

Review

Livestock Sector in Serbia: Challenges, Structural Gaps, and Strategic Pathways Towards Sustainability

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Abstract

The livestock sector in Serbia has been experiencing a prolonged period of structural and economic challenges, characterized by decreasing animal numbers, low productivity, and reduced competitiveness in both domestic and EU markets. This study analyses the key structural, technological, economic, and policy factors shaping these trends to provide strategic recommendations for sustainable sector revitalization. The methodology integrates macroeconomic analysis, agricultural economic accounts, and international trade data, applying regression modelling to examine relationships between domestic food prices, exchange rates, and agri-food import volumes. The results indicate that livestock's share of agricultural gross value added remains below 35%, significantly lower than EU averages, while export quotas remain underutilized and the trade balance for animal products is persistently negative. Contributing factors include fragmented farm structures, outdated production technologies, limited adoption of innovations, demographic decline in rural areas, and insufficient alignment with EU CAP Strategic Plans and Green Deal objectives. Climate change impacts, such as droughts and heat stress, alongside animal disease outbreaks and macroeconomic pressures, further exacerbate these vulnerabilities. The study recommends modernizing production systems through investment in technological upgrades, strengthening farmer organizations and cooperatives, enhancing biosecurity and animal welfare standards, and improving policy frameworks to align with EU sustainability objectives. Emphasis is placed on developing integrated approaches that simultaneously address productivity, economic resilience, and environmental sustainability. Implementing these strategic measures is essential for enhancing food security, supporting rural development, and ensuring Serbia's successful integration into the EU market as part of a more sustainable and resilient agri-food system.

Keywords: livestock production; economic sustainability; economic accounts for agriculture (EAAs); gross value added (GVA); competitiveness; climate-smart livestock; Serbia

Academic Editor: Francesco Bimbo

Received: 14 July 2025

Revised: 26 August 2025

Accepted: 27 August 2025

Published: 28 August 2025

Citation: Milićević, D.; Samolovac, L.; Lukić, M.; Milićević, D. Livestock Sector in Serbia: Challenges, Structural Gaps, and Strategic Pathways Towards Sustainability. *Sustainability* **2025**, *17*, 7751. <https://doi.org/10.3390/su17177751>

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1. Introduction

Livestock production has historically been the backbone of food systems, providing high-value proteins and essential micronutrients critical for human nutrition and health [1]. Beyond its nutritional role, livestock contributes significantly to rural economies

through employment opportunities and income generation, while also preserving cultural landscapes, culinary traditions, gastronomic heritage, and the cultural and historical identity of communities [2]. The European Union (EU) is among the world's leading producers of animal-origin food, accounting for approximately 20% of global meat production and over 20% of global milk production, with livestock representing around 40% of total agricultural output value in the EU [3]. This sector plays a central role in ensuring food security and maintaining a positive agri-food trade balance, which reached a EUR 58 billion surplus in 2022, driven largely by dairy and meat exports [4].

However, despite its global significance, the EU livestock sector faces structural challenges, including a gradual decline in herd sizes. For example, the total cattle population decreased from 78 million in 2013 to approximately 71.9 million in 2024. The number of pigs in the EU has shown a gradual but persistent decline from about 141.9 million in 2013 to 132.1 million in 2024 [5]. This downward trend is primarily driven by a combination of interrelated factors: (i) Social drivers: shifting consumer preferences toward plant-based diets and decreasing consumption of red meat, influenced by health, ethical, and sustainability concerns. (ii) Environmental drivers: heightened awareness of the environmental impacts of livestock farming, particularly greenhouse gas emissions and resource use. (iii) Economic drivers: rising input and production costs, including feed, energy, and labor, which are increasingly undermining farm profitability. (iv) Political drivers: stricter EU regulations on animal welfare, food safety, and environmental compliance, which increase operational burdens for producers. In addition, recurring outbreaks of transboundary animal diseases, such as African Swine Fever (ASF), have led to significant economic and herd losses, further destabilizing the sector [6]. In response, the EU is implementing targeted measures to revitalize the sector, such as supporting eco-schemes within the *Common Agricultural Practice (CAP) 2023–2027* framework, promoting precision livestock farming and digitalization, strengthening producer organizations, and incentivizing young farmers to enter animal production. These measures are embedded within the EU's broader Vision for Agriculture and Food, which builds upon the CAP framework to ensure that agriculture remains a strategic, competitive, and future-proof sector by focusing on sustainability, innovation, and rural resilience [6]. These EU measures reflect a broader understanding that the future of agriculture depends on its capacity to integrate sustainability principles into all production systems.

