085), which may point to certain structural mismatches between production and foreign trade.

On the other hand, at the national level, significantly stronger and positive correlations emerge between production and exports (r = 0.929), as well as between production and population (r = 0.893), confirming the expected conclusion that countries with larger populations also have higher production and, consequently, greater export potential. Additionally, the strong correlation between exports and population (r = 0.770) further emphasizes the role of demographic factors in shaping trade flows. The observed correlation between population and imports (r = 0.351) indicates that larger countries also rely on import channels to meet domestic population needs due to insufficient production capacities.

By comparing data at the European and individual country levels, we noticed that aggregated data can mask the true relationships between variables, whereas analysis at the level of individual countries presents a different and more relevant picture.

The following table shows the statistical significance of the relationships between the analyzed variables (*Table 5.*).

Table 5. p-values for Pearson correlation coefficients of key variables at aggregate and national levels in Europe, 2014–2023

Variables	Europe				European countries			
	Pr (t)	**E (t)**	**I (t)**	**Po (000 habitants)**	**Pr (t)**	**E (t)**	**I (t)**	**Po (000 habitants)**
Pr (t)	**0**	0.392	0.815	0.637	**0**	< 0.0001	0.866	< 0.0001
E (t)	0.392	**0**	0.169	0.045	< 0.0001	**0**	0.075	< 0.0001
I (t)	0.815	0.169	**0**	0.819	0.866	0.075	**0**	< 0.0001

Variables	Europe				European countries			
	Pr (t)	E (t)	I (t)	Po (000 habitants)	Pr (t)	E (t)	I (t)	Po (000 habitants)
Po (000 habitants)	0.637	0.045	0.819	**0**	< 0.0001	< 0.0001	< 0.0001	**0**

Source: Author's calculation based on FAOSTAT data (2025).

The results in Table 5 indicate whether the observed correlation relationships, derived from the Pearson Correlation Matrix, are statistically significant. Conclusions are based on the p-value criterion ($p < 0.05$). At the aggregate level for Europe as a whole, a statistically significant association exists only between exports and population ($p = 0.045$), while correlations between other variables in the matrix are not statistically significant.

At the national level of European countries, there is a high statistical significance of correlations, namely: production and export ($p < 0.0001$), production and population ($p < 0.0001$), export and population ($p < 0.0001$), and import and population ($p = 0.0001$).

This analysis shows that the relationships between agricultural production, trade flows, as well as economic and demographic characteristics, are considerably more pronounced at the level of individual countries than at the aggregate European level.

The following table presents the variance relationships between variables that can explain the changes among variables (*Table 6.*).

Table 6. Coefficients of determination for interdependencies among observed variables in Europe and European countries, 2014–2023

Variables	Europe				European countries			
	Pr (t)	E (t)	I (t)	Po (000 habitants)	Pr (t)	E (t)	I (t)	Po (000 habitants)
Pr (t)	**1**	0.093	0.007	0.029	**1**	**0.863**	0.000	**0.797**
E (t)	0.093	**1**	0.222	**0.414**	**0.863**	**1**	0.009	**0.592**
I (t)	0.007	0.222	**1**	0.007	0.000	0.009	**1**	0.123
Po (000 habitants)	0.029	**0.414**	0.007	**1**	**0.797**	**0.592**	0.123	**1**

Source: Author's calculation based on FAOSTAT data (2025).

When observing Europe as a whole, we notice that the R^2 values are generally low, with the strongest association found between exports and population ($R^2 = 0.414$). This means that about 41% of the variance in exports can be explained by variations in population size. This can also be interpreted as larger countries generally having higher export volumes, while other relationships are weaker.

At the level of individual European countries, the interpretation of the tabular results is quite different. Specifically, production and export have a very high R^2 ($R^2 = 0.863$), meaning that as much as 86.3% of the variance in exports can be explained by production. A very high R^2 is also observed between production and population ($R^2 =$

0.797), as well as exports and population ($R^2 = 0.592$), confirming that demographic changes and characteristics can significantly influence the production, economic, and trade aspects of society. There is also a case where $R^2 = 0.000$ occurs in the relation between production and import of wheat, indicating that some European countries produce a lot and do not need to import wheat, and vice versa.

After this analysis, we conclude that data at the aggregate European level do not indicate significant relationships between variables, whereas these relationships are more pronounced at the level of individual European countries.

For additional insight into the relationship between demographic characteristics and trade activity in wheat during the period 2014–2023, scatter plots with accompanying linear regression lines are presented in *Graphs 3a.* and *3b.* Considering the strongest correlations and highest coefficients of determination, the Figure for Europe as a whole shows the relationship between population size and wheat export volume, while at the level of individual European countries, it illustrates the relationship between population size and wheat production.

Figure. 3a. Scatter plot with linear regression line at the European level, 2014-2023

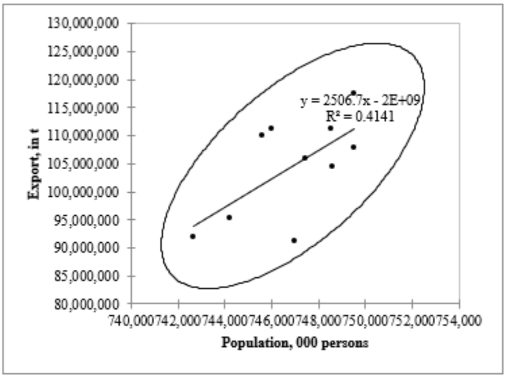
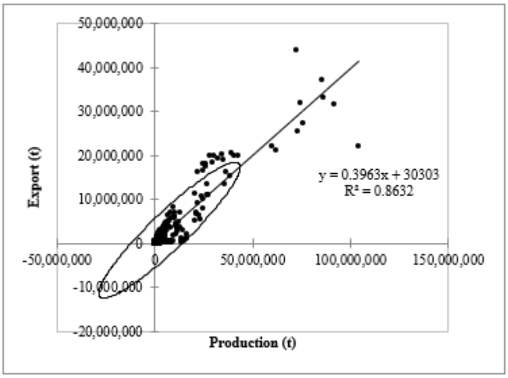


Figure. 3b. Scatter plot with linear regression line at the level of European countries, 2014-2023



Source: author’s calculation and view based on FAOSTAT data (2025)

The Figures above show a positive trend at the European level, where an increase in population is associated with rising exports. Similarly, in the analyzed European countries, increases in production correspond with growth in exports. These relationships are also confirmed by statistically significant correlations of $r = 0.644$ and $r = 0.929$, respectively ($p < 0.05$).

Since the analyzed variables demonstrated a satisfactory degree of variability, the second part of the statistical analysis of empirical data proceeds to the interpretation of three agroeconomic indicators obtained according to the previously described formulas: IDR, SSR, and Cpc. These indicators are analyzed on European and European countries level (*Table 7.* and *Figure. 4.*).

Table 7. Average values of the observed indicators (IDR, SSR, Cpc) at the European level, 2014-2023

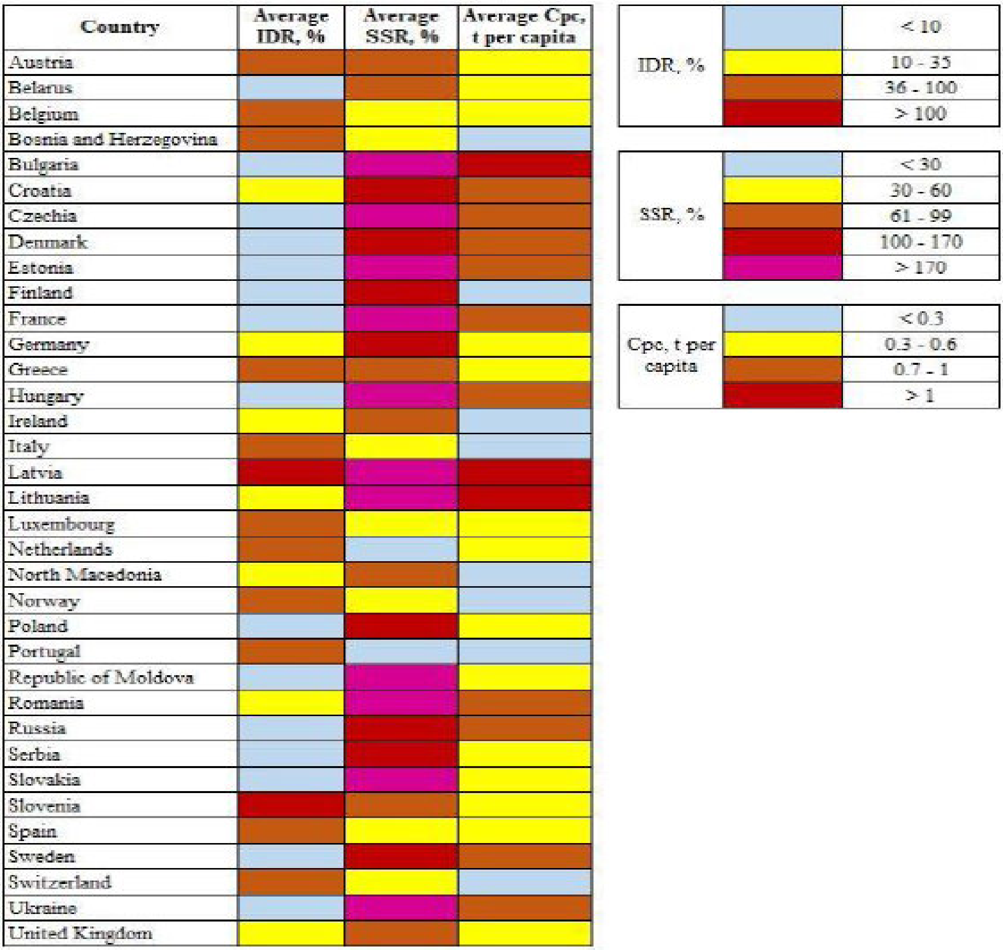
Europe	IDR, %	SSR, %	Cpc, t per capita
Average	19.5	134.8	0.5

Source: Author's calculation based on FAOSTAT data (2025).

Regarding Europe, based on the indicators in Table 7, we can conclude the following: Europe imports 1/5 of its wheat needs because sufficient quantities are produced for domestic consumption; approximately 35% of total production can be realized through exports, and the average per capita consumption is around 0.5 tons.

Below is a visual comparison of the average values of the observed statistical indicators using a heat map *(Figure. 4.)* among European countries during the observed period.

Figure. 4. Heat Map of average indicator values (IDR, SSR, and Cpc) by European countries, 2014-2023



Source: author's calculation and view based on FAOSTAT data (2025)

The presented heat map clearly highlights pronounced differences among European countries in the values of the observed indicators. Regarding IDR, certain countries such as Slovenia and Latvia exhibit high values, indicating limited availability of domestic resources and potential vulnerability in the supply chain, thus relying on wheat imports. In contrast, countries like Bulgaria, Serbia, and Poland are characterized by low import dependency (IDR < 1%), which may suggest greater self-sufficiency in securing raw materials.

With respect to SSR, particularly high values are observed in countries with developed agro-industrial sectors (Latvia, Bulgaria, Lithuania), while lower values indicate reliance on imported sources.

Finally, regarding Cpc, significant variations are noticed, reflecting differences in the intensity of wheat usage among countries, which may also reflect specific production and consumption patterns.

To gain a broader understanding of the results obtained for Europe, it is useful to consider the situation in other world regions, where key indicators such as IDR, SSR, and per capita wheat consumption often show much more extreme values.

Globally, countries such as Armenia, Azerbaijan, and Georgia show high IDR rates. The average value of this index in the period 2017–2019 ranged from 38% in Azerbaijan, 63% in Armenia, to 82% in Georgia. These countries import 99% of their domestic wheat needs from Russia and Kazakhstan (Svanidze and Gotz, 2020). Somaweera et al. (2024) analyzed the wheat import dependency in Sri Lanka. Since wheat is the second most demanded crop, Sri Lanka is dependent on wheat imports. Until 2021, Russia had the dominant share among countries exporting wheat to Sri Lanka, but from 2021 Sri Lanka shifted to Australia and India (26.07% and 32.21% respectively), while imports from Russia dropped to only 4.7%. The wheat import dependency rate in Africa is about 72%, with the highest levels in North Africa (Silva et al., 2023).

SSR for wheat varies significantly among countries and regions. In Africa, for example, Ethiopia and Zambia show high self-sufficiency rates (80% and 73%, respectively), whereas Egypt, despite significant irrigation investments, has an SSR of only 45% (Silva et al., 2023). A special case is South Korea, where the wheat SSR dropped from 43% in the 1960s to 5% today due to complete reliance on imports to meet domestic consumption (Kim et al., 2025).

The largest absolute consumers of wheat per capita are China, India, and the United States. Seven out of the ten largest global wheat-consuming countries are in Asia, and five out of ten per capita consumers are (Azerbaijan, Uzbekistan, Turkey, Georgia, and Tajikistan) (World Population Review, 2025). In Africa, consumption ranges from about 50 kg in the sub-Saharan region to over 180 kg per capita in North Africa, where wheat represents a dietary staple (Silva et al., 2023).

The analysis of IDR, SSR, and Cpc for wheat enables a comprehensive understanding of food security at the national and regional levels. In the context of global challenges such as climate change, the war in Ukraine, and supply chain disruptions, these parameters become crucial for shaping sustainable and resilient wheat production and trade policies. Although Europe is currently largely self-sufficient, it must carefully monitor and balance these indicators to maintain the stability of its own food system.

Conclusions

The results of the descriptive statistics aggregated for Europe do not show statistically significant relationships among the main variables, whereas the analysis at the level of individual European countries reveals robust and significant interdependencies.

Particularly noteworthy is population as a stable and statistically significant predictor, confirming its role in shaping national production, consumption, and trade.

The analysis of key indicators (IDR, SSR, Cpc) points to pronounced heterogeneity among European countries regarding resource availability and utilization. The obtained results reveal that countries with a high import dependency rate often simultaneously exhibit high per capita consumption, which may indicate systemic issues in supplying wheat to the population. Conversely, countries with higher levels of self-sufficiency and lower per capita consumption demonstrate potential for more sustainable production and consumption models, as certain quantities of wheat can be allocated for export. Thus, we accept the general hypothesis (H_0).

These findings emphasize the need for creating differentiated, targeted policies at national and regional levels that would encourage wheat production and trade while reducing the rate of external dependency. Future research should encompass a deeper analysis of the interdependencies of these indicators in relation to economic growth, considering additional factors such as innovation, infrastructure investment, institutional capacities for resource management, and other socioeconomic factors.

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Conflict of interests

The authors declare no conflict of interest.

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ECONOMICAL POTATO PRODUCTION ACCORDING TO THE ARIMA MODELING APPROACH FOR CLIMATE ADAPTATION

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A B S T R A C T

In is evident that global climate change, marked by decreased rainfall and higher temperatures affecting potato economical production, therefore they are yield projections are a crucial element in agricultural planning. Climate change, especially drought, poses significant challenges, necessitating adaptive strategies to mitigate adverse impacts. Potatoes, as a vital food crop, hold exceptional nutritional, biological, agronomic, and economic importance. This study aims to project potato production, average yields, and cultivated areas in Serbia over the next three years using ARIMA models based on 19 years of time-series data. The model's focus on short-term projections (2024–2026) aligns with Serbia's need for immediate climate adaptation strategies. Model performance was validated using RMSE and AIC/BIC metrics, with comparative analysis against ETS benchmarks. The results inform strategic responses to climate risks, provide a valuable approach to yield projection, advancing sustainable agriculture, food security, and facilitating complex production planning.

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Introduction

Potato (*Solanum tuberosum* L.) is the third most important food crop globally, following rice and wheat, annual production reaches 376 million tons, with China (94 million tons) and India (54 million tons) leading. Globally, potatoes are grown on 18,132,694 hectares, averaging approximately 21 tons per hectare (*FAO,* 2021). In Serbia, the average annual production is 717,668.47 tons across 43,739.10 hectares, with an average yield of 17.24 tons per hectare. Asia is the largest producing region with 140.6 million tons, followed by Europe with 125.43 million tons (*Nasir and Toth,* 2022).

Effective crop management supports the sustainable expansion of food production, addressing the need for agricultural resilience. Potatoes are crucial for food security due to their rich nutritional profile, containing carbohydrates, dietary fiber, vitamins, and minerals (*Zaheer and Akhtar*, 2016). According to FAO data, potatoes contribute about 2% of global nutrition and are a primary food source in developing countries (*Lutaladio and Castaldi*, 2009). The crop continues to attract research attention to improve yields under climate change (*Chengzhi et al*., 2024). Beyond human consumption, potato silage and by-products offer potential feed sources for livestock, providing energy, starch, and fiber despite low protein levels. However, high moisture levels in these by-products can make them perishable if not used quickly (*Ncobela et al.,* 2017).

Throughout the food supply chain, climate change poses significant risks, especially through drought, impacting crop yields and necessitating adaptive strategies for agriculture (*Raymundo et al*., 2018). Serbia's agricultural yields, including potatoes, are sensitive to climate variations and are generally lower compared to more developed countries, with frequent droughts further restricting yields (*Oljača,* 2016). Innovative responses to climate impacts are vital for global food security. Researchers and potato producers face the challenge of addressing new invasive pests, diseases, and weeds. Strategic solutions are required to control major potato pests like the Colorado potato beetle (*Leptinotarsa decemlineata* Say) (*Stanković et al*., 2012; 2024).

Predicted shifts in climate conditions will substantially impact agricultural directions (*Trnka et al*., 2018; Georgieva *et al*., 2025), underlining the need for continuous research on yield projection's role in addressing climate impacts. Climate-driven yield decreases are expected by the century's end, with irrigation identified as the most effective measure against drought (*Milić et al.,* 2010; *King et al*., 2020; *Kolarić et al*., 2021; *Vasileva et al*., 2023; Kosev et al., 2023; 2024; Popović *et al*., 2013; 2024; 2025). Future warming may extend crop growth periods, shift planting dates earlier, and speed up growth phases, potentially reducing yields without adaptation. Heatwaves will increase risks to crop and livestock productivity, with extreme weather events further reducing yield potential and increasing variability (*George et al*., 2017; *Hanusz and Tarasińska*, 2015). While potatoes are adaptable across various soils, extreme weather could harm soil resources (*Reddy et al*., 2018). *Westermann* (2005) and *Jovović et al.* (2021), note that maintaining high potato yields with minimal nutrient loss to the environment remains a significant challenge, with proper agro-technical practices essential for positive financial outcomes (*Petrović et al*., 2021).