In this context, the concept of sustainable agriculture becomes particularly relevant. Sustainable agriculture is understood as an approach that is economically viable, environmentally friendly, and socially acceptable [7,8]. Economic sustainability implies that only agricultural production that is market-oriented and economically justified can endure in the long term. Environmental sustainability requires preserving natural resources for future generations while protecting or enhancing ecosystems affected by agricultural activities, thus viewing agriculture as an ecosystem management system based on the soil–plant–animal–human balance. Social sustainability involves fulfilling broader societal values, including a high quality of life for farmers and rural communities, while preserving cultural heritage and traditions. Furthermore, agriculture must be multifunctional, contributing to environmental protection and biodiversity, ensuring food security and safety, and supporting rural economic development through economic growth, diversification, and the maintenance of socially vibrant rural settlements [9].

Similarly, Serbia's livestock sector has been experiencing a prolonged decline, with national data showing significant reductions in cattle and pig numbers over the past two decades [10,11]. While in the EU this decline is primarily driven by market-related and environmental factors, in Serbia it largely stems from systemic challenges within the agricultural sector. Currently, livestock contributes only ~30–35% of Serbia's agricultural gross value added (GVA), compared to 40–60% in EU countries, highlighting structural

disparities [10]. Contributing factors include fragmented farm structures, technological stagnation, underdeveloped genetic improvement programs, and demographic decline in rural areas [10,12]. Productivity and competitiveness are further constrained by delays in aligning with EU standards for product quality, environmental sustainability, and biosecurity [10,12]. Limited adoption of innovative technologies—such as artificial intelligence, precision livestock farming, and IoT-based monitoring—restricts efficiency and adaptation to market and climate demands [13,14]. Unlike the EU, where comprehensive strategies and investments are being deployed to counter these negative trends, Serbia lacks effective policies and sufficient financial mechanisms to revitalize its livestock sector and achieve sustainable production levels that ensure national self-sufficiency in animal-derived food. This structural gap is particularly concerning in the light of the latest vision for the Common Agricultural Policy (CAP), presented in 2025, which emphasizes greater flexibility and increased national responsibility in shaping agricultural policy. The proposed framework outlines a more targeted and future-oriented CAP for the period after 2027, aiming to streamline performance-based measures, enhance national accountability, and adapt interventions to local realities. For Serbia, as a candidate country, this underscores the urgent need to strengthen institutional capacities for evidence-based planning, performance evaluation, and the long-term sustainability of the livestock sector in alignment with future EU requirements. While several studies have examined agricultural production and trade trends in Serbia, there is still a lack of integrated analyses that directly connect the livestock sector with sustainability imperatives under the EU Green Deal and CAP reforms. To address this gap, the present research provides a comprehensive review that combines statistical evidence, structural challenges, and policy perspectives to identify strategic pathways for revitalizing the Serbian livestock sector.

Building on this, the study analyses the economic drivers behind the sector's decline, identifies structural, technological, and policy determinants, and proposes strategic recommendations for revitalizing livestock production and enhancing its sustainability in line with EU priorities. Such timely insights are essential for ensuring food security, strengthening rural development, and facilitating Serbia's integration into the EU market within an increasingly climate-challenged and competitive agri-food system.

In order to operationalize these research objectives and provide a clear structure for the reader, the manuscript addresses the identified issues in a systematic manner and proceeds through a series of interconnected sections. Section 2 introduces the data sources and analytical approach. Section 3 presents an overview of the current state of Serbian livestock production, structured into subsections that analyze global and domestic drivers, economic constraints, structural gaps, and competitiveness challenges within the broader EU context. Based on this comprehensive analysis, the manuscript synthesizes the key findings and formulates strategic recommendations together with policy measures aimed at revitalizing the sector and improving its sustainability. Finally, Section 4 concludes, presenting the main insights, highlighting policy implications, and outlining directions for future research.

2. Data Sources and Analytical Approach

The methodological framework of this paper is based on a comprehensive analysis of quantitative economic data relevant to the livestock sector in Serbia [10,15]. The following data sources were utilized:

- National statistical databases, including the Statistical Office of the Republic of Serbia [10], for data on livestock numbers, production volumes, and agricultural output.
- Economic Accounts for Agriculture (EAAs), harmonized with the System of National Accounts [16], are used to assess the contribution of livestock production to the gross value added of the agricultural sector.