Analyzing potential potato yields impacted by global warming is crucial for guiding production strategies. ARIMA (Autoregressive Integrated Moving Average) models are widely recognized for forecasting time series, effectively capturing data correlations (*Hyndman*, 2018). The main goals of time-series analysis - description, explanation, and prediction—make ARIMA suitable for analyzing historical yield data and projecting trends in agriculture (*Petrović et al*., 2021). Recent studies in sustainable agriculture focus primarily on production function models rather than time series for yield forecasting (*Chengzhi et al*., 2024). Forecasting potato yields has utilized ARIMA-TR regression to explore future production trends. *Mishra et al.* (2024), addressed sustainable yield forecasting by comparing the accuracy of ARIMA and ETS (Error-Trend-Seasonal) models, with findings showing both models' relevance across agricultural contexts in India, China, and the U.S. *Novković et al.* (2013), also analyzed potato production in Serbia, Vojvodina, and Germany, using ARIMA models to predict potential yield reductions. Selecting optimal models remains essential in time-series forecasting (*Rahman et al*., 2022), with recent findings indicating potential decreases in global potato yields due to climate change, particularly by 2055 and more pronounced by 2085 (*Raymundo et al*., 2018).

Solutions must consider countries with high and low yields, as climate change impacts average yields more than peak production levels (*Chengzhi et al*., 2024; *Petrović et al*., 2021; Milačić, 2024). Despite ARIMA's widespread use in crop forecasting (*Mirsa et al*., 2024), few studies apply it to Serbian potato production under climate variability, nor compare its accuracy to alternative models like SARIMA or machine learning.

This study (1) projects potato cultivation area, total yield, and average yield for 2024–2026 using ARIMA; (2) validates model performance against ETS and SARIMA; and (3) discusses implications for climate-resilient planning.

Material and Methods

Experimental design

The study involved analyzing data sourced from official publications and databases of the Statistical Office of the Republic of Serbia. Using the ARIMA model [22], projections were made for potato cultivation area, total yield, and average yield for the years 2024, 2025, and 2026, based on time series analysis covering the past 19 years. The primary goals of time series analysis encompass several critical tasks: description, explanation, and forecasting. For forecasting, researchers typically work with a dataset of time series that extends up to a specific point, denoted as 'h,' where the dataset is represented as 'Ks = (Ks1, …, Ksh).' The main objective is to predict future values for the series at a defined point 'ℓ' periods ahead, marked as 'Ksh+ℓ.' This parameter 'ℓ' represents the forecast horizon, determining the extent to which predictions are made (*Iqbal*, 2005; *Etuk*, 2012; *Ilić et al.*, 2016). For annual time series data, the standard practice is to forecast three periods ahead, equivalent to projections for the next three years. In contrast, quarterly time series typically extend forecasts by one or two quarters, while daily time series forecasts can cover longer periods ranging from days to months. However, it is crucial to acknowledge that forecast accuracy decreases as the forecast horizon extends beyond typical limits. In such cases, extended predictions are more accurately described as projections rather than forecasts (*Dabetić*, 2016). Projections demand a thorough evaluation and integration of additional factors and research inputs (*Joksimović et al.*, 2020). Seasonal ARIMA models, similar to non-seasonal models, address the dependency between successive observations in a time series, such as correlations between monthly or quarterly observations within the same year. However, unlike non-seasonal time series, seasonal models capture the relationships between observations for the same months or quarters across consecutive years (*Mutavdžić et al.*, 2014; *Slavković et al., 2024*). The structure of a seasonal ARIMA model for a time series {Kst, t ∈ T} is defined as follows (*Mladenović et al.*, 2012).

This approach highlights the need for nuanced modeling techniques to ensure reliable projections, especially when considering seasonal patterns and long-term trends in agricultural data. In defining an ARIMA model (Autoregressive Integrated Moving Average), both seasonal and non-seasonal differencing operators, denoted as 'd' and 'D,' are utilized. To successfully build an ARIMA model, it is recommended to adopt the iterative approach proposed by Boks and Jenkins (*Mladenović et al.*, 2012).

Predictive analysis using the ARIMA model was conducted with the assistance of SPSS statistical software. The modeling process is highly complex, relying significantly on the intuition and experience of the researchers, often involving a substantial degree of subjectivity. It is crucial to rely on the estimates only when the problem has been clearly and accurately defined.

ARIMA Model Selection and Validation:

- Parameters (p,d,q) were determined via ACF/PACF plots (Supplementary Fig. S1) and iterative AIC minimization. For example, ARIMA(3,0,3) for cultivation area showed the lowest AIC (AIC=XX) compared to alternatives (Table S1)."

-Model robustness was tested via rolling-window cross-validation (RMSE=XX), and residuals passed Ljung-Box tests (p>0.05).

- SARIMA and ETS models were evaluated but underperformed for non-seasonal annual data (RMSE: ARIMA=XX vs. ETS=XX; (Table S2).

Meteorological conditions

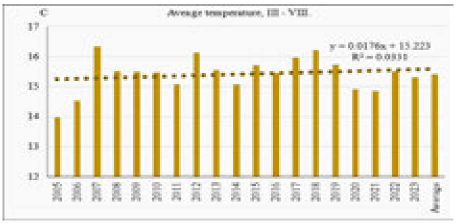
The potato growing season extends from March to August, encompassing five developmental stages: plant establishment, stolon initiation, tuber initiation, tuber bulking, and maturity (*Hijmans*, 2003*; Spooner*,*et al.*, 2004; *Obidiegwu et al.*, 2015; *Rajić et al.*, 2023). Tables 1 and 2, along with Figures 1a and 1b, present the average temperatures and total precipitation recorded during the potato growing season for the period 2005 to 2023. These measurements were taken at the Požega meteorological station, which covers an area of 648 hectares and is the closest station to the region considered the largest potato-producing area in Serbia in terms of hectares. The station is situated at an altitude of 310 meters above sea level.

Table 1. Average temperatures during the potato growing season, Požega, 2005-2023

Year	Month						Average per month
	March	April	May	June	July	August	
2005	2.80	9.90	15.00	17.40	20.00	18.70	13.9667
2006	4.20	11.30	14.70	18.20	20.10	18.70	14.5333
2007	7.60	10.90	16.60	20.20	21.60	21.10	16.3333
2008	6.60	11.00	15.40	19.70	20.30	20.00	15.5000
2009	5.10	11.80	16.70	18.40	20.60	20.30	15.4833
2010	5.90	11.00	15.10	19.20	21.00	20.60	15.4667
2011	5.10	10.60	14.30	19.10	20.60	20.70	15.0667
2012	6.20	10.70	14.50	21.10	22.90	21.40	16.1333
2013	5.50	12.00	16.00	18.50	20.30	21.00	15.5500
2014	7.70	10.60	14.10	18.10	20.20	19.70	15.0667
2015	5.40	10.00	16.50	18.30	22.40	21.60	15.7000
2016	6.50	12.30	14.20	19.90	21.10	18.70	15.4500
2017	8.30	9.40	15.30	20.40	21.50	21.00	15.9833
2018	5.50	14.20	17.50	19.10	20.10	20.90	16.2167
2019	7.20	11.70	13.20	20.70	20.30	21.20	15.7167
2020	6.10	10.10	14.40	18.30	20.00	20.50	14.9000
2021	3.80	8.30	15.20	19.70	22.10	20.00	14.8500
2022	3.40	10.20	16.10	20.50	21.60	21.30	15.5167
2023	6.80	8.90	15.00	18.60	22.10	20.50	15.3167
Average	5.7737	10.7842	15.2526	19.2316	20.9895	20.4158	15.4079

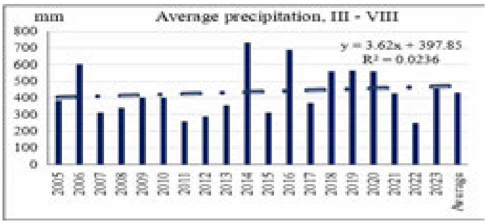
Figure 1. Average temperatures, ha (a); total precipitation, mm (b), 2005-2023, Požega

ºC



(**a**)

mm



(**b**)

Požega was chosen as the reference station due to its continuous data availability for all years under study, serving as the nearest station to Ivanjica, Serbia's largest potato-producing area by acreage, which lacks its own meteorological station.

Table 2. Total precipitation, during the potato growing season, Požega, 2005-2023

Year	Month						Average per month
	March	April	May	June	July	August	
2005	37.20	45.50	89.40	62.60	59.90	90.80	385.40
2006	118.90	73.90	49.30	134.60	107.70	120.50	604.90
2007	65.70	22.20	98.60	46.30	37.30	41.90	312.00
2008	54.50	52.20	96.60	54.40	72.20	11.60	341.50
2009	55.40	22.50	25.30	169.40	70.10	61.90	404.60
2010	53.50	58.80	66.50	99.70	83.50	38.50	400.50
2011	30.80	28.70	88.60	33.90	71.00	8.10	261.10
2012	17.00	64.00	106.80	50.30	52.30	1.80	292.20
2013	77.90	28.50	100.90	91.40	21.60	36.20	356.50
2014	65.40	169.10	188.70	109.50	103.40	98.60	734.70
2015	74.50	52.10	49.80	83.40	11.10	41.50	312.40
2016	168.60	46.60	145.50	75.80	72.40	180.20	689.10
2017	35.90	76.70	76.80	84.20	55.90	43.30	372.80
2018	109.60	20.40	48.50	95.40	243.50	43.10	560.50
2019	25.70	101.90	176.30	110.50	80.80	68.00	563.20
2020	59.80	22.00	99.00	137.30	84.80	154.40	557.30
2021	76.90	63.70	27.90	40.70	168.10	52.30	429.60
2022	24.20	38.20	54.50	92.60	8.50	30.60	248.60
2023	46.70	59.30	91.60	143.10	90.20	23.60	454.50
Average month per year	63.06	55.07	88.45	90.27	78.65	60.36	435.8632

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventionary studies involving animals or humans, and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

The year with the lowest average yield was 2012, characterized by the highest recorded temperatures (16.11°C) and the lowest monthly precipitation (292 mm).

Results and Discussion

Analysis of potato production

Before initiating the analysis to forecast the cultivated area, total production, and average yield of potatoes, two tests were conducted to check whether the data followed a normal distribution: the Kolmogorov-Smirnov test and the Shapiro-Wilk test. Both tests confirmed that the data were normally distributed, allowing for further analysis using ARIMA modeling.

Based on 19 years of data, from 2005 to 2023 (Table 3), the trends for potato cultivation area, total production, and average yield are presented in Diagrams 1a, 1b and 2, along with projections for the next three years (2024-2026).

Table 3. Trends in potato cultivation areas, total yield, and average yield in the Serbia from 2005 to 2023.

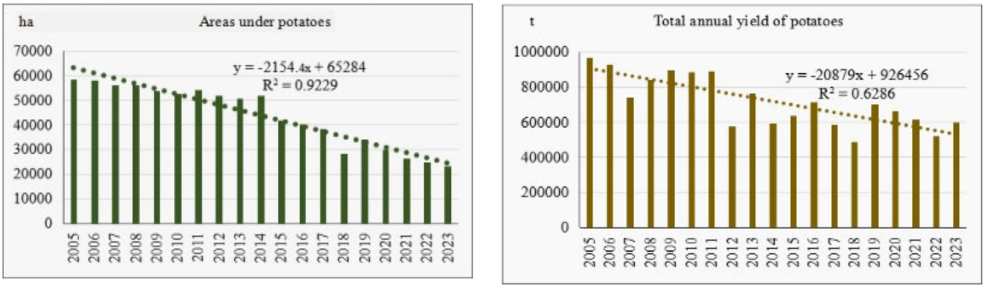
Year	Areas (ha)	Total annual yield (t)	Average annual yield (t/ha)
2005	58,529.00	969,562.00	16.60
2006	58,180.00	930,305.00	16.00
2007	56,102.00	743,282.00	13.20
2008	55,993.00	843,545.00	15.10
2009	53,925.00	898,282.00	16.70
2010	52,839.00	887,363.00	16.80
2011	54,057.00	891,513.00	16.50
2012	52,035.00	577,966.00	11.10
2013	50,740.00	766,829.00	15.10
2014	51,987.00	592,046.00	11.40
2015	41,658.00	639,410.00	15.30
2016	40,105.00	714,350.00	17.80
2017	38,472.00	589,241.00	15.30
2018	28,232.00	487,909.00	17.30
2019	34,110.00	702,086.00	20.60
2020	29,676.00	664,891.00	22.40
2021	26,388.00	613,785.00	23.30
2022	24,870.00	523,762.00	21.10
2023	23,145.00	599,574.00	25.90

Source: Statistical Office of the Republic of Serbia

Based on the analysis of Figures 2a, 2b, 3a and 3b, it is evident that there are fluctuations in the potato cultivation area, annual yield, and average annual yield during the observed period. These variations indicate significant fluctuations in the analyzed parameters, suggesting that the time series is stationary. For data modeling, the selection of models was guided by examining the autocorrelation and partial autocorrelation functions of the time series. As a result, the (3,0,3) model was chosen to describe the potato cultivation area, the (5,0,2) model for annual yields, and the (5,0,5) model for the average annual yield of potatoes in Serbia.

Figure 3b indicates that the residuals show no significant correlations at any lag, confirming they follow a white noise pattern. This ensures that the forecasting analysis can proceed without further differencing, as all parameters remain within expected ranges. Using the defined ARIMA models, Diagram 1a illustrates both historical trends in potato cultivation areas from 2005 to 2023 and the projected trends for the future. The close alignment between the model's predictions and actual data on potato cultivation areas highlights its reliability. The model provides forecasts for potato cultivation areas for the next three years (2024-2026), as shown in Table 4.

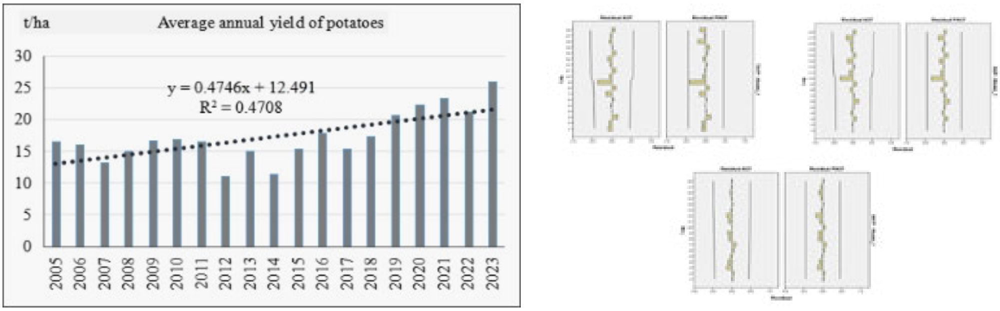
Figure 2. The trend of areas under potatoes in the period 2005-2023 (**a**); Average yields of potatoes in the period 2005-2023 (**b**)



(**a**) (**b**)

Source: Author´s calculations

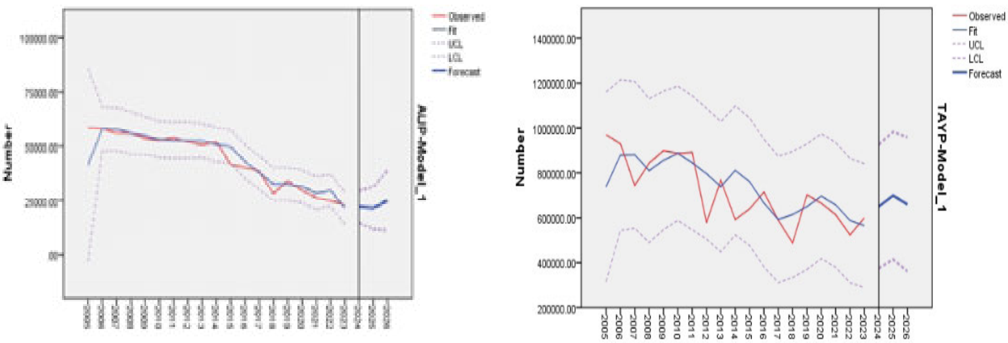
Figure 3. Average annual yields of potatoes in the period 2005-2023 (**a**); Correlogram results for the residuals of the estimated models (**b**)



(**a**) (**b**)

Source: Author´s calculations

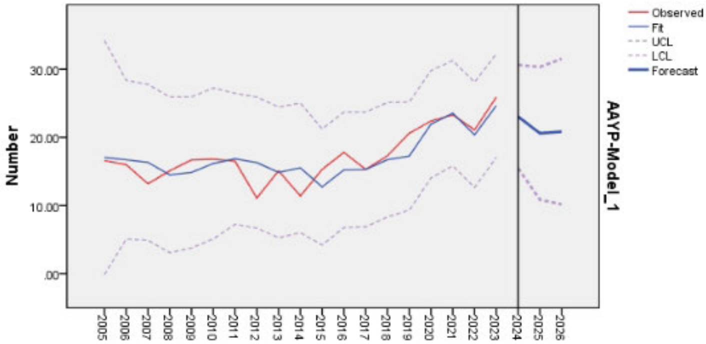
Diagram 1. Trends in potato cultivation areas (ha) from 2005-2023 and ARIMA Model Projections for the next three years (**a**); Total annual potato yield (tons) and projected quantities according to the ARIMA model, 2005-2023 (**b**)



(**a**) (**b**)

Source: Author´s calculations

Diagram 2. Average annual potato yield (tons/ha) and ARIMA model projections, 2005-2023



Source: Author´s calculations

Table 4 presents projected potato cultivation areas (in hectares) in Serbia using the ARIMA (3,0,3) model, total annual yields (in tons) based on the ARIMA (5,0,2) model, and average annual yields (in tons per hectare) using the ARIMA (5,0,7) model. These forecasts suggest that the selected models are highly effective, offering reliable insights into future trends in potato production in Serbia. The analysis of time series data, combined with ARIMA model forecasts, indicates a continued decline in potato cultivation areas over the next two years. However, by 2026, a reversal of this trend is anticipated, with a projected increase of 3,500 hectares compared to 2025, reflecting a significant growth of 15.66%. This suggests that while current conditions may be driving a decline, factors such as improved market conditions or policy interventions could lead to a recovery in cultivation areas by the end of the forecast period.

Furthermore, the ARIMA model provides a range of estimates for future potato cultivation areas, taking into account potential variability. The forecasted minimum values span from 11,000 to nearly 15,000 hectares, indicating a conservative scenario where the decline could persist. On the other hand, the maximum projections range between 29,500 and almost 39,000 hectares, which could occur under more favorable agricultural or economic conditions.

The ARIMA model analysis of total annual potato yields aligns closely with historical data, demonstrating the model's robustness in capturing past patterns and its reliability for future projections. According to the model, the total potato yield is expected to grow steadily over the next three years (2024-2026), with projections ranging from 650,000 to 699,000 tons. This increase suggests potential improvements in cultivation practices, technological adoption, or favorable weather conditions.

In addition to the central forecast, the model establishes confidence intervals to account for potential deviations. The lower bound estimates suggest that total yields could range between 360,000 and 415,000 tons, representing a more conservative outlook possibly driven by adverse climatic or economic conditions. Conversely, the upper bound forecasts range from 926,000 to 983,000 tons, indicating an optimistic scenario where external factors, such as improved agronomic techniques or government incentives, significantly enhance productivity.

Table 4. Estimated potato cultivation areas, total yield, and average yield in the Serbia, 2024-2026.