- International databases, such as Eurostat [3,5] and Trademap.org [17], for comparative data on livestock production, yields, trade flows, and agri-food export/import balances.
- Macroeconomic indicators from the National Bank of Serbia [18] and the International Monetary Fund [19] reports, including inflation rates and average annual exchange rates.

To ensure analytical consistency, all monetary values were deflated to real terms using 2013 as the base year. The reliability and relevance of these data sources are affirmed through their alignment with EU methodologies and international statistical standards. Additionally, a simple linear regression model was employed to evaluate the relationship between agricultural imports and macroeconomic variables, particularly domestic food price growth and exchange rate fluctuations. Variables were log-transformed to address differences in scale and interpret elasticity coefficients.

Literature Review and Keywords

To support this analysis, a comprehensive literature review was conducted to identify peer-reviewed studies examining livestock production systems, economic performance, competitiveness, and sustainability in Serbia and EU countries. The search spanned major scientific databases, indexing services, and publisher platforms, including PubMed, Scopus, Web of Science, Google Scholar, CAB Abstracts, Wiley Interscience, Springer/Kluwer, Science Direct, and Taylor & Francis Online, covering the period from 2012 to 2025.

Keywords used included: “livestock production Serbia”, “agricultural economics”, “farm profitability”, “Economic Accounts for Agriculture (EAA)”, “agri-food competitiveness”, “dairy sector productivity”, “climate change agriculture Serbia”, “animal welfare”, “biosecurity”, “AI in livestock production”, “agrarian policy Serbia”, “rural demography”, “food security”, and “sustainable food production”.

Over 50 peer-reviewed papers, national reports, and policy documents were analyzed to identify systemic weaknesses, structural challenges, and potential policy interventions required to revitalize the Serbian livestock sector and align it with EU standards of economic performance, sustainability, and food system resilience.

3. Present Situation in Livestock Production in Serbia

The Serbian livestock sector has experienced significant structural shifts over the past two decades [20]. Analysis of recent data (Figures 1 and 2) reveals a continuous decline in livestock numbers across major categories. For example, cattle herds decreased from approximately 1056 thousand heads in 2007 to 699 thousand in 2024, while pig numbers fell from 3429 thousand to 2349 thousand in the same period [10]. Sheep herds have remained relatively stable at around 1759 thousand heads, whereas poultry numbers have grown moderately (14,774), driven primarily by intensive production systems [12,21]. According to the Statistical Office of the Republic of Serbia [10], as of 1 December 2024, compared to the same date in 2023, the total number of cattle decreased by 3.7%, while the number of pigs increased by 9.7%, sheep by 2.5%, and poultry by 3.5%. Regionally, cattle are predominantly raised in the Šumadija and Western Serbia region (accounting for 45.6% of the national herd), whereas pig farming is concentrated in the Vojvodina region (43.7% of the national pig population). When viewed in the context of the ten-year average (2014–2023), the structural decline becomes even more evident. The total number of cattle has decreased by 19.5%, pigs by 18.4%, and poultry by 7.0%, while only the sheep population has recorded a modest increase of 3.0%. These figures reflect a long-term contraction in herd sizes and a reorientation of production structures that continues to shape the Serbian livestock sector’s trajectory.