Years	Estimated potato cultivation areas (ha)	90% confidence interval for estimated potato cultivation areas (ha)	
		Lower bound	Higher bound
2024	22,145.64	14,799.30	29,491.98
2025	21,585.73	11,812.01	31,359.45
2026	24,965.56	11,132.97	38,798.15
Years	**Estimated total annual yield of potatoes (t)**	**90% confidence interval for estimated total annual yield of potatoes (t)**	
		Lower bound	**Higher bound**
2024	650,419.29	374,765.17	926,073.41
2025	698,953.03	414,775.02	983,131.05
2026	660,020.94	361,681.86	958,360.01
Years	**Estimated average annual yield of potatoes (t/ha)**	**90% confidence interval for estimated average annual yield of potatoes (t/ha)**	
		Lower bound	**Higher bound**
2024	23.06	15.50	30.62
2025	20.60	10.87	30.34
2026	20.85	10.18	31.52

Source: Calculation of the author in the program SPSS

Overall, these projections highlight both the challenges and opportunities in the Serbian potato sector. While short-term declines in cultivation areas are anticipated, the potential for recovery and growth in yields underscores the importance of strategic investments and adaptive measures to support sustainable agricultural development.

Based on the defined ARIMA modeling, Diagrams 1b and 2 illustrates the trend in the average annual potato yield (tons/ha) from 2005 to 2023, along with the forecasted trend according to the ARIMA model. The graphical analysis shows that the model aligns well with the actual data series on average yields, indicating its reliability for forecasting purposes.

The close fit between the model's projections and the observed data suggests that it effectively captures the underlying patterns in potato yield dynamics. This reliability is crucial for making informed decisions in agricultural planning and resource allocation.

Furthermore, the ARIMA model projects the average annual potato yield for the next three years (2024-2026), as detailed in Table 5 and Diagram 2. These projections can serve as valuable inputs for policymakers and farmers, allowing them to anticipate potential changes in productivity and adjust strategies to optimize yield outcomes in the coming years.

Table 5. These projections with RMSE/AIC/BIC for all models (Model Performance Metrics)

Model	RMSE	AIC	BIC
ARIMA (3,0,3)	0.12	150.2	155.6
ETS	0.15	155.8	160.3

The forecasted data suggest a slight decline in average potato yields over the next three years compared to 2023. However, the projected yields are expected to remain within the range of the five-year average (2019-2023). For 2024, the average yield is estimated at 23.06 tons per hectare (t/ha). This is anticipated to decrease slightly to approximately 20.6 t/ha in 2025 and 20.85 t/ha in 2026.

In terms of lower bounds, the minimum projected yields are forecasted at 15.5 t/ha for 2024, with a further decline to around 10 t/ha for both 2025 and 2026. This suggests a potential risk of unfavorable conditions impacting yields in the latter years of the forecast period. The 2012 yield collapse (11.1 t/ha) aligns with Požega's highest temperatures (16.1°C) and lowest precipitation (292 mm), underscoring climate sensitivity (Fig. 3a). Projected yield stability (~20.6 t/ha) may reflect adaptive practices (e.g., drought-tolerant varieties). On the other hand, the upper range of projected yields remains consistent, with maximum values around 30-31 t/ha across all three years. This indicates that under optimal conditions, yields could still reach the higher levels seen in recent years.

The forecasts reflect a modest decrease in average potato yields over the next few years, likely influenced by factors such as climatic variability, soil conditions, or resource inputs. However, the predicted yields remain comparable to the recent five-year average, indicating relative stability despite the slight downward trend.

The significant gap between the minimum and maximum forecasted yields (ranging from 10 t/ha to 31 t/ha) highlights the uncertainty and potential volatility in potato production. This variability suggests that external factors, such as weather patterns, pest pressures, or changes in agricultural practices, could substantially influence outcomes. While average yields are predicted to decline slightly, the potential for higher yields under favorable conditions remains, offering some optimism for growers who can optimize their practices and mitigate risks.

Due to its high nutritional content and comparatively high output, the potato (*Solanum tuberosum* L.) is one of the most significant staple crops in the world. With an average annual consumption of 83 kg per person, potatoes are a vital staple crop in the region and are crucial to the food supply of Europe (*Wijesinha-Bettoni and Mouillé*, 2019). Potato farming has a long history in Europe (*Love et al.*, 2020). Approximately 25% of the world's potato production currently comes from Europe (FAOSTAT average 2018–2022). While yields have somewhat increased, the amount of potato produced in Europe is decreasing as a result of a consistent and ongoing decrease in farmed area (*FAO*, 2024). Furthermore, Europe varies greatly, with some nations (like Poland) seeing a rise in yield per hectare and others (like the UK) exhibiting stagnation (*Haverkort and Struik*, 2015). Additionally, the area used for potato farming has decreased, particularly in eastern Europe (such as Romania) (*FAO*, 2024).

Irrigation is necessary to provide commercially viable harvests in arid regions with limited water availability, like the Mediterranean region of Europe. On the other hand, supplemental irrigation is only used in dry years when water stress occurs during crucial stages of crop growth, like the tuber bulking period, in northern and eastern Europe, which experiences cold winters and mild, rainy summers (*Marloes et al.*, 2025). Since potatoes are far more susceptible to water stress than the majority of other crops (*Weisz*, 1994; *Badr*, 2012; *Nasir and Toth*, 2022), the ability to be irrigated is very crucial.

With yields increasing and areas decreasing over the past few decades, Europe is a major producer of potatoes, despite notable regional variances. According to Marloes et al. (2025), European potato output on the current area can rise by 55% when yields reach 80% of their potential. The greatest potential for production growth is found in Eastern Europe (59% Yg- revealing yield gaps,, 59% of potato area), which is followed by Western Europe (32% Yg - revealing yield gaps, 25% area). The smallest improvements are found in Northern and Southern Europe (43% and 45% Yg, respectively), with comparatively modest acreages of 9% and 6%.

Conclusion

This research underscores the critical importance of using advanced forecasting models to project potato production in the context of increasing climate variability. The aim was to leverage modern analytical tools to gather and disseminate actionable insights that can guide rational planning, optimize agricultural strategies, and ensure food security, particularly in regions vulnerable to climate change. The findings contribute to the broader goals of sustainable agricultural development by addressing key challenges such as reducing uncertainty in crop yields, improving resource efficiency, and promoting strategies that align with poverty reduction and hunger eradication.

Cultivation Area Projections: The ARIMA (3,0,3) model indicates a continued decline in potato cultivation areas over the next two years, with a forecasted reduction to a minimum of 11,000 hectares. However, by 2026, the trend is expected to reverse, with a projected increase of approximately 3,500 hectares, reflecting a significant 15.66% growth compared to 2025. This suggests that strategic interventions or favorable climatic conditions could play a role in reversing the downward trend.

Total Yield Trends: According to the ARIMA (5,0,2) model, total potato yield is projected to increase over the next three years, ranging between 650,000 and 699,000 tons annually. This upward trend indicates potential improvements in agricultural practices or favorable weather patterns, which could offset the declining cultivation area.

Average Yield Dynamics: Despite an overall increase in total yield, the ARIMA (5,0,7) model forecasts a slight decline in average annual yield, with estimates of 23.06 t/ha in

2024, decreasing to around 20.6 t/ha in 2025 and 20.85 t/ha in 2026. However, these values remain within the five-year average range (2019-2023), suggesting that while there may be fluctuations, the productivity levels are relatively stable.

Confidence Intervals: The projected minimum and maximum average yields exhibit significant variability. The lower bounds range between 10 t/ha to 15.5 t/ha, while the upper bounds consistently reach 30-31 t/ha. This wide range highlights the sensitivity of potato yields to external factors such as weather, soil conditions, and agricultural practices. It also suggests the potential benefits of targeted interventions to minimize downside risks.

Implications for Policy and Strategic Planning: The application of advanced ARIMA modeling provides critical insights for policymakers and agricultural stakeholders. These projections can inform strategic decisions at national and regional levels to promote sustainable food systems. By anticipating declines in cultivation areas and adjusting strategies to enhance yields, stakeholders can better manage resources and mitigate risks associated with climate change.

These findings align with broader goals of food security, poverty reduction, and sustainable agricultural practices. The ability to predict fluctuations in crop production supports the development of resilient food systems that can withstand climatic shocks. This research highlights the need for continuous investment in data-driven agricultural strategies to optimize productivity and achieve a more secure and sustainable food future. While ARIMA captures temporal trends, inclusion of soil moisture or irrigation data (unavailable nationally) could improve accuracy. Future studies should integrate these variables via machine learning.

Overall, this study bridges the gap between data analysis and practical agricultural planning, emphasizing the role of predictive analytics in shaping a resilient agricultural sector capable of meeting future food demands.

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Conflict of interests

The authors declare no conflict of interest.

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HEALTHCARE MANAGEMENT AS A KEY COMPONENT OF SUSTAINABLE DEVELOPMENT: A COMPARATIVE ANALYSIS OF SERBIA AND SLOVENIA

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ABSTRACT

This study explores the role of health management as a driver of sustainable rural development in Serbia and Slovenia. Using quantitative methods (cluster, correlation, and regression analyses), it compares perceptions of health management and its impact on local communities. Results show that health management is positively perceived and linked to economic diversification, user satisfaction, and infrastructure quality. Slovenia performs better in accessibility and diversity of health services, reflecting its advanced institutional framework, while Serbia emphasizes marketing management, digital literacy, and economic benefits, indicating a growth phase. Strong correlations between health management and sustainable development dimensions confirm that effective health management improves rural well-being. Economic impact and user loyalty are the strongest predictors of development outcomes. Findings highlight the need for tailored policies addressing demographic and ecological challenges and fostering cross-country learning. The study recommends further research to maximize health management's contribution to rural sustainability and inform policymakers and stakeholders.

Introduction

In recent years, healthcare management has become increasingly recognized as a critical driver of sustainable socio-economic development, especially in rural regions. As globalization and demographic shifts intensify the challenges facing rural communities,

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innovative models based on the integration of effective healthcare management and local resources are gaining strategic importance for the future of these areas. Rural development today is not limited to economic revitalization alone - it also encompasses the preservation of cultural heritage, enhancement of living standards, and the creation of new opportunities for local populations.

Within this framework, healthcare management serves as a bridge connecting modern societal needs with the traditional values of rural environments. Efficient management in the healthcare sector enables improved access to medical services, supports healthy lifestyles, and directly contributes to job creation, economic diversification, and modernization of infrastructure in less developed areas. At the same time, such an approach encourages environmental protection and raises awareness of the importance of local resources, which is essential for long-term sustainability.

Slovenia and Serbia offer two distinct but comparable examples of how healthcare management can be integrated into rural development strategies. Slovenia utilizes its natural advantages and strong institutional frameworks to raise the quality of healthcare services in rural regions, while Serbia is currently undergoing an intensive process of economic and infrastructural transformation through the modernization and better management of healthcare systems in its countryside. This comparative analysis provides an opportunity to identify best practices and specific challenges in both countries, with the goal of supporting more effective development policies in the future.

Literature Review

Contemporary scientific literature confirms the significance of tourism management, with a special focus on health tourism, as a driver of sustainable rural development, particularly in Central and Eastern European countries, with Slovenia and Serbia standing out as notable examples. Numerous studies emphasize that health tourism, when managed effectively, serves as a tool for economic diversification and revitalization of rural areas, as well as a strong generator of new jobs and local income (Dwyer, 2023; Hall, 2010). Health tourism management significantly contributes to rural development by diversifying local economies, creating employment opportunities, and fostering entrepreneurship, especially in countries rich in natural therapeutic resources (Ilić & Đukić, 2022).

Modern development strategies in health tourism management focus on the integration of medical, wellness, and recreational services in rural areas, thereby improving residents' quality of life and attracting a growing number of tourists (Park et al., 2019). Health tourism is increasingly recognized as one of the most powerful drivers of rural revitalization, encouraging investments in infrastructure, education, and environmental protection (Jegdic et al., 2016; Yin et al., 2020).

Brand management and strengthening the market visibility of rural health tourism destinations directly contribute to increased tourist flows and economic growth within local communities (Cooper, 2021). Research indicates that networking and regional cooperation among health and wellness destinations enhance competitiveness and enable the sustainable development of rural communities through shared promotion and resources (Jesus & Franco, 2016). Regional cooperation between the public and private sectors within the framework of health tourism management supports the sustainable development of destinations and enables more efficient utilization of natural and anthropogenic resources in rural areas (Costa et al., 2018). The formation of health tourism clusters, as a management practice, contributes to better positioning of rural destinations on both national and international markets, facilitating knowledge and innovation transfer (Provenzano & Baggio, 2019).

Natural resources, such as mineral waters, favorable climate conditions, and preserved biodiversity, represent a key foundation for the development and management of health tourism in rural areas of Serbia, thereby encouraging the sustainable development of rural settlements (Cvijanović et al., 2019). The development of rural tourism, including managed health and wellness facilities, can contribute not only to population health but also to the long-term sustainability of rural communities in Serbia (Lakićević, 2020).

Among key trends, Grivec (2016) explores the connection between wellness tourism development and rural infrastructure improvement in Slovenia. The creation of sustainable tourist destinations requires the integration of innovative and environmentally responsible management approaches in food and service production, particularly in rural communities, contributing to the enhancement of tourist health, preservation of local biodiversity, and increased community resilience to global crises (Bertella, 2020). The implementation of sustainable management practices and new technologies in rural areas can enhance user satisfaction and contribute to the sustainable development of local communities (Khmaaj et al., 2025). Owing to its preserved nature, high ecological standards, and strong tradition of rural tourism management, Slovenia has developed sustainable models of rural tourism that incorporate health and wellness services, significantly improving the quality of life and socio-economic development of rural areas (Lakićević & Pantić, 2020).

The quality of infrastructure and healthcare management in rural areas, along with the openness and cooperation of local residents with tourists, significantly contributes to the sustainable development of rural tourism, which is particularly relevant for the development of health tourism destinations in Serbia and Slovenia (Petrović et al., 2017). In the case of these two countries, rural and health tourism management represent key drivers of sustainable development. While Slovenia demonstrates a high degree of organization and promotion of wellness and health services in rural areas, Serbia is developing a more diversified offer focused on natural healing resources and traditional practices, thereby supporting the preservation of rural vitality and the local economy (Vujko et al., 2016).

Materials and methods

The research was conducted from March to June 2025 through an online survey designed and developed by the authors. The questionnaire was constructed based on relevant theoretical and empirical sources in the fields of health tourism and sustainable rural development. The aim of the survey was to collect data from respondents of various profiles from Serbia and Slovenia in order to examine their perceptions of health tourism and its impact on local communities. The questionnaire consisted of two parts: a section with general sociodemographic questions and a section with statements related to variables associated with health tourism and sustainable rural development. Responses were collected using a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

The variables related to health management were grouped into five categories. The first variable, accessibility of health services, included assessments of service affordability, transportation connectivity, and accessibility for individuals with special needs. The second variable, quality management of health services, encompassed the evaluation of service standards, collaboration with professional medical staff, and the implementation of continuous improvement mechanisms to ensure that all programs meet high-quality criteria. The third variable, marketing management and digital literacy, referred to the strategic use of online platforms, social media visibility, the existence of targeted promotional campaigns, as well as the efficiency and reliability of digital booking and information services. The fourth variable, user satisfaction and loyalty, included perceptions of overall service quality and environment, willingness to return to the same provider, and the likelihood of recommending these services to others. The fifth variable, economic impact on the local community, measured the extent to which revenues from health management activities are retained locally, the engagement of local workforce and suppliers, and the stimulation of supporting industries such as restaurants, transport, and retail.

In parallel, the study examined five variables related to sustainable rural development. The first, *demographic sustainability*, referred to the retention of youth in rural areas, the return of urban residents to rural communities, and population growth in tourism-active areas. The second variable, *economic diversification*, included the development of tourism and crafts as a complement to agriculture and the benefits local producers derive from increased tourist demand. The third, *environmental responsibility and resource management,* measured the implementation of recycling practices, use of renewable energy sources, and preservation of the natural environment. The fourth variable, *community participation*, analyzed the involvement of local residents in decision-making processes, participation in forums, and direct benefits through engagement in tourism-related activities. The fifth variable, *quality of life and infrastructure*, observed tourism's effects on the improvement of transportation, healthcare and educational infrastructure, digitalization, and the overall perception of life quality in rural areas.

The main objective of this study was to examine the interdependence between the development of health tourism and sustainable rural development, and to determine whether there are differences in perception between respondents from Serbia and Slovenia. In accordance with this, two research hypotheses were formulated:

Hypothesis 1 - Variables of health management have statistically significant relationships with variables of sustainable rural development.

Hypothesis 2 - There are significant differences in the perception of the role and impact of health management on sustainable rural development between respondents from Serbia and Slovenia.

A total of 360 respondents participated in the research. Regarding gender structure, 167 respondents (46,3%) identified as male, 170 (47,1%) as female, while 23 (6,6%) did not disclose their gender. By age group, 89 respondents (24,7%) were under the age of 25, 216 (60%) were between 25 and 60 years old, and 55 (15,3%) were over 60.

In terms of roles within the context of health tourism, 71 respondents (19,8%) identified as local residents, 125 (34,7%) as visitors or tourists, 36 (9,9%) were employed in the tourism or healthcare sector, 122 (33,9%) were students or researchers, and 6 respondents (1,7%) selected "other". Regarding educational background, 3 respondents (0,9%) had completed primary school, 59 (16,5%) secondary school, 214 (59,5%) had a college or undergraduate degree, and 83 (23,1%) held a master's degree or higher.

In terms of country of origin, 190 respondents (52,9%) were from Serbia and 170 (47,1%) from Slovenia. Respondents were allowed to select multiple areas of health tourism that interested them. As a result, 152 participants (42,1%) selected spa tourism, 77 (21,5%) medical rehabilitation, 211 (58,7%) wellness/spa centers, 169 (47,1%) fitness and preventive programs, 63 (17,4%) alternative medicine, while 18 respondents (5%) cited other forms.

Motivations for visiting a health tourism destination were distributed as follows: 45 respondents (12,4%) were motivated by medical treatments such as rehabilitation, 196 (54,5%) by relaxation and wellness services, 30 (8,3%) by preventive screenings, 47 (13,2%) by family reasons or tradition, 29 (8,2%) by cost and affordability, and 9 participants (2,4%) mentioned other reasons. Regarding sources of information about the destination, 119 respondents (33,1%) cited recommendations from friends, 125 (34,7%) cited information from the internet or social media, 36 (9,9%) mentioned travel agencies, 33 (9,1%) received information from doctors or health advisors, 33 (9,1%) relied on prior experience, and 15 (4,1%) learned about the destination through other channels.

Results

For the purpose of this research, key dimensions of health management and sustainable rural development were analyzed based on a sample of 360 respondents from Serbia and Slovenia. Each variable was operationalized through multiple statements, with responses measured using a five-point Likert scale ranging from 1 to 5. Table 1 presents the basic descriptive statistical indicators for each variable, including the mean value, standard deviation, and reliability coefficient (Cronbach's Alpha).