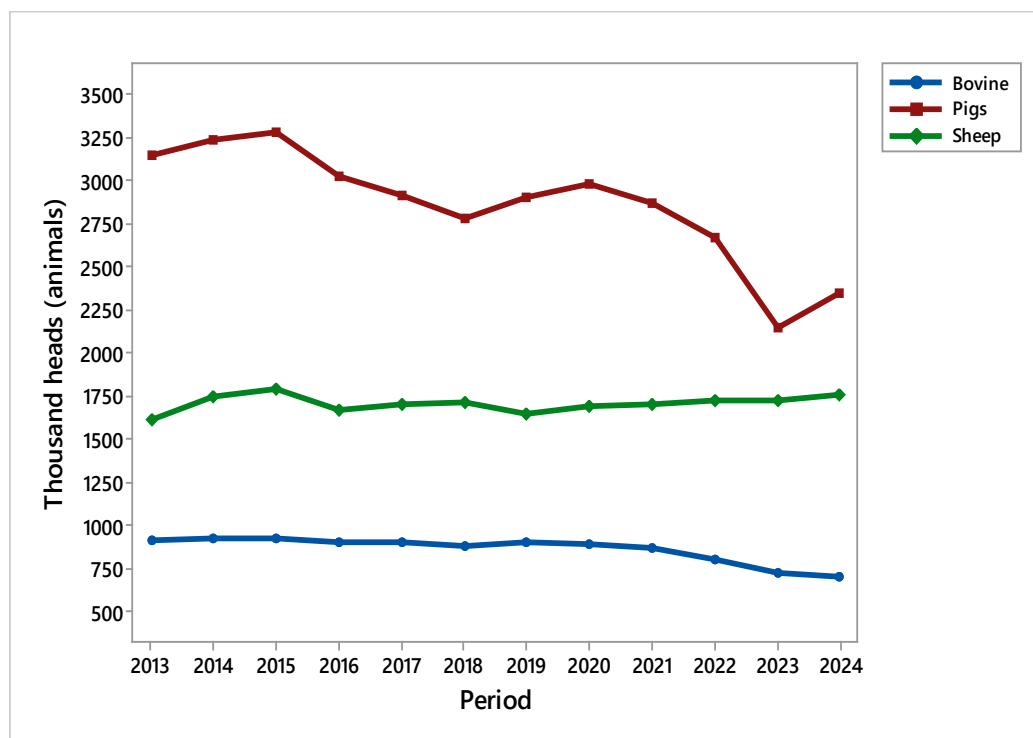


Figure 1. Trend in livestock numbers in Serbia by year [5].

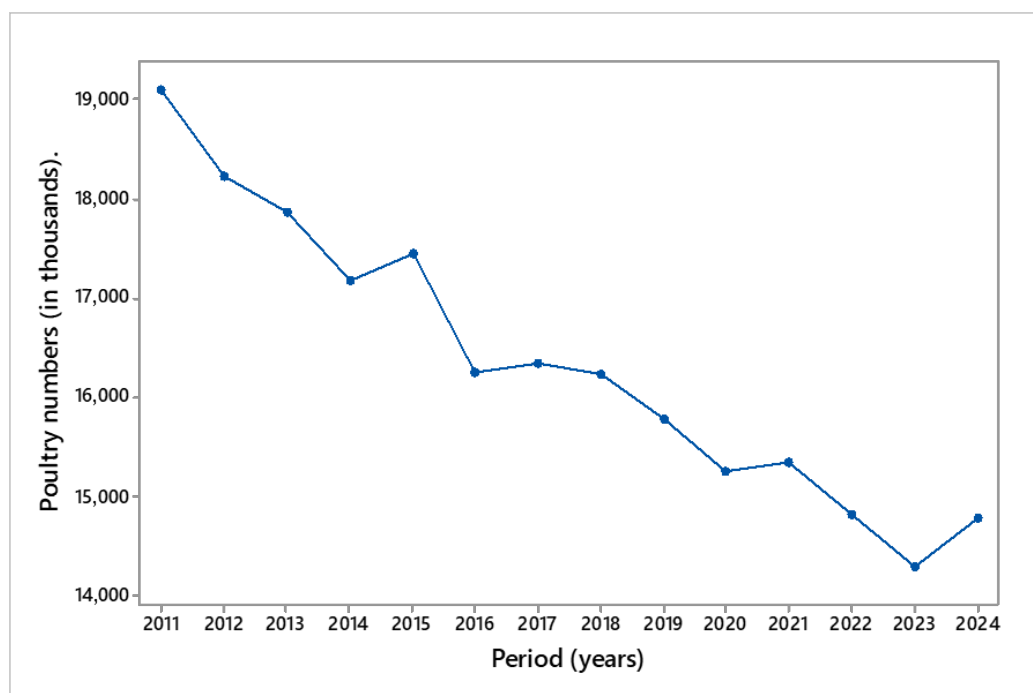


Figure 2. Trend in poultry numbers in Serbia by year [5].

These changes are reflected in production outputs. In Table 1, data indicate that production of meat, milk, and eggs has generally stagnated or declined over the past decade, despite periodic fluctuations. Beef and pork outputs remain below their 2013 levels, and milk production has shown only limited increases, insufficient to reduce the productivity gap compared to EU averages [21]. These trends indicate a deepening structural crisis in livestock production, exacerbated by limited technological advancement and insufficient policy support [22]. However, a comprehensive understanding of this decline also requires reflection on the historical context. Data from a socio-metabolic study of Yugoslavia

indicate that livestock populations in the region began declining as early as the 1980s, continuing throughout the post-conflict period and reflecting structural and institutional disruptions [23]. This long-term downward trend in livestock numbers was further exacerbated by the economic marginalization of agriculture in the post-socialist period, as investments were disproportionately directed toward industrial sectors. Despite Serbia's favorable natural and climatic conditions—particularly in regions like Vojvodina and parts of Central Serbia—agriculture was pushed to the margins of economic development, lacking adequate public investment [24]. While the disintegration of the SFRY and the post-transition restructuring explain much of the sector's initial decline, a comprehensive understanding must also consider the evolving global and domestic challenges that have continued to shape livestock production in Serbia. Multiple global and domestic factors have contributed to these negative trends.

Table 1. Production of meat, milk, and eggs in Serbia by year (tons) [10].

Period	Beef	Pork	Lamb	Chicken	Beef	Pork	Lamb	Chicken	N	Beef	Pork	Lamb	Chicken
	Meat Production in Tons				Consumption per Household in Kg				Total Consumption in Tons				
2013	35,574	131,942	936	56,678	10.9	47.8	2.0	46.9	2,465,799	26,877	117,865	4932	115,646
2014	36,844	150,294	1296	62,847	12.4	50.5	2.7	46.8	2,466,316	30,582	124,549	6659	115,424
2015	40,014	166,350	1260	66,876	13.9	46.4	2.5	47.2	2,466,316	34,282	114,437	6166	116,410
2016	42,160	163,688	1404	70,550	14.4	46.0	2.4	47.5	2,466,316	35,515	113,451	5919	117,150
2017	45,034	155,925	1768	86,139	13.9	45.4	2.3	50.0	2,466,316	34,282	111,971	5673	123,316
2018	44,461	170,709	2006	93,245	16.2	47.2	6.2	48.6	2,466,316	39,954	116,410	15,291	119,863
2019	46,537	173,082	2312	101,662	16.8	49.6	6.5	50.2	2,466,316	41,434	122,239	16,031	123,809
2020	47,300	169,728	2465	100,409									
2021	48,327	168,630	3723	100,405	21.3	49.9	12.0	47.2	2,466,316	52,533	123,069	29,596	116,410
2022	43,952	139,524	3893	115,328	20.0	46.0	9.6	47.3	2,589,344	51,787	119,110	23,304	122,476
2023	43,040	136,752	3468	124,609	19.8	47.5	8.6	48.4	2,589,344	51,269	122,994	22,268	125,324
2024	45,592	140,067	3179	137,228					2,589,344				

N—number of households.

3.1. Global Factors

Climate change has emerged as a critical constraint for livestock systems, with more frequent droughts and heat stress events reducing pasture productivity and feed crop yields, thereby threatening the economic viability of farms [25]. Beyond these direct impacts on feed availability, climate change also contributes to broader disruptions in animal production by causing feed and water shortages, the erosion of animal genetic resources, and a decline in overall productivity [26]. These environmental stressors often manifest as lower daily weight gains, delayed maturation, poor body condition, reduced milk yield, and compromised reproductive performance—effects that cumulatively undermine animal health and production efficiency, especially in climate-sensitive regions [27,28]. In parallel, outbreaks of transboundary animal diseases, such as African Swine Fever and Avian Influenza, have further stressed livestock systems by periodically reducing production capacity and disrupting regional and global trade flows [14].

Additionally, trade disruptions and market volatility, exacerbated by geopolitical tensions, particularly the conflict in Ukraine, have destabilized global grain and energy markets, leading to higher feed and input costs for Serbian farmers [12]. Beyond these well-documented constraints, the animal feed industry is increasingly recognized as both a driver of environmental pressure and a victim of global instability [29]. On one hand, it faces mounting scrutiny over its environmental footprint, particularly in terms of greenhouse gas emissions, land and water use, and nutrient losses associated with intensive feed production; on the other, energy price volatility, including fuel, fertilizer, and electricity costs, has further increased production expenses and narrowed profit margins [30].

3.2. Domestic Factors

Demographic decline in rural areas, driven by outmigration and population ageing, has reduced the agricultural labor force and accelerated farm closures [12]. Farm structures dominated by small, extensive holdings with limited investment capacity continue to constrain modernization and efficiency improvements. Moreover, despite the availability of EU IPARD funds, many farmers face administrative barriers and lack the capacity to develop eligible projects [31]. As highlighted by Marković and Simonović [32], inadequate agricultural policy frameworks and rigid subsidy criteria weaken the sector's market orientation and sustainability prospects. Furthermore, reductions in milk premiums and the limited effectiveness of direct support measures, as discussed by Đurić et al. [33], have further undermined the income stability and competitiveness of dairy producers.