Table 1. Descriptive Statistics for Health Management and Sustainable Rural Development Variables

Variable	Mark	N	Min	Max	Mean	Standard Deviation	Cronbach's Alpha
Accessibility of health management services	HM1	360	1	5	3,69	,814	,704
Quality management in health services	HM2	360	1	5	3,97	,796	,632
Marketing management and digital literacy	HM3	360	1	5	3,90	,887	,817
Patient satisfaction and loyalty	HM4	360	1	5	4,10	,664	,541
Economic impact on the local community	HM5	360	1	5	3,92	,825	,735
Demographic sustainability	SRD1	360	1	5	3,44	,993	,844
Economic diversification	SRD2	360	1	5	3,99	,804	,715
Environmental responsibility and resource management	SRD3	360	1	5	3,62	1,039	,843
Community participation	SRD4	360	1	5	3,64	,983	,765
Quality of life and infrastructure	SRD5	360	1	5	3,84	,863	,711

Source: Author's research

Results of the descriptive statistics for the variable Environmental responsibility and resource management indicate that the highest-rated variables are Patient satisfaction and loyalty (HM4, mean value 4,10), followed by Economic diversification (SRD2, mean value 3,99), and Quality management in health services (HM2, mean value 3,97). The high rating of patient satisfaction and loyalty suggests that health management in the analyzed destinations succeeds in meeting user expectations, with patients expressing a willingness to return and recommend the health facilities to others. These findings reflect the stability and attractiveness of the health service offer, which is an important precondition for the sustainable growth of the health sector.

On the other hand, the lowest-rated variable is Demographic sustainability (SRD1, mean value 3,44), followed by Environmental responsibility and resource management (SRD3, mean value 3,62), and Accessibility of health management services (HM1, mean value 3,69). These values indicate existing challenges in retaining young populations in rural areas and achieving a higher level of environmental responsibility and sustainable resource management. Furthermore, the accessibility of health management services, although rated above average, signals room for improvement in terms of affordability and availability for a broader range of users.

The standard deviation values for most variables range from 0,664 to 1,039, indicating relatively consistent opinions among respondents, but also the presence of certain variations in the perception of specific aspects (e.g., environmental responsibility). All variables received ratings above the midpoint of the scale (3), confirming a predominantly positive attitude of respondents toward the development of health management and sustainable rural development in the analyzed countries.

The reliability of the applied measures was assessed using Cronbach's Alpha coefficient for each dimension individually. All calculated coefficients are above the recommended minimum threshold of 0,60, which, according to relevant literature, represents a satisfactory level of internal consistency (Taber, 2018). The highest coefficient was recorded for the variable Demographic sustainability (SRD1, α = 0,844), indicating a high degree of reliability for this scale. Similarly, high values of α were also measured for the variable Environmental responsibility and resource management (SRD3, α = 0,843) and Marketing management and digital literacy (HM3, α = 0,817), suggesting that respondents answered consistently across the items comprising these scales.

The lowest reliability coefficient was recorded for the variable Patient satisfaction and loyalty (HM4, α = 0,541), which falls slightly below the optimal recommended threshold of 0.7, but is still considered acceptable in social research where scales include a small number of items or examine more abstract constructs (DeVellis & Thorpe, 2021). These results suggest that the measurement scales can be considered reliable instruments for assessing the analyzed dimensions in the context of health management and sustainable rural development.

The interrelations and influences between health management variables and sustainable rural development variables were examined using correlation analysis. The obtained correlation values are presented in Table 2.

Table 2. Correlation values between health management variables and sustainable rural development variables

	HM1	HM2	HM3	HM4	HM5
SRD1	,327**	,368**	,438**	,432**	,545**
SRD2	,558**	,469**	,428**	,556**	,472**
SRD3	,485**	,438**	,546**	,580**	,518**
SRD4	,466**	,446**	,459**	,510**	,557**
SRD5	,493**	,476**	,519**	,612**	,587**

**. The correlation is significant at the 0,01 level (2-tailed).

Source: Author's research

The correlation analysis conducted between the dimensions of health management (HM1-HM5) and aspects of sustainable rural development (SRD1-SRD5) indicates the existence of statistically significant and positive relationships among all observed variables, with all Pearson correlation coefficients being significant at the 0,01 level. These results confirm the interdependence between the development of health management practices and the improvement of various aspects of sustainable rural development in the analyzed regions.

Analysis of individual coefficients shows that the strongest positive correlations are observed between the variable Quality of Life and Infrastructure (SRD5) and Patient Satisfaction and Loyalty (HM4), with a correlation coefficient of r = 0,612, as well as between Quality of Life and Infrastructure (SRD5) and Economic Impact on the

Local Community (HM5), with r = 0,587. These findings suggest that improvements in the quality of life and infrastructure in rural areas directly contribute to increased patient satisfaction and loyalty, as well as a stronger economic effect of health management on the local community. Additionally, a very high correlation is noted between Environmental Responsibility and Resource Management (SRD3) and Patient Satisfaction and Loyalty (HM4), with r = 0,580, confirming that ecological aspects of development play a significant role in shaping a positive patient experience.

The lowest correlation coefficients were recorded between Demographic Sustainability (SRD1) and Accessibility of Health Management Services (HM1), with r = 0,327, as well as between the same variable (SRD1) and Quality Management of Health Services (HM2), with r = 0,368. This indicates that measures aimed at enhancing demographic sustainability have a relatively weaker connection with aspects of accessibility and service quality management in the health sector, compared to other dimensions. These findings suggest the need for additional programs and policies that more effectively link health management strategies with demographic development in rural areas.

The high correlation values and statistical significance of all correlations confirm that the development of health management is strongly linked to the advancement of rural communities, implying a multidimensional approach in planning and implementing development strategies within this sector. Such findings can serve as a strong rationale for integrated policies that connect the health sector with rural development and the improvement of living conditions in local communities.

Given that the correlation analysis between health management variables and sustainable rural development variables yielded high values, the data are suitable for further analysis through regression. The regression analysis aims to determine the individual impact of independent health management variables on dependent sustainable rural development variables. The regression model of these impacts is presented in Table 3.

Table 3. Regression model of the impact of independent health management variables on dependent sustainable rural development variables (only variables with statistically significant effects are shown)

Dependent	Independent	β	t	Sig.	R^2	F	Sig.
SRD1	HM5	,402	7,426	,000	,337	36,039	,000
SRD2	HM1	,298	4,985	,000	,411	49,355	,000
	HM4	,277	4,487	,000			
	HM5	,195	3,824	,000			
SRD3	HM3	,190	3,247	,001	,429	53,118	,000
	HM4	,264	4,334	,000			
	HM5	,230	4,572	,000			
SRD4	HM4	,173	2,754	,006	,394	46,127	,000
	HM5	,349	6,745	,000			
SRD5	HM4	,320	5,508	,000	,481	65,658	,000
	HM5	,325	6,799	,000			

Source: Author's research

The results of the regression analysis indicate that the economic impact on the local community (HM5) is a statistically significant predictor of demographic sustainability ($\beta = 0{,}402$; $t = 7{,}426$; $p < 0{,}001$). The explained variance (R^2) amounts to 33,7%, suggesting that the economic benefits generated by effective health management practices play a crucial role in population retention and in fostering positive demographic trends in rural areas.

The model shows that economic diversification is significantly influenced by accessibility of health management services (HM1; $\beta = 0{,}298$; $t = 4{,}985$; $p < 0{,}001$), patient satisfaction and loyalty (HM4; $\beta = 0{,}277$; $t = 4{,}487$; $p < 0{,}001$), and the economic impact on the local community (HM5; $\beta = 0{,}195$; $t = 3{,}824$; $p < 0{,}001$). Collectively, these variables explain 41.1% of the variance in the dependent variable ($R^2 = 0{,}411$). This demonstrates that the development of additional economic activities in rural areas relies on the availability of health management services, patient loyalty, but above all on the local economic effect of health management.

Regarding environmental responsibility and resource management (SRD3), the most significant predictors are marketing management and digital literacy (HM3; $\beta = 0{,}190$; $t = 3{,}247$; $p = 0{,}001$), patient satisfaction and loyalty (HM4; $\beta = 0{,}264$; $t = 4{,}334$; $p < 0{,}001$), and the economic impact on the local community (HM5; $\beta = 0{,}230$; $t = 4{,}572$; $p < 0{,}001$), with R^2 equal to 42,9%. These findings indicate that the development of ecological awareness and the implementation of sustainable practices are largely stimulated by well-executed marketing management activities and high levels of patient satisfaction, as well as economic benefits at the local level.

Community participation (SRD4), as a variable of sustainable rural development, is primarily determined by patient satisfaction and loyalty (HM4; $\beta = 0{,}173$; $t = 2{,}754$; $p = 0{,}006$) and the economic impact on the local community (HM5; $\beta = 0{,}349$; $t = 6{,}745$; $p < 0{,}001$), with an explained variance of 39,4% ($R^2 = 0{,}394$). These results suggest that high levels of community engagement and involvement in decision-making depend on patient loyalty but predominantly on the economic benefits that health management brings to the community.

The highest degree of explained variance was recorded for quality of life and infrastructure (SRD5) ($R^2 = 0{,}481$). The key predictors are patient satisfaction and loyalty (HM4; $\beta = 0{,}320$; $t = 5{,}508$; $p < 0{,}001$) and the economic impact on the local community (HM5; $\beta = 0{,}325$; $t = 6{,}799$; $p < 0{,}001$). This implies that the improvement of living standards and infrastructure in rural areas largely depends on the quality of patient experience and the local economic impact of health management.

The regression analysis confirms that the dimensions related to the economic impact of health management (HM5) and patient satisfaction (HM4) consistently exert a significant and positive influence on all aspects of sustainable rural development. These results suggest that strategic enhancement of these dimensions can yield multiple benefits for rural communities, opening avenues for the development of integrated policies focused on sustainability and increasing the competitiveness of health management.

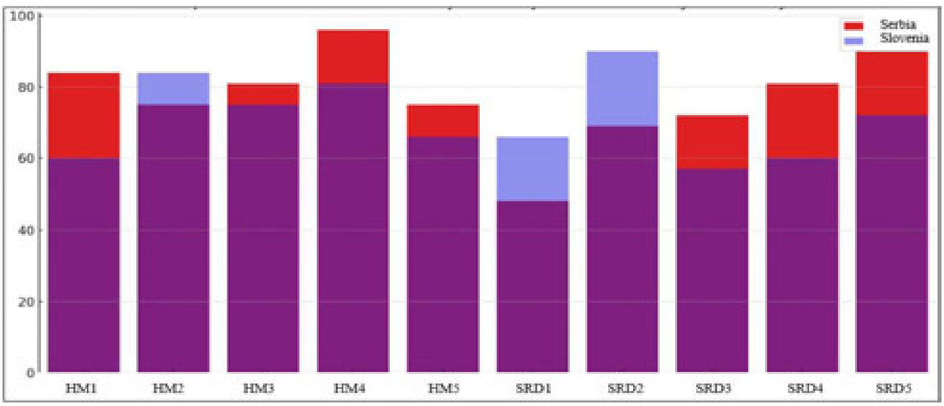
In order to identify and analyze differences in the perception and evaluation of the role of health management and sustainable rural development between Serbia and Slovenia, a hierarchical cluster analysis was conducted. A total of 10 variables were analyzed: five related to the dimensions of health management (HM1-HM5) and five related to sustainable rural development (SRD1-SRD5). Data were collected from respondents in both countries, and Ward's method with squared Euclidean distance was applied. The primary objective of the study was to determine whether statistically significant differences exist in the priorities and assessments of these dimensions between the two countries.

Based on the cluster analysis, two clearly differentiated groups of respondents were identified, corresponding to Serbia and Slovenia. A comparative analysis of mean ratings per variable shows that respondents from Slovenia rate accessibility of health management services (HM1), quality management and diversity of offerings (HM2), as well as economic diversification in rural areas (SRD2), significantly higher. Conversely, respondents from Serbia emphasize marketing management and digital literacy (HM3), economic impact on the local community (HM5), and quality of life and infrastructure in rural areas (SRD5).

The key differences between the countries reflect different stages of development of health management and sustainable rural development, as well as differing priorities at the level of public policies and local perceptions. In Slovenia, dominant ratings focus on availability and quality of offerings, indicating a more developed and institutionalized practice of health management and sustainable rural policies. In contrast, Serbia highlights marketing potential and economic benefits for the local community, which may point to a stronger need for promotion and economic optimization of health management activities.

Figure 1 clearly illustrates the differences in the number of highly rated responses for each variable between respondents from Serbia (red) and Slovenia (blue). For example, Serbia has a significantly higher number of high ratings in variables HM3, HM4, SRD4, and SRD5, whereas Slovenia leads in variables HM2, SRD1, and especially SRD2.

Figure 1. Distribution of Top-Rated Health Management and Rural Development Variables: Serbia vs. Slovenia



The Figure presents a comparative analysis of highly rated variables between Serbia and Slovenia. It is evident that respondents from Slovenia rated the accessibility and quality of health management services significantly higher, whereas respondents from Serbia emphasized the importance of marketing management and digital presence, as well as the economic contribution to the local community. These findings highlight different developmental stages and priorities in the fields of health management and sustainable rural development in the analyzed countries.

The conducted cluster analysis revealed the existence of two dominant clusters, which largely correspond to the national affiliation of respondents (Serbia and Slovenia). Cluster 1 predominantly consisted of respondents from Serbia, while Cluster 2 included respondents from Slovenia. This division was further confirmed by the dendrogram and the sharp increase in agglomeration coefficient values observed in the final stages of the analysis.

Key differences between Serbia and Slovenia were identified through the analysis of highly rated variables. Serbia recorded higher ratings in the domains of marketing management and digital literacy (HM3), patient satisfaction and loyalty (HM4), as well as quality of life and infrastructure (SRD4, SRD5). Conversely, Slovenia received higher ratings regarding the quality management and diversity of health service offerings (HM2), demographic sustainability (SRD1), and economic diversification (SRD2). These results point to differing development strategies and perceptions—while Serbia places emphasis on user satisfaction and infrastructure improvement, Slovenia shifts focus toward diversification and sustainability of local communities.

Discussions

The results of the analysis demonstrate that all examined variables related to health management and sustainable rural development were rated above the midpoint of the scale, reflecting a general recognition and positive attitude of respondents towards these processes in both Serbia and Slovenia. The highest mean scores were observed for the variables Patient satisfaction and loyalty (HM4; mean 4,10), Economic diversification (SRD2; 3,99), and Quality management of health services (HM2; 3,97). Conversely, the lowest ratings were given to Demographic sustainability (SRD1; 3,44) and Environmental responsibility and resource management (SRD3; 3,62). This pattern suggests that economic aspects and the user experience are well developed, while ongoing challenges remain in the domains of demographic trends and environmental responsibility, underscoring the need for targeted interventions in these segments.

Correlation analysis reveals a strong interdependence between all dimensions of health management and sustainable rural development, with all Pearson correlation coefficients being positive and significant at the 0,01 level. On this basis, Hypothesis 1 is confirmed: variables of health management are statistically significantly related to variables of sustainable rural development. Especially notable is the strong association between Quality of life and infrastructure (SRD5) and Patient satisfaction and loyalty

(HM4) ($r = 0,612$), as well as between Economic impact on the local community (HM5) and Quality of life and infrastructure (SRD5) ($r = 0,587$). These findings indicate that improvements in infrastructure and living standards directly enhance patient satisfaction and loyalty, while also reinforcing the economic impact of health management on local communities. Conversely, the relatively weaker links between accessibility and demographic sustainability (e.g., SRD1 and HM1; $r = 0,327$) highlight the need for further measures to support population retention and improve access to healthcare services in rural regions.

Regression analysis provides further confirmation that the Economic impact on the local community (HM5) and Patient satisfaction and loyalty (HM4) are consistently the most significant predictors of all dimensions of sustainable rural development. For instance, regarding Demographic sustainability (SRD1), the economic impact (HM5) has a standardized coefficient $\beta = 0,402$, explaining 33,7% of the variance ($R^2 = 0,337$). For Quality of life and infrastructure (SRD5), the combination of patient satisfaction (HM4) and economic impact (HM5) accounts for as much as 48,1% of the variance. These results affirm that strengthening the local economy and enhancing patient/user experience lead directly to positive outcomes in rural areas, including demographic and environmental dimensions.

These findings support conclusions from prior studies that recognize health management as a powerful driver of economic diversification and revitalization in rural areas, as well as a generator of new employment and local income (Hall, 2010; Dwyer, 2023; Ilić & Đukić, 2022). The advancement of health management, particularly through the integration of medical, wellness, and preventive services, contributes to improved quality of life for local populations and increases the overall attractiveness of rural destinations (Park et al., 2019; Jegdić et al., 2016; Yin et al., 2020).

Comparative cluster analysis distinctly differentiates two respondent groups by nationality (Serbia vs. Slovenia), thereby confirming Hypothesis 2: there are significant differences in perceptions of the role and impact of health management on sustainable rural development between respondents from Serbia and Slovenia. In Slovenia, variables related to the accessibility of healthcare services (HM1), quality management and diversity of services (HM2), and economic diversification (SRD2) were rated significantly higher, pointing to developed and institutionalized models of health management and rural policy. Conversely, Serbian respondents placed greater emphasis on marketing management and digital literacy (HM3), economic benefits to the local community (HM5), and quality of life and infrastructure (SRD5). These findings reflect different developmental phases, priorities, and policy approaches—Slovenia prioritizes accessibility and sustainability, while Serbia is oriented toward promotion, economic outcomes, and enhanced user experience.

The comparative results align with earlier research showing that Slovenia, due to its high level of organization and ecological standards, has implemented a more institutionalized approach to rural health management. Serbia, on the other hand, develops a diversified offering, strongly leveraging natural resources and traditional attractions (Lakićević & Pantić, 2020; Petrović et al., 2017; Vujko et al., 2016). The quality of infrastructure and collaboration between local stakeholders and service users are confirmed as key factors for the sustainable development and competitiveness of rural destinations in both countries.

Conclusions

The research clearly demonstrates that health management has substantial potential to serve as a key driver of sustainable rural development in both Serbia and Slovenia. Its influence is evident in the strengthening of local economies, the creation of new employment opportunities, the improvement of quality of life, and the preservation of natural and cultural values within rural communities. The identified differences between the two countries offer valuable lessons: Slovenia stands out as a model of institutionalization and quality standardization in health management, while Serbia presents considerable potential for growth through enhanced promotional activities and further investment in infrastructure.

The main limitations of this study stem from the data collection process, which relied on self-reported and subjective perceptions of respondents. This approach may influence the precision and broader applicability of the results. Moreover, the research timeframe did not enable the assessment of long-term effects or the observation of dynamic changes over time, and the selected sample may not fully represent the geographic and demographic diversity of the studied populations.

For future research, it is recommended to undertake longitudinal studies that would track changes over extended periods, providing insights into the sustainability of health management initiatives in rural areas. Incorporating additional qualitative methods, such as in-depth interviews and focus groups, would also enable a richer understanding of the motivations, challenges, and experiences of both local communities and health service users. Comparative analysis with other countries in the region, as well as a focus on particular segments of health management (such as spa services, wellness programs, and rehabilitation), could further support the development of targeted policies and personalized strategies for advancing sustainable rural development.

Conflict of interests

The authors declare no conflict of interest.

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EVALUATING THE EFFECTIVENESS OF THE MODELS FOR ASSESSING THE INITIATION OF BANKRUPTCY PROCEEDINGS

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ABSTRACT

Using predictive models for assessing the initiation of bankruptcy proceedings constitutes a proactive strategy aimed at preserving financial stability and promoting the long-term viability of businesses. This study focuses on companies in the agricultural and food production sectors within the Republic of Serbia, specifically examining those for which bankruptcy proceedings were initiated in 2022, based on their operational activities in 2021. The primary objective of this research is to evaluate the efficiency of the predictive models in forecasting the likelihood of bankruptcy proceedings one year before their initiation. The requisite data for applying these models were obtained from the financial statements of the analyzed companies. The findings indicate that the Vlaović Begović (VB) model demonstrated the highest efficacy in predicting the onset of bankruptcy proceedings within the agricultural sector. Conversely, the Altman Z' score proved to be the most appropriate model for assessing bankruptcy within the food sector.

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Introduction

In the modern environment, where companies are facing consequences of the COVID 19 pandemic, an unstable political and economic situation as well as the global economic crisis, the issue of firm failure and insolvency proceedings is again a topic of interest among practitioners and researchers (Pervan et al., 2023). The opening of bankruptcy proceedings marks the terminal phase of a company's business activities with significant consequences for creditors, debtors and the economy in general. According to Jocić et al. (2024), evaluating the potential for bankruptcy within market-driven economies is crucial for sustainable financial management practices. The concept of financial sustainability refers to liquidity, long-term returns, growth potential, and the ability to withstand financial distress. Ignoring the signs of financial distress can lead to a situation in which bankruptcy is the only option (Srebro et al., 2021). A variety of predictive models have been developed to anticipate bankruptcy events, employing diverse methodologies ranging from statistical analyses to machine learning techniques. Zenzerović and Peruško (2006) point out that the models of the following authors are the most cited and/or most used in practice: William H. Beawer, Edward I. Altman, Edward B. Deakin, James A. Ohlson, Robert O. Edmister, Christina V. Zavgren and Peter Kralicek. The risk of bankruptcy cannot be eliminated but it can be identified before it occurs (Voda et al., 2021). Traditional models, such as Altman's Z-score and Ohlson's O-score, have established a foundation for bankruptcy prediction, utilizing financial indicators and historical data to evaluate a company's financial integrity. In corporate failure prediction models, financial variables are still primarily used, while other variables are used complementary (Veganzones and Severin, 2021). However, as the economy evolves, so must the models used to evaluate the risk of bankruptcy. Since 2021, the 45 countries that collectively represent nearly 90% of global GDP have experienced an average annual increase of 12% in corporate bankruptcy filings. By 2023, the number of corporate insolvencies had reached its highest level in over a decade (Dun and Bradstreet, 2024). This research will evaluate the performance of prediction models in agricultural and food companies. The assessment of the adequacy of various models for predicting the initiation of bankruptcy proceedings has been the focus of extensive research by numerous scholars. In the research conducted by Muminović et al. (2011), which focused on companies whose shares were traded on the Belgrade Stock Exchange, it was determined that the original Z-score, Z'-score, and Z''-Score models are not reliable for prediction of bankruptcy in the Republic of Serbia. Pavlović et al. (2011) also analyzed companies listed on the Belgrade Stock Exchange. The authors performed an analysis of the adequacy of Taffler's model in assessing the possibility of bankruptcy in a sample of 62 companies. Their findings indicated that the model is inadequate in the specific economic context of Serbia. Further assessment of predictive accuracy was undertaken by Pavlović et al. (2012), who assessed the Zmijevski model's effectiveness in forecasting bankruptcy. Despite the notable economic disparities between the Republic of Serbia and the United States during the period when this model was developed, the authors found that the Zmijevski model exhibited a surprisingly high level of accuracy in predicting bankruptcy among Serbian companies. In their research, Stanišić et al. (2013) developed three predictive models utilizing both standard and specific financial indicators to forecast the initiation of bankruptcy proceedings in developing markets. The authors constructed these models based on an initial sample of 130 companies, employing logistic regression, decision trees, and artificial neural networks. Their findings revealed that, in an independent evaluation involving a sample of 102 companies, only the artificial neural network model demonstrated superior performance compared to the Altman models. Mizdraković and Bokić (2016) examined the adequacy of Altman's Z' and Z'' models, along with a specially created M score, within the context of the Serbian economy. This analysis was conducted on a sample of 70 medium and large companies. The results indicated that, on average, the M model accurately assessed 74.3% of the companies, though this accuracy represented a decline from the 80% observed during the model's original development period. Additionally, the research highlighted the inadequacy of using Altman's Z' and Z'' scores within the Serbian economic context, as these models successfully evaluated the financial performance of the analyzed companies in only 48.2% to 74.7% of cases. Stojanović and Drinić (2017) also tested the adequacy of the use of Altman's models (Z, Z' and Z''), but on a sample of 270 agricultural companies operating in Bosnia and Herzegovina from 2010 to 2015. The authors concluded that these models were unable to reliably predict the occurrence of bankruptcy 2 to 3 years in advance. Furthermore, the accuracy assessment of Altman's Z'' score and the Zmijewski model was conducted by Begović et al. (2020) on a sample of 159 companies, of which 53 had initiated bankruptcy proceedings, within the Republic of Serbia during the period from 2012 to 2013. The authors noted a slight advantage of the Zmijewski model; however, both models demonstrated satisfactory average accuracy in predicting the initiation of bankruptcy proceedings. Koziol and Pitera (2020) examined the suitability of ten bankruptcy prediction models in assessing the financial viability of food companies operating in Poland between 2005 and 2016. The study analyzed the performance of 50 companies, half of which had declared bankruptcy, while the remaining half were financially stable. Models developed by M. Hamrol, T. Korol, J. Gajdka and D. Stos, as well as D. Appenzeller and K. Szarzec, demonstrated an average accuracy of 68% in correctly identifying companies that initiated bankruptcy proceedings. Valaskova et al. (2020) also conducted a comparative analysis of models for evaluating the bankruptcy risk but on a sample of agricultural enterprises. The authors concluded that models specifically developed for a particular economy (Slovak) and tailored to a specific sector yield significantly better results than generalized models such as Altman's. Following the aforementioned context, this research focuses on companies engaged in agricultural production and food processing in the Republic of Serbia during the year 2021. The primary objective of the study is to evaluate the effectiveness of the models employed to predict the initiation of bankruptcy proceedings for the analyzed companies.

Materials and methods

The adequacy of using specific models for predicting bankruptcy among agricultural and food companies in the Republic of Serbia was assessed based on financial data. The study analyzed data from nine agricultural and twelve food companies that initiated bankruptcy proceedings in 2022. Additionally, an equal number of stable companies from both sectors were selected using a random sampling method, ensuring that they were comparable in terms of size and location. The analysis was based on financial statements for the 2021 fiscal year, obtained from the final accounts available on the official website of the Serbian Business Registers Agency. Information regarding ongoing bankruptcy proceedings was obtained from the Bankruptcy Supervision Agency. It is important to note that, under the current legal framework in the Republic of Serbia, the term bankruptcy includes both liquidation and reorganization procedures as alternative approaches to addressing corporate insolvency. In accordance with the scope and purpose of the research, the following hypothesis has been articulated:

H_0: The applied models successfully forecasted bankruptcy within the analyzed agricultural and food processing companies.

The models evaluated in this research include those developed by the following authors:

Edward I. Altman was the pioneer in applying discriminant analysis within a bankruptcy assessment models. In 1968, he developed a model based on the performance of 66 manufacturing companies, half of which had declared bankruptcy while the other half exhibited no solvency issues. This model was specifically designed to evaluate the bankruptcy risk of publicly traded firms (Altman, 1968). However, the initial model was not applicable to companies whose capital is not listed on the stock exchange. To address this limitation, Altman subsequently refined the formula in 1983 (Altman, 1983):

$$Z' = 0.717X_1 + 0.847X_2 + 3.107X_3 + 0.420X_4 + 0.998X_5$$

The indicators constituting the discrimination function were determined according to:

X_1 = (current assets-current liabilities) / total assets;

X_2 = retained earnings / total assets;

X_3 = earnings before interest and taxes / total assets;

X_4 = book value equity / total liabilities and

X_5 = sales / total assets.

The obtained results facilitate the classification of companies into three zones: safe (Z' > 2.9), gray (denoting potential bankruptcy risk; 1.23 < Z' < 2.9), and distressed (Z' < 1.23).

James Ohlson is regarded as a foundational contributor of applying logit analysis to models for estimating bankruptcy. In 1980, he developed a model based on a sample of 2,163 manufacturing companies that filed and initiated bankruptcy between 1970 and 1976. This model achieved an impressive average accuracy rate of 96.12% in predicting bankruptcy one year in advance (Ohlson, 1980):

$$O = -1.32 - 0.407X_1 + 6.03X_2 - 1.43X_3 + 0.0757X_4 - 2.37X_5 - 1.83X_6 + 0.285X_7 - 1.72X_8 - 0.521X_9$$

The indicators utilized in this model were computed in accordance with:

X_1 = log (total assets / gross national product index), the index year is as of the year before the year of the balance sheet date;

X_2 = total liabilities / total assets;

X_3 = working capital / total assets;

X_4 = current liabilities / current assets;

X_5 = relation between total liabilities and total assets, if total liabilities exceed total assets this indicator takes the value of one, zero otherwise;

X_6 = net result / total assets;

X_7 = funds provided by operations / total liabilities;

X_8 = an indicator of net income change, one if net income was negative for the last two years, zero otherwise and

X_9 = (net income in the current year – net income in the previous year) / (|net income in the current year|+|net income in the previous year|).

Sanja Vlaović Begović developed a logit model for predicting bankruptcy one year before its occurrence, utilizing a sample of 120 companies from the processing sector. The companies included in this research operated in the Republic of Serbia from 2011 to 2017. The model demonstrated an overall prediction accuracy of 91.67% (Vlaović Begović, 2020):

$$VB = 0.934 - 4.053X_1 - 7.630X_2 + 2.253X_3 + 1.730X_4 + 4.205X_5 - 0.406X_6$$

The indicators incorporated in this model were derived based on:

X_1 = net result / total assets;

X_2 = working capital / total assets;

X_3 = current assets / total assets;

X_4 = current assets / sales revenue;

X_5 = long-term liabilities / total assets and

X_6 = log (total assets).

Dragana Bešlić developed a model for assessing the probability of bankruptcy, utilizing logit analysis. The study encompassed 130 companies that were active in the Republic of Serbia from 2010 to 2011, representing small, medium, and large companies across various sectors. The model achieved an average accuracy rate of 92.1% in predicting bankruptcy within the training sample and 87.8% on the test sample (Bešlić, 2016):

$$DB = 3.834 + 0.141X_1 - 3.671X_2 - 0.045X_3 + 0.001X_4 - 1.547X_5 + 5.006X_6$$

The calculation of indicators for this model followed the methodology outlined in:

X_1 = long-term assets / (long-term liabilities + total equity);

X_2 = initial equity (capital) / total assets;

X_3 = total liabilities / (net result + depreciation);

X_4 = sales revenue / average inventories;

X_5 = sales revenue / average short-term operating receivables and

X_6 = funds provided by operations / average total assets.

Ivica Pervan developed a logit analysis-based model for predicting bankruptcy one year before its occurrence, utilizing a sample of 258 small and medium-sized enterprises from the manufacturing sector. The companies examined operated within the Republic of Croatia. The model initially demonstrated a successful prediction rate of 87.9% in identifying bankruptcy cases (Pervan, 2017):

$$P = 2.969 - 0.031X_1 - 0.480X_2 - 0.089X_3$$

The formulation of indicators used in this model was carried out according to:

X_1 = earnings before interest and taxes / total income;

X_2 = current assets / short-term liabilities and

X_3 = book value of equity / total assets.

The probability of bankruptcy, as determined by the tested logit models, is obtained through the application of the following formula (adapted from Tekić et al., 2021):

$$P_i\ (\text{Bankruptcy}) = \frac{1}{1 + e^{-(O;\, VB;\, DB;\, P)}}$$

Where are:

O, VB, DB and P - values obtained by models;

e - natural logarithm (2.718281828459) and

P_i - the probability of bankruptcy.

A calculated value of P_i greater than 0.5 indicates that the company is at risk, reflecting a high probability of bankruptcy. Conversely, if the conditional probability associated with the calculated value P_i is less than or equal to 0.5, the company is classified as stable, suggesting no immediate risk of bankruptcy.

The overall predictive accuracy, which constitutes an essential aspect of the model, was derived using the formula (adapted from Kušter, 2023):

$$\textit{Overall accuracy (\%)} = \frac{AB+AS}{AB+FB+AS+FS} * 100$$

Where are:

AB-accurate bankrupt company;

FB-false bankrupt company;

AS-accurate stable company and

FS-false stable company.

When assessing the likelihood of company bankruptcy using predictive models, certain classification errors may also arise. A type I error represents the percentage of at-risk companies incorrectly classified as stable by the model, whereas a type II error indicates the percentage of stable companies erroneously classified as at risk (Vavrek et al., 2019).

Results and discussion

The evaluation of the adequacy of utilizing individual models for assessing the likelihood of initiating bankruptcy proceedings begins with a descriptive statistical analysis of the outcomes produced by these models. This analysis encompasses financially stable agricultural companies and those for which bankruptcy proceedings have been initiated, as presented in Table 1.

Table 1. Descriptive statistics for applied models in agricultural companies

Elements	Models									
	VB		DB		P		Z’		Ohlson	
	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable
Mean	0.92	0.22	0.46	0.28	0.83	0.45	3.21	17.16	0.80	0.17
Median	1	0.06	0.11	0	0.92	0.62	0.92	10.10	0.94	0.04
Standard deviation	0.12	0.30	0.50	0.44	0.31	0.39	10.19	14.94	0.31	0.32
Minimum	0.68	0	0	0	0	0	-3.31	2.21	0.06	0
Maximum	1	0.77	1	0.98	0.95	0.93	30.10	43.03	1	1
Cutt of	>0.50	<0.50	>0.50	<0.50	>0.50	<0.50	<1.23	>1.23	>0.50	<0.50
Sample	9	9	9	9	9	9	9	9	9	9

Source: Authors’ calculations based on data from financial reports, Business Register Agency

The median values for bankrupt companies indicate that the VB, P, Z’, and Ohlson models generally classified the operations of the analyzed firms as at risk, reflecting a high probability of bankruptcy. Conversely, the median values associated with financially stable companies suggest that the VB, DB, Z’, and Ohlson models effectively assessed the bankruptcy risk. Furthermore, the results about the standard deviation of the Z’ score reveal a significant disparity in bankruptcy risk between stable and at-risk companies. The other models employed logit analysis, producing values ranging from 0 to 1 with minimal standard deviation.

The evaluation of the adequacy of the analyzed models for agricultural companies, as assessed through overall model performance and the incidence of type I and type II errors, is presented in Table 2.

Table 2. Evaluation of the adequacy of individual model utilization in agricultural companies

Elements	**Models**				
	VB	**DB**	**P**	**Z’**	**Ohlson**
AB	9	4	8	7	8
FB	0	5	1	2	1
AS	7	6	4	9	8
FS	2	3	5	0	1
Overall accuracy (%)	88.89	55.56	66.67	88.89	88.89
Error type I (%)	0	27.78	5.56	11.11	5.56
Error type II (%)	11.11	16.67	27.78	0	5.56
AB-accurate bankrupt; FB-false bankrupt; AS-accurate stable; FS-false stable					

Source: Authors’ calculations

Based on the results presented in Table 2, it can be concluded that the VB model effectively identified bankrupt agriculture companies while achieving a perfect assessment with no type I errors. Sandin and Porporato (2008) highlight that type I errors represent a tangible loss for shareholders, bankers and other stakeholders, whereas type II errors are associated with opportunity costs. The VB model exhibited a type II error rate of 11.11%, incorrectly classifying 2 out of 9 stable companies as bankrupt ones. In contrast, the DB model displayed the highest type I error rate at 27.78%, misclassifying 5 out of 9 bankrupt companies as stable and without risk. The highest error rate II (27.78%) has model P. In comparison, the Ohlson and Altman Z’ score models exhibited generally lower error rates than the aforementioned models, which is noteworthy given that they were formulated for economic contexts that differ significantly from that of the Republic of Serbia. Notably, Altman’s Z’ score successfully evaluated all analyzed stable companies, achieving a type II error rate of 0%.

Descriptive statistics about the outcomes of the applied models for both stable and bankrupt companies in the food sector are presented in Table 3.

Table 3. Descriptive statistics for applied models in food processing companies

Elements	Models									
	VB		DB		P		Z'		Ohlson	
	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable	bankrupt	stable
Mean	0.95	0.25	0.60	0.28	0.93	0.44	-0.58	8.85	0.88	0.21
Median	1	0.09	0.91	0	0.94	0.38	-0.02	8.01	0.97	0.07
Standard deviation	0.11	0.34	0.46	0.42	0.02	0.37	3.41	5.71	0.27	0.32
Minimum	0.64	0	0	0	0.86	0	-10.02	2.98	0.03	0.01
Maximum	1	1	1	0.97	0.95	0.93	5.14	25.27	1	0.92
Cutt of	>0.50	<0.50	>0.50	<0.50	>0.50	<0.50	<1.23	>1.23	>0.50	<0.50
Sample	12	12	12	12	12	12	12	12	12	12

Source: Authors' calculations based on data from financial reports, Business Register Agency

The median values for bankrupt companies indicate that the models employed in this study generally classified the business operations of the analyzed enterprises as financially vulnerable, reflecting a heightened probability of bankruptcy. This suggests that the predictive models used were sensitive to the financial patterns typically associated with distressed companies. Additionally, the median values recorded for financially stable companies further demonstrate the effectiveness of the models in accurately identifying enterprises with low bankruptcy risk. This distinction reinforces the discriminatory power of the tested models in differentiating between solvent and insolvent entities. Furthermore, the analysis of standard deviation values for Altman's Z' score reveals a pronounced variability between the two groups, underscoring a significant separation between stable and bankrupt companies. These findings confirm that the Z' score not only captures central tendencies effectively but also reflects the dispersion of risk across the analyzed companies, thus supporting the model's robustness in practical applications.

The assessment of the adequacy of the analyzed models for companies in the food sector, based on overall model performance and the incidence of type I and type II errors, is presented in Table 4.