Underdeveloped rural infrastructure—including insufficient livestock markets, slaughterhouses, and cold storage facilities—weakens value chains and limits market access, particularly for smallholders [22]. Macroeconomic imbalances, with cumulative inflation exceeding 130% between 2007 and 2023 and only modest exchange rate adjustments (+17%), have eroded purchasing power parity and diminished the competitiveness of domestic products relative to imports [18,19].

Taken together, these global and local pressures have created a livestock sector characterized by declining productivity, weak competitiveness, and limited resilience. As Bešić et al. [34] emphasize, addressing these challenges will require a comprehensive approach encompassing structural modernization, farm consolidation, targeted policy reforms, and strategic investments in innovation, genetic improvement, and climate adaptation. Such measures are essential to prepare the sector for alignment with upcoming analyses of its economic contributions, discussed in the following section.

3.3. Economic Accounts for Agriculture in Serbia

Economic Accounts for Agriculture (EAAs) provide an essential framework for evaluating the structural performance and policy outcomes of livestock production in Serbia. Between 2007 and 2023, data indicate that while nominal agricultural gross value added (GVA) increased, real growth adjusted to constant 2007 prices remained minimal, signaling persistent economic stagnation within the sector [15]. Table 2 presents a summary of Serbia's agricultural economic accounts for the period from 2013 to 2023, illustrating trends in gross value added and highlighting the relative contribution of livestock production to the overall agricultural sector. These data provide a basis for assessing structural strengths and weaknesses, as further discussed below.

Table 2. Economic Accounts of Serbian Agriculture from 2013 to 2023 [15].

Period	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Current Prices in Millions of Dinars											
Output	599,638	624,425	584,834	643,686	590,707	640,862	653,184	700,488	785,423	918,689	842,083
IC	349,334	367,327	344,056	371,854	336,109	366,069	377,541	399,919	437,684	514,034	490,408
GVA	250,304	257,098	240,778	271,832	254,598	274,793	275,642	300,570	347,739	404,655	351,675
FI	225,787	236,171	217,348	243,416	228,284	246,111	246,158	267,437	299,920	357,482	333,868
EEA (%)	6.50	6.60	5.60	6.00	5.40	5.40	5.40	5.50	5.50	5.70	4.00
Output	389,186	398,499	367,717	398,347	354,914	377,498	377,582	399,731	415,383	422,123	359,594
IC	226,730	234,423	216,327	230,123	201,944	215,632	218,243	228,212	231,476	236,190	209,419
GVA	162,456	164,076	151,391	168,224	152,970	161,866	159,339	171,519	183,907	185,932	150,175
FI	146,544	150,721	136,681	150,639	137,160	144,971	142,295	152,612	158,617	164,257	142,572

Legend: Output—value of production in base prices; IC—intermediate consumption; GVA—gross value added; FI—factor income; EEA (%)—participation of BDV agriculture in GDP (%).

Analysis of Table 2 shows that agriculture accounts for approximately 6.8% of Serbia's national GDP. However, within this sector, livestock production remains structurally weak. Its share of agricultural GVA consistently falls below 35%, significantly lower than the EU average of 60–70% [15,22]. This underscores livestock's declining contribution to national economic output and highlights fundamental limitations in competitiveness, productivity, and sustainability. The key factors shaping these EAA trends include the following:

- Strategic and structural factors

The absence of a comprehensive livestock development strategy aligned with EU CAP Strategic Plans and the Green Deal continues to limit sectoral transformation [12]. Farm fragmentation remains widespread, with production dominated by small-scale holdings of limited economic viability and market orientation [31]. Additionally, agricultural policies and subsidy frameworks often fail to incentivize livestock-specific investments, constraining development opportunities [33].

- Technological factors

Technological modernization remains insufficient, with outdated housing systems and limited uptake of innovations such as precision livestock farming technologies, artificial intelligence, IoT, and robotics [34]. Consequently, productivity remains below EU benchmarks; for instance, average milk yield per cow in Serbia is 3500–4500 L/year compared to over 7000 L in EU countries [35].

- Economic and financial factors

Low profitability characterizes both farms and agri-food SMEs, primarily due to high indebtedness and poor liquidity [12,35]. Although IPARD funds offer opportunities for investment and modernization, their utilization remains limited, with less than 50% of applications implemented successfully [31]. Macroeconomic pressures, including cumulative inflation exceeding 130% (2007–2023) alongside a relatively stable exchange rate, have reduced the competitiveness of domestic livestock products relative to imports [15,18].