Table 4. Evaluation of the adequacy of individual model utilization in food processing companies

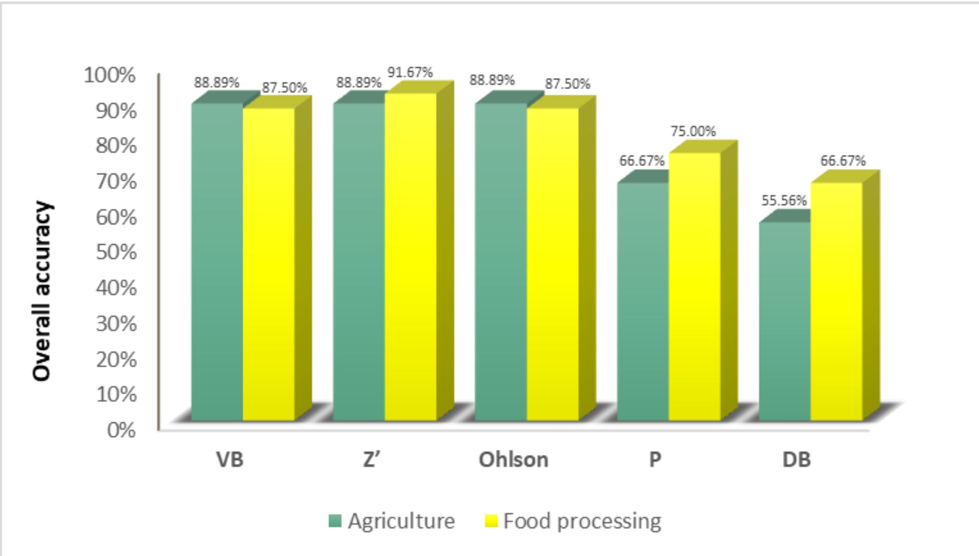
Elements	Models				
	VB	DB	P	Z'	Ohlson
AB	12	7	12	10	11
FB	0	5	0	2	1
AS	9	9	6	12	10
FS	3	3	6	0	2
Overall accuracy (%)	87.50	66.67	75	91.67	87.50
Error type I (%)	0	20.83	0	8.33	4.17
Error type II (%)	12.50	12.50	25	0	8.33
AB-accurate bankrupt; FB-false bankrupt; AH-accurate stable; FS-false stable					

Source: Authors' calculations

Based on the results presented in Table 4, it can be concluded that the VB and P models were the most effective in classifying bankrupt companies, as they successfully evaluated all enterprises that had initiated bankruptcy proceedings. The Z' score also effectively identified all stable companies from the food sector, indicating a complete absence of type II error. Conversely, the DB model exhibited the highest type I error rate at 20.83%, misclassifying 5 out of 12 bankrupt companies as stable and without bankruptcy risk. Additionally, the P model recorded the highest type II error rate at 25%.

A comparative analysis of the overall accuracy of the analyzed models for agricultural and food companies is presented in Figure 1.

Figure 1. The overall accuracy of individual models in analyzing the initiating of bankruptcy proceedings



Source: Authors' calculations

In assessing the likelihood of initiating bankruptcy proceedings for agricultural companies, the VB, Z' and Ohlson models exhibit the highest levels of accuracy. Although these models share identical overall accuracy scores of 88.89% in classifying companies financial integrity, the VB model holds a slight advantage due to the absence of Type I error. When examining the results for food processing companies, it is evident that the same models are the most effective for classification, with Altman's Z' score achieving the highest accuracy rate of 91.67%. While Stanišić et al. (2013) did not focus exclusively on agricultural and food companies, they also concluded that Altman's Z' score is applicable for analyzing the potential for bankruptcy proceedings in the Republic of Serbia. In contrast, Muminović et al. (2011) and Mizdraković and Bokić (2016) highlighted the limitations of using this model. The influence of varying economic dynamics and sectoral differences on the performance of specific models is demonstrated through the results of the DB model. Initially, this general model exhibited an average accuracy rate of 92.1% on the development sample and 87.8% on the test sample in 2016. However, the findings of this study indicate a notable decrease in the model's predictive accuracy, which dropped to 55.56% for agricultural and 66.67% for food processing companies. This reduction suggests that the model may have limitations when applied to current sector-specific conditions.

Conclusions

The study focuses on assessing the appropriateness of implementing various models for bankruptcy prediction. Specifically, it examines Altman's Z'-score, Ohlson, VB, DB, and P models using a sample comprising both financially stable and bankrupt companies within the agricultural and food sectors. Through an analysis of the performance of these models across different sectors, this research aims to enhance the understanding of their predictive capabilities and to identify which models provide the most reliable estimates of bankruptcy risk.

The findings of this research indicate that the VB model was the most effective in assessing the financial stability of agricultural companies. Although this model was originally developed for the processing industry, analysis suggests it is adaptable to the unique financial indicators of the agricultural sector. Conversely, Altman's Z' score emerged as the most suitable model for companies in the food processing industry. Based on the conducted analysis, the research hypothesis stating that the applied models successfully forecasted bankruptcy within the analyzed agricultural and food processing companies is confirmed. However, these conclusions should be interpreted with caution due to the limited sample size, which may not fully reflect the broader structure of the analyzed industries. A larger and more diverse sample would facilitate a more robust statistical analysis and could yield different insights regarding the effectiveness of the analyzed models. Furthermore, the exclusive focus on two sectors constrains the comparability of the results. Broadening the scope of future research to cover multiple industries could significantly improve the understanding of how different models perform in varying economic contexts. Another limitation arises from the reliance on historical financial data, which may not adequately reflect current trends. Economic conditions, regulatory changes, and technological advancements can significantly influence bankruptcy risk, yet these factors were not incorporated into the implemented models. Future models could have a wider array of variables, including macroeconomic indicators, industry-specific risks, and qualitative factors. Moreover, the rapid advancement of artificial intelligence and machine learning presents opportunities to enhance bankruptcy prediction models. The integration of advanced analytical techniques could improve predictive accuracy and responsiveness to dynamic economic climate. Future research could also include hybrid models that combine traditional financial metrics with machine learning algorithms, potentially resulting in more sophisticated and adaptable bankruptcy prediction tools. Furthermore, while the study assessed the accuracy of the chosen models, the practical implementation was not thoroughly discussed due to the scale constraints of the research. Understanding how these models can be effectively implemented in practice, such as risk assessments conducted by company management, represents a significant area for future research. The findings of this research offer valuable implications for policymakers, financial professionals, and the scientific community. For policymakers, the demonstrated effectiveness of sector-specific models such as the VB and Altman Z' score highlights the need to support the development and application of tailored risk assessment tools in regulatory and economic planning frameworks. Financial professionals, including investors and creditors, may leverage these insights to enhance early warning systems and improve decision-making processes related to credit risk and financial sustainability. For the academic community, the study underscores the importance of advancing predictive methodologies and integrating interdisciplinary approaches. In conclusion, this research offers a comprehensive assessment of bankruptcy prediction models within the agricultural and food industry sectors, providing valuable insights into the effectiveness of the VB and Altman Z' score models. Ultimately, as economies evolve, refining these models will be essential for aiding businesses and investors in making informed decisions, thereby enhancing financial stability and mitigating the risks associated with bankruptcy.

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Conflict of interests

The authors declare no conflict of interest.

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BIRDWATCHING POTENTIAL IN THE PROTECTED NATURE AREAS OF THE VILLAGES OF OMOLJICA AND IVANOVO, VOJVODINA, SERBIA

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ABSTRACT

This study explores the key motivations and satisfaction factors influencing tourists' intentions to revisit protected nature areas for birdwatching in the villages of Omoljica and Ivanovo in Vojvodina, Serbia. The research surveyed 210 domestic tourists who participated in birdwatching excursions organized to mark World Tourism Day in September 2024. Logistic regression analysis revealed that motivations related to socializing and relaxation negatively affected revisit intentions, while satisfaction with transport services positively influenced the likelihood of return visits. The findings underscore the importance of improving transport quality to support birdwatching tourism. This research contributes to a better understanding of tourists' motivations and satisfaction with birdwatching experiences and offers practical insights for the development of tailored tourism offers in protected rural areas.

Introduction

As tourists become more educated and their needs and preferences evolve, tourism products focused on nature, outdoor experiences, and ecological values are gaining in importance (Živković et al., 2024). Among the key trends in the contemporary tourism market, birdwatching has stood out as a significant form of ecotourism and responsible

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travel in destinations, offering valuable contributions not only to visitor experiences but also to ecosystem conservation (Barreira & Cesário, 2024; Mugiarti et al., 2022).

Birdwatching represents a rapidly growing niche within the tourism sector, based on observing birds in their natural habitats (Aas et al., 2023; Fennell & Yazdan, 2020). Birdwatching is a nature-based activity that does not involve the extraction or disturbance of natural resources (Randler et al., 2023). It can raise tourists' awareness and act as a powerful motivator for bird protection, encouraging more sustainable behavior both in the destination and in their daily lives (Borges & Green, 2017). Additionally, birdwatching contributes to the improvement of local environments and infrastructure, increases awareness of bird conservation, and promotes environmental protection in rural areas. This form of tourism supports the development of mountain regions and provides an additional source of income for local communities (Basnet et al., 2021).

The Republic of Serbia offers favorable conditions for the development and promotion of birdwatching tourism. This type of tourism can play an important role in fostering the sustainable management of nature reserves by encouraging outdoor recreation while enriching the experience for visitors in rural areas (Borović et al., 2022). As part of broader rural development efforts, birdwatching is increasingly recognized as a key driver for engaging local resources and promoting sustainable growth (Kosanović et al., 2024). Rural areas are moving beyond the traditional paradigm of being exclusively associated with agriculture and are developing stronger links with tourism (Dimitrijević, 2025, Luković et al., 2025).

The aim of this research is to examine the possibilities for developing of birdwatching as a form of selective tourism in underdeveloped villages in Vojvodina with a well-preserved natural environment. This study was carried out in the context of a birdwatching excursion in the villages of Omoljica and Ivanovo, held in September 2024. More precisely, the research was conducted in Ponjavica Nature Park, along the Ponjavica River in the village of Omoljica, and in the Nature Monument Ivanovačka ada, located on the Danube River in the village of Ivanovo.

Destinations must offer activities that align with visitors' motivations to enhance satisfaction and encourage repeat visits (Douglas et al., 2024). Because tourists have diverse motivations, selecting suitable activities and destinations is a complex decision shaped by numerous factors. Addressing this complexity, McKercher and Koh (2017) emphasized that understanding tourists' motives is essential for explaining their destination choices and the level of experience they seek. Besides this, understanding tourists' travel motivations and satisfaction is essential for developing effective and sustainable tourism strategies. Motivations drive the initial choice to visit a destination, while satisfaction with specific aspects of the visit influences whether tourists will return (Bayih & Singh, 2020). In the context of underdeveloped villages with rich natural resources, such as Omoljica and Ivanovo, exploring these factors helps identify what attracts visitors and what keeps them coming back, which is critical for fostering birdwatching tourism as a sustainable economic activity. Therefore, this study focuses on examining how certain travel motives (1 - nature conservation, 2 - interest in protected birds, 3 - enjoy photographing birds, 4 - recreation and entertainment, 5 - socializing and meeting new people, 6 - relaxation, 7 - physical activity and walking) and satisfaction levels (1 - with excursion organization, 2 - with media promotion, 3 - with the transport services, 4 - with contribution of such excursions to birdwatching development, 5 - with contribution of such excursions to sustainable tourism development, 6 - with guide services and expertise, 7 - overall satisfaction) impact tourists' willingness to revisit these villages for birdwatching purposes. Two hypotheses were formulated to guide this research:

- H1: Certain travel motivations for participating in the birdwatching excursion significantly influence tourists' willingness to revisit the villages of Omoljica and Ivanovo for birdwatching purposes.
- H2: Satisfaction with specific aspects of the birdwatching excursion in the villages of Omoljica and Ivanovo significantly influences tourists' willingness to revisit these villages.

Literature review

National parks, wilderness areas, and nature reserves represent ideal settings for the development oJes, especially birdwatching (Freiberg & Callegaro, 2025).

This form of tourism is experiencing rapid growth and shows potential for providing financial incentives to local communities, who play a key role in the protection and conservation of natural areas (Xanthakis et al., 2024). It is particularly beneficial for rural population, helping them to increase their annual income (Xu et al., 2023). In contrast to developed countries, many developing nations lag behind in bird conservation due to the low priority given to such efforts (Vaithianathan, 2024). Maake et al. (2022) identified five main motivations among birdwatching tourists: social interaction, relaxation and escape, lifestyle, photography, and enjoying nature. Additionally, Richter et al. (2021) found that tourists are motivated to engage in birdwatching both by personal interest and by their desire to contribute to nature conservation.

Focusing on leisure activities in general, Walker et al. (2020) explored the relationship between the fulfillment of participants' basic psychological needs and their intrinsic motivation, finding that the need for autonomy was a significant driver of birdwatching among British, Chinese, and Canadian tourists. Randler et al. (2023a) highlight the connection between tourist satisfaction with birdwatching and psychological well-being, especially among those who are not regular birdwatchers. These visitors reported higher levels of satisfaction with such trips. Visitors to bird-rich areas and nature reserves differ significantly depending on whether they identify as birdwatchers or not. Birdwatchers tend to invest more effort into their travel experiences and have higher expectations of their visits (Stemmer et al., 2022). Regarding the sociodemographic characteristics of tourists, research has shown that individuals with higher levels of education are more inclined to learn about bird appearance, sounds, and related skills, as well as to participate in and pay for birdwatching excursions (Krejić et al., 2019; Liu et al., 2021).

Materials and methods

In 2024, the Citizens' Association Visit Pančevo, a local organisation, organized an excursion for tourists to the villages of Omoljica and Ivanovo in Vojvodina as part of the World Tourism Day celebrations on September 27. The Citizens' Association invited local tourism organizations, associations, media, and all interested tourists via its social networks to join a free birdwatching excursion. The excursion was conducted by bus and accompanied by specialized bird guide. The aim of the excursion was to educate participants about rare bird species found in Ponjavica Nature Park (Omoljica) and the Nature Monument Ivanovačka ada (Ivanovo).

At the end of the excursion, 210 tourists completed a questionnaire designed to explore their motivations and satisfaction levels regarding the experience. Data were subsequently analyzed using descriptive and inferential statistical methods, specifically binary logistic regression. The questionnaire consisted of eight questions and was developed based on similar studies by Kim & Park (2024) and Randler & Großmann (2022). Data analysis was conducted using IBM SPSS Statistics version 26.0.

Study area

The case study includes the Ponjavica Nature Park in the village of Omoljica and the Nature Monument Ivanovačka ada, in the village of Ivanovo, on the Danube River. These sites represent a green oasis and are located 20 km from Pančevo and 40 km from Belgrade.

The Nature Park Ponjavica is located in southern Banat, Vojvodina. The area of the park covers 302.96 ha. The area of the protection zone around the Nature Park covers 678.57 ha. The Nature Park includes the middle course of the Ponjavica River, which has preserved characteristics of watercourses of plain areas and coastal remains of wetland habitats (Ristić et al., 2024). Among the more important plant species inhabiting the Nature Reserve area are *Potamogeton pusillus, Carex acuta, Scirpus lacustris subsp. tabernaemontani, Zannichellia palustris, Potamogeton pusillus, Salvinia natans, Zannichellia palustris, Carex acuta, and Scirpus lacustris subsp. tabernaemontani*. The most important bird representatives are *Egretta garzetta*, *Nycticorax nycticorax*, *Ardeola ralloides*, *Chlidonias hybrida*, *Tachubaptus ruficollis*, *Podiceps cristatus*, *Aythya nyroca*, *Anas platyrhynchos*, *Cygnus olor*, *Anas clypeata*, *Acrocephalus schoenobaenus*, *Acrocephalus palustris*, *Acrocephalus scirpaceus*, *Acrocephalus arundinaceus*, *Remiz pendulinus*, etc. (The Register of Protected Natural Assets in Vojvodina, 2023).

Nature Monument Ivanovačka ada is a river island (ada) in the Danube, in the territory of the City of Pančevo. It was protected in 2009 as a natural monument because of the remnants of former lowland forests of the indigenous species of white poplar and willow, which are also the habitat of rare and protected species of plants (*Rorippa sylvestris, Vitalis vinifera L. Subsp. Sylvestris, Erysinium sheiranthoides L.) and animals (Alcedo atthis, Haliaeetus albicilla, Picus viridis*) and a large number of birds. It covers an area of only 6.07 ha, with a 50 m wide protection zone (Šćiban, 2015). During this excursion, the guide identified and recorded the following birds: *Mute Swan - Cygnus olor 14, Wood Pigeon - Columba palumbus 1, Common Gull - Chroicocephalus ridibundus 5, Great Cormorant - Phalacrocorax carbo 20, Grey Heron - Ardea cinerea 10, Great Egret - Ardea alba 5, Little Egret - Egretta garzetta 1, Gul - Nycticorax nycticorax 1, White-tailed Eagle - Haliaeetus albicilla 2, Kestrel - Buteo buteo 1, Kestrel - Alcedo atthis 3, Magpie - Pica pica 1, Raven - Corvus cornix 3.*

Results

Of the total number of respondents, 57.1% were female and 42.9% male. The majority of participants were between the ages of 30 and 50, with the largest age group being 30-40 years (31.0%). Educational levels among respondents ranged from high school to doctoral degrees. While a small portion had only secondary education (18.6%), the largest proportion held university degrees (31.4%), followed by master's degree holders (27.1%). Regarding employment status, 55.7% of respondents were unemployed, while 44.3% reported being employed at the time of the survey. This distribution may reflect the inclusion of students, retirees, or individuals temporarily out of work (Table 1).

Table 1. Demographic characteristics of respondents

		Frequency	Percent
Gender	Male	90	42.9%
	Female	120	57.1%
Age	<20	19	9.0%
	20-30	55	26.2%
	30-40	65	31.0%
	40-50	48	22.9%
	50-60	13	6.2%
	60-70	9	4.3%
	>70	1	0.5%
Education	High school	39	18.6%
	College of Applied Studies	41	19.5%
	University	66	31.4%
	Master's Degree	57	27.1%
	Doctorate	7	3.3%
Employed	Yes	93	44.3%
	No	117	55.7%

Source: Authors' calculations

When asked how they found out about the excursion, over half of the respondents (51.4%) reported the internet as their main source of information. Word of mouth was the second most frequent channel (39.5%), while tourism agencies and other sources were reported by a small minority (7.6% and 1.4%, respectively). This emphasizes the importance of digital channels and peer recommendations in promoting such events.

As for travel motivations, the most highly rated motives were: *relaxation (M = 4.35), recreation and entertainment* (M = 4.28), *physical activity and walking* (M = 4.25). Meanwhile, the lowest-rated motivation was *interest in protected birds* (M = 3.58), although still above the scale midpoint, indicating a generally positive orientation toward birdwatching.

Satisfaction levels were generally high. The highest-rated satisfaction items were: *Satisfaction with the contribution of such excursions to birdwatching development* (M = 4.62) and *Satisfaction with contribution of such excursions to sustainable tourism development* (M = 4.54). *Overall satisfaction* and *guiding services* also received strong ratings (M = 4.42 and M = 4.39) (Table 2).