- Market organization and branding

Weak organization of livestock markets persists, with few producer groups or clusters to strengthen domestic and export competitiveness [32]. Furthermore, the sector underutilizes geographical indications and traditional branding, limiting product differentiation and added value [22].

- Biosecurity and animal health

Biosecurity protocols and veterinary monitoring systems remain insufficient, constraining export potential and sector resilience to disease risks [14].

- Climate and environmental factors

Climate change continues to reduce forage yields and pasture productivity, threatening economic sustainability [25]. Limited adaptation strategies to droughts and heat stress further exacerbate these vulnerabilities in the context of climate change [36]. Additionally, the absence of systematic environmental performance evaluation tools—such as the Life Cycle Assessment (LCA)—prevents Serbian livestock producers from identifying key environmental hotspots and adapting production systems to climate and ecological pressures.

- Demographic factors

Rural areas are facing a significant decrease in population due to the migration of young people to cities, resulting in the aging of the remaining population. Economic, social, and political factors, including the lack of jobs, centralization of the economy, and ineffective policies, contribute to this trend [37]. This demographic shift is particularly striking given that, according to the 2011 census, only about 40% of Serbia's population resided in non-urban settlements, even though rural areas cover the majority of the

country's territory [38]. These challenges are compounded by infrastructural and institutional weaknesses—including the absence of paved roads, educational and healthcare facilities, and reliable internet connectivity in many villages—which act as significant barriers to rural development, economic diversification, digital transformation, and the modernization of agricultural practices [22,39].

These trends should also be evaluated in the context of the European Commission's CAP strategic indicators, which emphasize fair income distribution, generational renewal, rural vitality, and improved environmental performance as pillars of the long-term economic viability of livestock farming [6]. Although Serbia is not yet an EU member state, its alignment with these CAP principles is essential to ensure sustainable transition and competitiveness in the regional market.

In addition to these structural, technological, and demographic constraints, macroeconomic factors further influence the competitiveness and sustainability of Serbia's livestock sector. One such dimension is the indicative exchange rate of the dinar against the euro, which estimates the rate necessary to maintain purchasing power parity between domestic and foreign currencies, taking into account relative inflation rates in Serbia and the Eurozone. For the end of 2024, the indicative exchange rate is calculated at 156.3 RSD/EUR, significantly higher than the official rate, indicating a real appreciation of the dinar. This appreciation reduces the competitiveness of domestic production relative to imports, as EU products become relatively cheaper on the Serbian market. To better understand the influence of macroeconomic variables on agri-food import volumes, a regression model was applied to quantify the relationship between domestic food price changes, exchange rate fluctuations, and import levels [40]. The regression equation is as follows:

$$Y = 0.132 + 0.207 \ln(\text{price}) - 0.602 \ln(\text{exchange rate})$$

- Standard errors: (0.027) (0.034) (0.549)
- t-statistics: (4.841) (1.057) (−3.081)
- R = 0.625; F-statistic = 5.127; DW = 2.464

where Y represents the logarithm of imports, $\ln(\text{price})$ is the logarithm of domestic food prices, and $\ln(\text{exchange rate})$ is the logarithm of the exchange rate.

These findings demonstrate that an increase in domestic food prices positively affects import volumes, while an appreciation of the dinar (reflected in a higher indicative exchange rate) has a positive effect on import competitiveness but negatively affects exporters' competitiveness. Analysis indicates that each 1% increase in domestic food prices, with a stable exchange rate, leads to a 0.2% rise in import volumes. Conversely, each 1% appreciation of the exchange rate results in a 0.6% increase in imports. These two variables, having opposite direct effects, simultaneously influence the overall import balance. When both variables change concurrently, their effects on import growth are multiplied, further amplifying their combined impact. This macroeconomic environment, combined with the structural weaknesses identified earlier, further constrains the profitability and sustainability of livestock production, highlighting the need for integrated policy measures to improve sector resilience and competitiveness.

3.4. Strategic Recommendations for Sustainable Livestock Competitiveness

Recent global research underscores that technological transformation, strategic economic management, and integrated policy frameworks are fundamental drivers of sustainability within the livestock sector. Across leading livestock economies, the adoption of artificial intelligence (AI), robotics, precision feeding, and climate-smart breeding has resulted in substantial improvements in productivity, animal welfare, and environmental performance [41]. Studies further indicate that AI-enabled diagnostics [42], precision feeding systems, and reproductive monitoring significantly enhance both efficiency and

welfare outcomes [43]. These technologies have been widely implemented in emerging livestock economies such as China [44] and India [45], underpinning notable gains in operational resilience and sustainability.