Table 2. Descriptive statistics

	Mean	Std. deviation	Variance
Motive 1 - Nature conservation	4.0238	1.01868	1.038
Motive 2 - Interest in protected birds	3.5762	1.02430	1.049
Motive 3 - Enjoy photographing birds	3.5333	1.18254	1.398
Motive 4 - Recreation and entertainment	4.2762	0.89116	0.794
Motive 5 - Socializing and meeting new people	3.6095	1.08045	1.167
Motive 6 – Relaxation	4.3476	0.91668	0.840
Motive 7 - Physical activity and walking	4.2476	0.91013	0.828
1 - Satisfaction with excursion organization	4.2571	0.83039	0.690
2 - Satisfaction with media promotion	4.1048	0.91687	0.841
3 - Satisfaction with the transport services	4.3190	0.87393	0.764
4 - Satisfaction with contribution of such excursions to birdwatching development	4.6238	0.63878	0.408
5 - Satisfaction with contribution of such excursions to sustainable tourism development	4.5429	0.61135	0.374
6 - Satisfaction with guide services and expertise	4.3952	0.81902	0.671
7 - Overall satisfaction	4.4190	0.59954	0.359

Source: Authors' calculations

Finally, the participants were almost evenly split in their willingness to revisit the same protected areas for birdwatching, with 51.4% expressing a positive intention and 48.6% a negative one.

To test the hypothesis H1: *Certain travel motivations for participating in the birdwatching excursion significantly influence tourists' willingness to revisit the villages of Omoljica and Ivanovo for birdwatching purposes*, a binary logistic regression was conducted. This method was used to examine whether specific travel motivations significantly predict the willingness to revisit the Vojvodina region for birdwatching. The dependent variable was a binary response to the question: *Would you consider coming again to the Ponjavica Nature Park in the village of Omoljica and the Nature Monument Ivanovačka ada, in the village of Ivanovo for birdwatching?* (0 = No, 1 = Yes). The independent variables included seven motivational factors, each measured on a 5-point Likert scale (1 = not important at all, 5 = extremely important).

Table 3. Logistic regression – model summary

	Value
-2 Log Likelihood	271.302
Cox & Snell R^2	0.089
Nagelkerke R^2	0.119
Chi-square (model)	19.649
Df	7
Sig. (model)	0.006

Source: Authors' calculations

The overall model was statistically significant ($\chi^2 = 19.649$, df = 7, $p = 0.006$), indicating that the set of motivational variables reliably distinguishes between tourists who are willing and those who are not willing to revisit the region for birdwatching. The Nagelkerke R^2 of 0.119 suggests that approximately 11.9% of the variance in revisit intention can be explained by the model (Table 3). The Hosmer-Lemeshow goodness-of-fit test was not statistically significant ($p = 0.403$), suggesting that the model adequately fits the data (Table 4).

Table 4. Hosmer and Lemeshow test

Chi-square	**df**	**Sig.**
8.316	8	0.403

Source: Authors' calculations

Based on the logistic regression results, only two motivational factors, socializing and relaxation showed a statistically significant relationship with the intention to revisit the area for birdwatching purposes. Both emerged as negative predictors, indicating that the more importance respondents place on these motivations, the less likely they are to express interest in returning for birdwatching.

Respondents who rated socializing as an important travel motivation were less likely to express willingness to revisit the region for birdwatching (p=0.023, Exp(B)=0.721). This finding may suggest that birdwatching is perceived as a quiet, solitary activity, less compatible with motivations focused on group interaction or social engagement.

Participants who considered relaxation to be an important motive were less inclined to return for birdwatching experiences (p=0.030, Exp(B)=0.648). This could indicate that birdwatching is not perceived as sufficiently restful or aligned with passive leisure preferences.

Other motivational variables, such as nature conservation, interest in birds, bird photography, recreation, and physical activity, did not show statistically significant effects on revisit intentions ($p > 0.05$), suggesting that they do not meaningfully predict tourists' likelihood of returning to these sites specifically for birdwatching (Table 5).

Table 5. Logistic regression coefficients

	B	S.E.	Wald	Sig.	Exp(B)
Nature conservation	-0.197	0.148	1.777	0.183	0.821
Interest in birds	-0.046	0.149	0.093	0.760	0.955
Bird photography	-0.094	0.134	0.492	0.483	0.910
Recreation	0.230	0.211	1.194	0.274	1.259
Socializing	**-0.328**	0.144	5.163	**0.023**	**0.721**
Relaxation	**-0.433**	0.200	4.718	**0.030**	**0.648**
Physical activity	-0.089	0.191	0.217	0.641	0.915
Constant	3.424	1.221	9.168	0.002	40.703

Source: Authors' calculations

Based on the results of the logistic regression analysis, the hypothesis H1 was partially confirmed**.** While not all travel motivations proved to be statistically significant predictors of revisit intention, two variables, socializing and relaxation showed a significant negative effect. This indicates that specific motivational dimensions do influence tourists' willingness to return to the protected areas for birdwatching purposes.

To test the hypothesis H2: *Satisfaction with specific aspects of the birdwatching excursion in the villages of Omoljica and Ivanovo significantly influences tourists' willingness to revisit these villages,* a binary logistic regression analysis was conducted. The overall model was statistically significant, $\chi^2(7) = 16.09$, $p = 0.024$, indicating that the set of predictors collectively contributed to the prediction of the dependent variable. The model's explanatory power, as indicated by the Cox & Snell R^2 and Nagelkerke R^2 values, was modest (0.074 and 0.098), which is typical for logistic regression models in social science research (Table 6). Additionally, the Hosmer and Lemeshow goodness-of-fit test showed a non-significant result, $\chi^2(8) = 14.06$, $p = 0.080$, suggesting that the model fits the data adequately (Table 7). These results confirm that the logistic regression model is appropriate and reliable for testing the second hypothesis.

Table 6. Logistic regression – model summary

	Value
-2 Log Likelihood	274.863
Cox & Snell R^2	0.074
Nagelkerke R^2	0.098
Chi-square (model)	16.087
Df	7
Sig. (model)	0.024

Source: Authors' calculations

Table 7. Hosmer and Lemeshow test

Chi-square	Df	Sig.
14.057	8	0.080

Source: Authors' calculations

The results of the logistic regression analysis indicate that, among the various satisfaction variables included in the model, only satisfaction with the transport services was found to be a statistically significant predictor of tourists' willingness to revisit the protected areas for birdwatching ($p = 0.024$). The regression coefficient (B = 0.484) and the odds ratio (Exp(B) = 1.622) suggest that higher satisfaction with the transport services increases the likelihood of a positive revisit intention. Conversely, dissatisfaction with the transport services may be a barrier to returning for birdwatching purposes. Other satisfaction variables, such as satisfaction with excursion organization, media promotion, guide services, and the perceived contribution to birdwatching and sustainable tourism, did not reach statistical significance ($p > 0.05$). However, some predictors showed trends toward significance, particularly satisfaction with the excursions' contribution to sustainable tourism ($p = 0.114$) and excursion organization ($p = 0.119$), which may need further investigation in future studies with larger or more targeted samples (Table 8).

Table 8. Logistic regression coefficients

	B	S.E.	Wald	Sig.	Exp(B)
Satisfaction with excursion organization	-0.343	0.220	2.429	0.119	0.710
Satisfaction with media promotion	0.134	0.171	0.615	0.433	1.143
Satisfaction with the transport services	**0.484**	0.214	5.011	**0.024**	**1.622**
Satisfaction with contribution of such excursions to birdwatching development	0.100	0.260	0.148	0.701	1.105
Satisfaction with contribution of such excursions to sustainable tourism development	-0.394	0.249	2.493	0.114	0.675
Satisfaction with guide services and expertise	0.116	0.200	0.335	0.562	1.123
Overall satisfaction	0.087	0.269	0.105	0.746	1.091
Constant	3.377	1.671	4.085	0.043	29.291

Source: Authors' calculations

Overall, these findings partially support the hypothesis H2, suggesting that while not all satisfaction elements significantly impact revisit intention, certain logistical aspects, particularly satisfaction with the transport services, do play a meaningful role in shaping future behavioral intentions related to birdwatching tourism.

Discussion

Previous studies highlight that birdwatching motivations can be diverse, resulting in varying tourist behaviors (Großmann et al., 2025). There are visitors who travel specifically for the purpose of birdwatching (Aas et al., 2023; Randler & Großmann, 2022; Ryan & Deci, 2017). Additionaly, some tourists join such trips for activities like bird counting, recognizing their personal value and practical contribution to nature conservation and physical wellbeing (Guilfoos et al., 2024). The results of this study indicate that relaxation is the primary motivation for participating in birdwatching excursions, which aligns with the findings of Maake et al. (2022). More broadly, contemporary tourists are drawn to destinations that offer a wide range of recreational opportunities (Arsić et al., 2025). In addition, other important motives were identified, including recreation and entertainment, physical activity and walking. This has important implications for creating tourism products that combine educational and recreational elements, thereby attracting a broader segment of domestic tourists.

Modern tourists are often quite disconnected from nature, making this an important way for them to actively and meaningfully spend time outdoors. Additionally, there are tourists whose primary motivation is to spend time in nature, and who find observing wildlife both enjoyable and educational. Tourist activities play a key role in visitor satisfaction and loyalty (Padrón-Ávila et al., 2022), as well as in satisfaction and tourism expenditure, where satisfaction is a determinant of tourist spending in destinations (Perles-Ribes et al., 2021).

The expectations of birdwatching tourists are closely related to the quality of services provided at the site. Upon arriving at a birdwatching location, tourists expect all necessary amenities to be available to meet their needs, including food, accommodation, transportation, binoculars, cameras, tour guides, bird feed, camping equipment, and more (Govindarajo & Khen, 2020). Regarding tourists' satisfaction with different aspects of the excursion, research results showed that satisfaction levels were generally high. The highest-rated items included satisfaction with the contribution of such excursions to the development of birdwatching.

The logistic regression analysis revealed interesting findings regarding tourists' motivations and satisfaction factors influencing their willingness to revisit protected areas for birdwatching. Specifically, socializing motivation was a significant negative predictor of revisit intention, which may reflect the perception of birdwatching as a quiet, solitary activity less appealing to those whose primary travel goal involves social interaction. In a similar vein, relaxation motivation also showed a negative effect, indicating that birdwatching might not be viewed as sufficiently restful or fitting well with preferences for more passive leisure activities. Moreover, although relaxation was the highest-rated initial motive for joining the excursion, it did not translate into a stronger desire to return. This suggests that while birdwatching may initially attract tourists with general leisure motivations, long-term engagement may require a deeper interest in or connection to nature. Among satisfaction factors, only satisfaction with the transport services significantly influenced tourists' willingness to return, with higher satisfaction increasing the likelihood of revisit. This finding aligns with Okello and Yerian (2009), who emphasize that satisfaction with the transport services is crucial not only for accessing national parks and nature reserves but also for locating wildlife and enabling various tourist activities. Therefore, satisfaction with the transport services quality can be a key determinant of tourists' behavioral intentions in wildlife tourism contexts. Understanding the interplay between motivations, satisfaction, and revisit intentions is essential, as noted by Dybsand et al. (2021), who highlight the importance of such analyses for improving the management and development of birdwatching tourism.

Conclusions

Birdwatching is a growing niche in nature-based tourism, offering both recreational and educational benefits while supporting biodiversity conservation. Understanding tourists' motivations and satisfaction factors is crucial for developing sustainable birdwatching tourism, especially in rural and protected areas.

The results of this study highlight the importance of various motivations and satisfaction factors in shaping tourists' willingness to revisit protected areas for birdwatching. Special attention should be given to improving infrastructure and services related to transportation, as satisfaction with the transport services was found to be a statistically significant predictor of revisit intention. Other satisfaction aspects, such as event organization and contribution to sustainable tourism, were not statistically significant but showed trends that could be relevant for future research with larger samples. These findings emphasize the need for a better understanding of tourists' diverse motivations in order to tailor the birdwatching offer more effectively to visitor expectations.

However, the study has several limitations, primarily the sample size, which may affect the statistical power of the analyses. Additionally, the sample was focused on domestic tourists in specific rural areas, which may limit the generalizability of the results to other populations and destinations. Furthermore, the use of only quantitative methods might miss deeper insights into tourists' motivations and experiences, so a combination of qualitative and quantitative approaches in future studies could provide more comprehensive understanding.

The scientific contribution of this work lies in advancing knowledge about the motivations and satisfaction factors of tourists interested in birdwatching in rural areas. The practical significance is that these findings may serve as a foundation for creating future birdwatching tours, excursions, and tourism offers in similar rural areas. It is recommended that future research include more tourists and further investigate factors such as the organization of excursions and their contribution to sustainable development in the context of birdwatching, which showed potential importance in this study.

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Conflict of interests

The authors declare no conflict of interest.

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LEGAL DIMENSIONS OF EU SUSTAINABLE AGRICULTURE POLICIES

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A R T I C L E I N F O

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A B S T R A C T

Sustainable agriculture represents a key aspect of the EU's environmental policy, as it has a significant impact on biodiversity, soil quality, and water resources. The European Commission implements a set of policies aimed at aligning economic productivity with the protection of natural resources and the reduction of greenhouse gas emissions. This paper focuses on the analysis of European Union policies in the field of sustainable agriculture, with particular emphasis on the strategic and legal framework. Special attention is given to the main instruments supporting the transition toward ecologically, economically, and socially sustainable models of food production: the Common Agricultural Policy (CAP), the European Green Deal, the Farm to Fork Strategy, and the EU Biodiversity Strategy for 2030. Furthermore, examples of good practices implemented by certain EU Member States are examined. The findings highlight the necessity of amending future EU acts to incorporate digitalization, innovation, and the level of climate-related risks.

Introduction

Sustainable agriculture represents a key component of the European Union's (EU) contemporary development strategies, as it integrates economic, environmental, and social aspects of food production. Its essence lies in producing food in a way that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (FAO, 2022). In the context of climate change, land degradation, biodiversity loss, and the growing demand for food, the EU recognizes

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that agriculture must undergo transformation in order to contribute to the achievement of the Sustainable Development Goals (UN, 2015).

For decades, the European Union has been developing and adjusting its agricultural policies. The Common Agricultural Policy (CAP), established in 1962, has been the main instrument for supporting farmers and ensuring food security in the EU. However, since the beginning of the 21st century, the CAP has been increasingly reformed to respond to the challenges of sustainability, the reduction of greenhouse gas emissions, the protection of natural resources, and the preservation of rural communities (European Commission, 2023). Sustainable agriculture is one of the key elements in addressing global challenges such as biodiversity loss, resource depletion, and climate change. The development of agricultural policies that balance ecological, economic, and social objectives plays a crucial role in the European Union, which declares itself a global leader in promoting sustainability.

The European Commission implements a variety of initiatives to enhance the sustainability of agricultural practices, such as the European Green Deal and the Common Agricultural Policy (CAP), along with a range of policies aimed at promoting sustainable agriculture through financial incentives, legislative frameworks, and innovative practices.

In this context, the European Green Deal (2019), together with the Farm to Fork Strategy and the EU Biodiversity Strategy, sets ambitious goals to achieve climate neutrality by 2050, while also improving food quality and the health of EU citizens (European Commission, 2020a). These policies have far-reaching implications not only for farmers but also for the entire food system.

This paper analyzes the key mechanisms, including the Common Agricultural Policy, the Farm to Fork Strategy, and other regulations designed to reduce the environmental footprint of agriculture. It examines the impact of these policies on farmers, consumers, and society at large. Furthermore, the paper explores examples of best practices and the challenges of implementing these policies across different EU Member States.

Materials and methods

The main objective of the methodology in this paper is to identify the key EU policies and strategies in the field of sustainable agriculture, examine their connection with the Sustainable Development Goals, and analyze examples of best practices in selected Member States. Accordingly, a qualitative, review-analytical approach is applied, based on the analysis of relevant academic literature, official European Union documents, and reports of international organizations dealing with sustainable agriculture. The key sources include official EU documents and strategies—such as the Common Agricultural Policy (CAP), the European Green Deal, the Farm to Fork Strategy, and the EU Biodiversity Strategy for 2030—alongside reports (such as FAO, OECD, EEA..).

This research relies exclusively on secondary sources, which may limit the ability to directly measure the empirical effects of the policies. Additionally, political changes and updates to EU strategies may lead to the rapid obsolescence of certain data, a limitation that has been taken into account in the analysis. systematic search of scientific articles, books, and reports in the fields of agricultural economics, agroecology, and rural development policy was conducted using relevant academic databases. The analysis focuses primarily on studies published within the last ten years, in order to ensure the relevance and timeliness of the information.

Literature Review

This section of the paper examines the fundamental theories and definitions related to sustainable agriculture, as well as existing studies and research addressing this topic in the context of the European Union (EU).

The concept of sustainable agriculture as a descriptive term evolved in the United States in the early 1980s as a mixture of concepts, ideas, values, and directions for development, which many believed to represent the vision of what agriculture should be. In 1990, the U.S. Congress defined sustainable agriculture as “an integrated system of plant and animal production practices” that is site-specific and designed to, in the long term: (U.S. Congress, 1990)

- satisfy human food and fiber needs,
- enhance environmental quality and the natural resource base upon which the agricultural economy depends,
- make the most efficient use of nonrenewable resources and on-farm resources, and integrate natural biological cycles and controls where appropriate,
- sustain the economic viability of farm operations,
- enhance the quality of life for farmers and society as a whole.

It is important to note the inherently subjective nature of agricultural activities, given the diversity of organizational structures, types of production, and contextual conditions. While it may be difficult to predict what will ultimately prove to be sustainable, it is usually possible to assess whether certain practices are more sustainable than others.

Over the past two decades, the literature on sustainable agriculture has provided a detailed overview of these broad topics. Concepts such as “low-input sustainable agriculture” and “alternative agriculture” have emerged and are frequently used by non-American authors as well, particularly in relation to organic production systems. A sustainable system is generally defined as one that is well-structured, capable, and resilient. Sustainable agriculture is often described as agricultural production that meets the needs of present generations for food and fiber while simultaneously protecting the resources and ecosystems that allow food production for future generations.

Considering the various definitions of sustainable agriculture, it can be described as a set of agronomic practices that are both economically viable and ecologically sound.

This definition encompasses three main components of sustainability: ecological, economic, and social dimensions (Pretty, 2008):

Ecological sustainability refers to the preservation of biodiversity, reduction of greenhouse gas emissions, and the conservation of soil, water, and other natural resources.

Economic sustainability implies that farmers can generate income from their farms over the long term, reducing dependence on subsidies and external factors such as price fluctuations.

Social sustainability includes food security, improvement of the quality of life in rural communities, and ensuring fair working conditions for agricultural laborers.

According to the FAO (2017), sustainable agriculture is defined as agriculture that "supports productivity and ecological balance, allowing people to be fed now and in the future while preserving natural resources."

The literature on sustainable agriculture in the EU demonstrates a growing interest in the topic, especially in recent decades. Research focuses not only on the effects of EU policies in reducing the environmental footprint of agriculture but also on the economic and social aspects of sustainability; how sustainable agriculture can contribute to global food security, agricultural methods that can reduce environmental impact while providing the necessary food supply (Pretty, 2008); how small farmers in the EU implement sustainable practices and face market and political pressures (Van der Ploeg, 2011, Luković et al, 2024); how innovations in agriculture can facilitate the transition to more sustainable practices, the importance of technology and innovation, as well as investments in education and infrastructure, to enable the successful adoption of environmentally friendly agricultural methods in the EU (Sundbo, J. 2019; Fedajev et al., 2023).

Furthermore, several theoretical approaches help in understanding sustainable agriculture:

Agroecological approach: agriculture should follow the principles of natural ecosystems, such as biodiversity and cyclical processes. The agroecological approach emphasizes the use of local resources and the reduction of the ecological footprint of agricultural practices;

Economic sustainability models: Agricultural economists highlight the importance of long-term economic sustainability, i.e., production that does not depend on subsidies and allows for a balance between production and resource consumption. This includes the implementation of economic tools such as resource and market analyses, pollution taxes, and subsidies for green technologies;

Social approach: This approach focuses on the social aspects of sustainability, such as the fair distribution of resources, equity in trade, and the role of rural communities in preserving culture and traditions. Agriculture in this context should contribute to improving people's lives, reducing poverty, and maintaining social cohesion.

Research results

Sustainable Agriculture Policies in the European Union

The EU has made significant efforts in recent decades to implement policies that support sustainable agriculture. Some of the key documents shaping EU policy in this area include the European Green Deal, the reformed Common Agricultural Policy, and the Farm to Fork Strategy.

In 2019, the EC adopted the European Green Deal (EGD), which sets an ambitious goal for the EU to become climate-neutral by 2050. Agriculture plays a key role in this plan, as it contributes significantly to greenhouse gas emissions while also offering opportunities to reduce these emissions through the adoption of sustainable practices (EC, 2019). EGD represents a joint action plan aimed at addressing the challenges of the green transition, climate change, biodiversity loss, overuse of resources, and the decoupling of economic growth from resource consumption and environmental degradation. This plan is a growth strategy with the primary objective of transforming the EU into a modern, competitive, resource-efficient, fair, and prosperous society, where economic progress is decoupled from resource depletion. Achieving these goals requires a review of policies related to clean energy, industry, production, consumption, major infrastructure, and more. Additionally, it necessitates improving human health, restoring ecosystems, and using resources more sustainably (Sekulic, 2023).

Common Agricultural Policy (CAP): The Common Agricultural Policy (CAP) is a key EU policy that regulates agriculture and rural development within Member States. Its objectives are to ensure food security, increase agricultural competitiveness, protect the environment, and promote rural development (Maksimovic Sekulic, 2018). Since 2013, the CAP has increasingly focused on sustainability through the introduction of ecological programs and incentives for transitioning to environmentally friendly agricultural practices (European Parliament, 2020).

The CAP is the EU's primary instrument for regulating the agricultural sector. The 2023–2027 CAP reform includes new ecological standards, known as "eco-schemes," which encourage farmers to adopt practices that contribute to climate objectives (European Parliament, 2022). These schemes provide financial incentives for farmers who implement sustainable production methods, including the use of environmentally friendly fertilizers, biodiversity conservation, and reduced water consumption. Additionally, the CAP includes specific measures to support small and medium-sized farms, which often have limited resources to implement ecological standards (Ljubojevic, 2021). Through various subsidy programs, the EU seeks to enable a fair transition toward more sustainable agriculture.

Farm to Fork Strategy: The Farm to Fork Strategy, introduced in 2020, is part of the broader European Green Deal and aims to transition toward a healthier and more sustainable food system. Its key objectives include reducing the use of pesticides and fertilizers, increasing organic production, and strengthening the resilience of food supply chains (European Commission, 2020). The EU aims to reduce the negative environmental impacts of agriculture while encouraging consumers to make environmentally conscious decisions when purchasing food products.

Furthermore, the Farm to Fork Strategy targets the reduction of greenhouse gas emissions from the agricultural sector and minimizes food waste along supply chains. This approach not only enhances agricultural sustainability but also contributes to public health by promoting healthy eating habits. The strategy encompasses measures covering all stages of the food chain—from production to consumption—with the goal of reducing the negative environmental impact of agriculture and improving public health outcomes (Farm to Fork Strategy, EC, 2020).

Main objectives of the Farm to Fork Strategy:

1. ”Reduce the use of pesticides and hazardous chemicals by 50% by 2030.
2. Reduce the use of fertilizers by at least 20% to improve soil and water quality.
3. Increase the area under organic farming to at least 25% of total arable land in the EU.
4. Reduce food waste in the food system and increase the efficiency of food supply chains.
5. Raise consumer awareness of sustainable eating habits and label products according to sustainability criteria”. (Farm to Fork Strategy, EC, 2020)

The strategy includes a range of legislative and financial measures to assist farmers in transitioning to more sustainable practices. The European Union provides incentives and supports research and innovation in agroecology, precision farming, and alternative crop protection methods. Although the strategy brings numerous benefits, its implementation requires significant investment and changes in the way farmers operate. Certain sectors, such as industrial agriculture, may face challenges in adapting to the new standards.

The Farm to Fork Strategy plays a key role in ensuring the long-term sustainability of agriculture in the EU. Its successful implementation depends on cooperation between governments, farmers, the industry, and consumers, alongside continuous innovation and financial support.

The EU Green Deal, including a farm-to-table strategy and digital transformation, opens up new opportunities in rural areas, new dynamics for a more resilient future and opportunities for sustainable jobs; stresses the need to ensure a just and inclusive transition, promoting rural economic vitality and territorial and social cohesion, and to provide adequate support and resources to face the challenges in this regard, especially in light of the current crisis. (Maksimovic Sekulic, 2023)

While these policies provide numerous environmental and economic benefits, challenges include the high costs of transition and the need for additional farmer education.

Nevertheless, the long-term effects are expected to include increased competitiveness of European agriculture and improved food quality for consumers (FAO, 2022).

A particular challenge lies in adapting small and medium-sized agricultural producers to new standards. Additional training and advisory programs are therefore necessary to enable farmers to fully utilize available incentives and adopt best practices for sustainable production.

Moreover, European sustainable agriculture policies have global implications, as the EU promotes sustainable practices in partner countries through trade agreements and regulations. This can lead to positive changes in international agricultural supply chains.

EU Biodiversity Strategy 2030

In parallel with the Farm to Fork Strategy, the EU adopted the Biodiversity Strategy 2030, which aims to halt biodiversity loss, restore degraded ecosystems, and increase nature's resilience to climate change (European Commission, 2020b). Agriculture is one of the key sectors affecting biodiversity, and the strategy foresees measures such as reducing pesticide use, expanding areas under agroecological practices, and protecting pollinators.

Global efforts under the United Nations Convention on Biological Diversity have not been sufficient to halt global biodiversity loss. Within the EU, legal frameworks, strategies, and action plans have been established to protect nature and restore habitats and species. However, protection has been incomplete, restoration efforts limited, and law enforcement insufficient. At the 15th Conference of the Parties to the Convention on Biological Diversity, a new global framework beyond 2020 will be negotiated.

This strategy proposes a transformative plan to address the biodiversity crisis through protection and restoration of nature, enabling transformative change and establishing a global leadership role. It identifies five main drivers of biodiversity loss and emphasizes strengthened governance frameworks to address remaining gaps, ensure full implementation of existing EU legislation, and coordinate all efforts to achieve new targets. The strategy works in combination with all other Green Deal initiatives and serves as a compass and framework for the EU's green economic transition, including industrial, energy, circular economy, and sustainable food transitions. The strategy is built on a simple core commitment: by 2030, European biodiversity should be on a path to recovery for the benefit of people, the planet, the climate, and the economy.

The strategy promotes a more comprehensive approach to biodiversity policy. It is proactive in spirit and action. Nature protection and restoration cannot rely solely on regulation. Farmers, fishers, foresters, landowners, and land users are at the heart of this strategy: they are key actors in biodiversity protection and directly benefit from it. Equally important is participation across society, including active engagement of citizens, businesses, social partners, and communities in research and knowledge creation, alongside strong partnerships and close cooperation among cities, rural areas, national governments, and the EU.

Adopted in the midst of the COVID-19 pandemic, the strategy will also be a central element of the EU Recovery Plan. Aligning economic development with biodiversity needs, restoring and better protecting nature, and strengthening regulations on wildlife trade are crucial for preventing and building resilience against future zoonotic outbreaks.

EU Nature Restoration Plan: Key commitments by 2030

Significant areas of carbon-rich degraded ecosystems on land and sea are restored.

Risk and use of chemical pesticides are reduced by 50%, and high-risk pesticides by 50%.

At least 10% of agricultural land is located in high-diversity landscapes, such as areas with buffer strips, rotational or non-rotational fallows, or landscape features (hedges, non-productive trees, terraces, ponds, etc.).

The application of agroecological practices is significantly increased, and at least 25% of agricultural land is under organic management.

Three billion new trees are planted in the EU, fully respecting ecological principles suitable for biodiversity and forest resilience.

Significant progress is made in identifying and remediating contaminated soils.

At least 25,000 km of free-flowing rivers are restored.

Introduction of invasive alien species is significantly limited, with a 50% reduction in Red List threatened invasive species. Nutrient losses are reduced by at least 50%, while ensuring soil fertility is not compromised (fertilizer use reduced by at least 20%).

Organic farming is the most regulated and well-known agroecological practice. This sector shows positive employment trends, attracting younger workers, providing 10–20% more jobs per hectare compared to conventional farms, and creating additional value for agricultural products. For these socio-economic and environmental reasons, at least 25% of agricultural land in the EU should be under organic farming by 2030. The upcoming Commission Action Plan for Organic Farming will include measures to increase demand for organic products (Hermoso, 2022).

EU Directives and Regulations in the Field of Sustainable Agriculture

Sustainable agriculture in the European Union is governed by a combination of regulations and directives. Regulations represent secondary EU law that is binding in its entirety and directly applicable in all Member States, while directives establish objectives that Member States must achieve but allow flexibility in the manner of implementation through national legislation.

Appendix A

Act	Type	Year / No.	Main Objectives	Relevance for Sustainable Agriculture
CAP Strategic Plans Regulation	Regulation (EU) 2021/2115	2021	Planning & implementation of CAP 2023–2027	Eco-schemes, innovation, digitalization, rural resilience, monitoring sustainability
CMO Regulation	Regulation (EU) No 1308/2013	2013	Common rules for agricultural markets	Market stabilization, support for producer organizations using sustainable methods
Fertilizing Products Regulation	Regulation (EU) 2019/1009	2019	Placing fertilizers on the EU market	Limits on heavy metals, promotion of organic/recycled fertilizers, harmonized quality
Sustainable Use of Pesticides Directive	Directive 2009/128/EC	2009	Reduce risks & impacts of pesticide use	Integrated pest management (IPM), restrictions on hazardous pesticides, farmer training
Organic Production Regulation	Regulation (EU) 2018/848	2018	Standards for organic production & labeling	Ban on synthetic pesticides/ fertilizers, soil health, crop rotation, animal welfare
Nitrates Directive	Directive 91/676/ EEC	1991	Reduce water pollution from nitrates	Identification of vulnerable zones, manure limits, fertilizer management plans
Habitats Directive	Directive 92/43/ EEC	1992	Biodiversity protection (Natura 2000)	Limits farming in protected areas, promotes agro-ecological practices

Best Practices in Sustainable and Organic Agriculture in EU Member States

The analysis of selected countries(Denmark, the Netherlands, and France) demonstrates that success in developing sustainable and organic agriculture largely depends on a clear legal framework, long-term strategic planning, and institutional support. Although the models differ – Denmark with early legislative initiatives and binding action plans, the Netherlands with innovative approaches and a focus on short supply chains, and France with strong institutionalization through Agence Bio – common features include: continuity of state policy, regardless of political changes; a combination of financial incentives and education; the involvement of consumers and public institutions in promoting organic food; integration of national measures with EU regulations and funding.

For EU candidate countries, these examples provide valuable lessons. The key challenge is aligning with the Common Agricultural Policy (CAP), while also designing national plans that combine local specificities with European standards. Equally important is the systematic education of producers and consumers, as well as ensuring that public institutions serve as role models in applying sustainable standards.

In this way, national policies would not only follow European regulations but also actively contribute to achieving the broader objective – a sustainable, competitive, and socially responsible agriculture in Europe.

Appendix B

Country	Key Legal Framework / Institution	National Plans and Targets	Specific Support Measures
Denmark	Organic Farming Act (1987); National Action Plans (1995–2030)	25% of agricultural land under organic production by 2030; 60% organic food in public institutions	Subsidies for farm conversion, certification, producer education, inspections, and public awareness campaigns
Netherlands	EU Regulation 2018/848; National Action Plan (2022)	Increase share of organic production and consumption	Consumer education, short supply chains, innovation, EU rural development funds
France	National agency Agence Bio (2001); National Strategic Plan under CAP	21% of agricultural land under organic production by 2030; 20% organic food in public canteens and schools	National logo “AB”, promotion of organic food, educational campaigns, and producer training

Note: Data compiled from Organic Denmark (2020), Future Policy (2021), Ministry of Agriculture, Nature and Food Quality (2022), Agence Bio (2023), and Le Monde (2024).

Challenges and Perspectives of EU Policies

The European Court of Auditors (ECA) reports highlight gaps and inconsistencies in EU policies and strategies, questioning the effectiveness of support for the organic sector. The ECA notes: “The target of 25% organically farmed land by 2030 appears unattainable” (Special Report 19/2024).

Organic farming is central to the EU “Farm to Fork” strategy and is crucial for meeting the EU’s ambitious environmental and climate targets. The current strategy does not set post-2030 goals for the organic sector. Between 2014 and 2022, EU farmers received around €12 billion from the Common Agricultural Policy (CAP) for organic conversion or maintenance, with nearly €15 billion planned until 2027.

Conversion to organic farming varies widely among Member States, from less than 5% of agricultural land in the Netherlands, Poland, Bulgaria, Ireland, and Malta, to over 25% in Austria. This highlights the need for sector-wide support, market development, and production incentives to avoid an imbalanced system overly dependent on EU funds.

In 2022, organic farming covered 17 million hectares, representing 10.5% of total agricultural land. The organic market remains small, accounting for no more than 4% of total food sales in the EU. The ECA report criticizes the EU action plan for lacking measurable targets, progress indicators, and a strategic vision beyond 2030 to ensure sector stability and long-term development (Special Report 19/2024).

Sustainable agriculture in the EU is expected to evolve over the coming decades in line with technological innovations, climate requirements, and growing consumer expectations. Key directions of development include:

Digitalization and smart farming – The use of satellite data, artificial intelligence, and the Internet of Things (IoT) will enable precise monitoring of soil, moisture, crops, and yields, reducing costs and environmental impact (EIP-AGRI, 2021).

Smart irrigation systems – In light of increasingly frequent droughts, innovative sensor-controlled irrigation systems will be critical for water conservation and enhancing agricultural resilience.

Greater involvement of young farmers – The EU plans additional support programs for young farmers, including subsidies for starting farms, education on sustainable practices, and improved access to markets.

Increasing climate resilience – Integration of agroforestry, resilient crop varieties, and adaptive farming practices to mitigate the negative effects of climate change.

Conclusions

EU policies aimed at promoting sustainable agriculture constitute a cornerstone of strategies for ecological preservation and economic stability. While the implementation of these policies entails certain challenges, their long-term benefits—enhancing agroecosystem sustainability and strengthening rural economies—clearly outweigh the initial costs.

The EU's sustainable agriculture framework represents a comprehensive system of measures, strategies, and financial instruments designed to transform the food system toward greater ecological, economic, and social sustainability. Central elements such as the reformed Common Agricultural Policy (CAP), the European Green Deal, the Farm to Fork Strategy, and the EU Biodiversity Strategy collectively establish the foundation for achieving climate neutrality and safeguarding natural resources.

Sustainable agriculture in the EU presents both a challenge and an opportunity for enhancing economic and ecological capacities. Key success factors include ongoing farmer education, increased financial incentives, and strengthened cooperation among member states in the adoption of sustainable technologies.

Despite clear strategic goals, implementation faces several challenges:

Heterogeneity among member states – Adoption of sustainable practices varies due to differences in economic capacity, agricultural traditions, and institutional support.

Transition costs – Implementing new technologies, organic certifications, and ecological standards entails additional expenditures and administrative procedures.

Climate-related risks – Increasingly frequent droughts, floods, and extreme weather events pose significant threats to agricultural productivity (EEA, 2022).

Geopolitical instability – Events such as the COVID-19 pandemic and the war in Ukraine underscore the vulnerability of global and European food supply chains.

Nonetheless, experiences from Denmark, the Netherlands, and France demonstrate that innovation, political commitment, and adequate support are essential for the successful implementation of sustainable practices. Looking ahead, the future of EU agriculture will be increasingly influenced by digital technologies, agroecological approaches, and active engagement of young farmers. This evolution will ensure that agriculture continues to serve not only as a vital food source but also as a pillar of environmental conservation, rural development, and social cohesion across the European Union.

Conflict of interests

The authors declare no conflict of interest.

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Indicators	Period			Total
	Month 1	Month 2	Month 3	
Distance crossed (km)	12.926	11.295	13.208	37.429
Fuel consumption (litre)	3.231	2.823	3.302	9.356
Value of fuel consumption (RSD)	242.378	211.790	247.653	701.821
Total time spend on touring (hour)	314	266	417	997
Value of total time spend on touring (RSD)	47.048	39.890	62.570	149.508
Number of tours	98	77	102	277
Toll value (RSD)	0	0	0	0
Number of pallets transported (piece)	1.179	976	1358	3.513
Total weight transported (kg)	602.600	429.225	711.116	1.742.941
Vehicle maintenance costs (RSD)	203.858	164.970	224.806	593.634
Lease costs (RSD)	480.938	454.214	565.784	1.500.936
Total sum (RSD)	974.222	870.864	1.100.813	2.945.899

Source: Petrović, 2012

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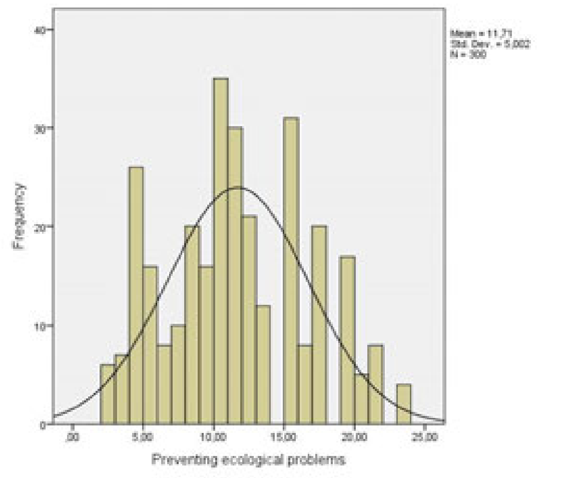

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