Within the European Union, countries such as the Netherlands and Denmark have extensively integrated intelligent systems, real-time sensor networks, and big data analytics into livestock production. Wolfert et al. [46] highlight that such smart farming approaches not only improve productivity and economic efficiency but also strengthen biosafety measures, reduce antibiotic use, and promote higher standards of animal welfare, thereby supporting the integrated One Health framework that links animal, human, and environmental health outcomes. Additionally, Munz et al. [47] note that the adoption of Farm Management Information Systems (FMISs) in European dairy farms supports strategic decision-making, facilitates productivity benchmarking, and promotes comprehensive digital farm management.

Supporting these findings, Goller et al. [48] emphasize that successful digitalization requires continuous farmer education, development of advanced data interpretation skills, and transformation of advisory services to provide targeted support for digital tool adoption. Verdouw et al. [49] similarly outline how big data and IoT technologies enable real-time monitoring of animal health, nutrition, and biosecurity parameters but stress that infrastructural investments and platform standardization are necessary for widespread adoption, particularly among smallholder farms. Mukhamedova et al. [50] argue that interoperable platforms, open data systems, and standardized digital infrastructures are critical for effectively integrating small farms into broader national and regional digital ecosystems, while Schwering et al. [51] highlight that AI and digital technologies can deliver significant productivity and welfare improvements only if supported by robust farmer training and education policies.

Technological modernization in livestock production increasingly relies on robotics and automation, with evidence from poultry farming showing improvements in feed efficiency and biosecurity, suggesting potential for similar applications across other subsectors [52]. At the same time, the integration of artificial intelligence (AI) and modern digital innovations is transforming both livestock and poultry systems, creating opportunities to enhance efficiency, sustainability, and overall competitiveness [53]. In addition to technological solutions, climate adaptation strategies are essential. Adesogan et al. [54] emphasize practices such as heat stress mitigation, improved feed conversion efficiency, and genetic selection for resilience, which have been successfully implemented in South Asia and sub-Saharan Africa to maintain economic viability under rising climate risks. Complementing these insights, Katsini et al. [55] note that dairy sectors in Mediterranean countries have invested in advanced ventilation technologies and thermal tolerance breeding to sustain milk production despite increasing temperatures.

Finally, strengthening economic management remains vital. Langemeier [56] highlights that in the United States, implementing formal benchmarking frameworks using indicators such as Earnings Before Interest, Taxes, and Amortization (EBITA), operating profit margins, and return on assets has improved strategic planning, operational efficiency, and competitiveness. However, the absence of such systems in Serbia limits evidence-based advisory services and constrains sector-wide performance optimization.

In addition to national specificities, broader European research highlights that sustainable competitiveness in agri-food systems cannot be achieved solely through productivity growth or production expansion. The importance of market diversification and specialization for building economically sustainable competitiveness, and the need to move from quantity-oriented towards value-oriented strategies, have been emphasized in recent studies [57]. Likewise, systemic competitiveness is shown to emerge from the interplay of factor endowments, trade strategies, resource productivity, and environmental

sustainability [58]. Taken together, these perspectives confirm that the revitalization of the Serbian livestock sector requires integrated and value-oriented strategies that strengthen productivity, enhance market positioning, and align with sustainability objectives.

Despite the availability of these proven global models, the Serbian livestock sector remains hampered by outdated infrastructure, low levels of digital adoption, and the absence of cohesive strategic frameworks. Bridging these gaps will require comprehensive reforms that integrate economic benchmarking, technological modernization, targeted farmer education with proper information [59], climate adaptation strategies [60], and robust alignment with EU Green Deal objectives to secure long-term competitiveness and sustainability [8,61]. Among the tools available to facilitate this alignment, LCA stands out as a scientifically validated method for evaluating environmental performance across the livestock production chain. LCA would enable evidence-based assessment of greenhouse gas emissions, land and water use, and nutrient runoff associated with animal production.

Developing a comprehensive Life Cycle Assessment (LCA) framework is essential for quantifying environmental impacts, optimizing resource efficiency, and guiding adaptation to climate variability, thereby ensuring that innovations in Serbia's livestock sector deliver measurable progress toward the sustainability benchmarks set by the EU Green Deal and Farm to Fork Strategy. In line with the European Commission's Strategic Plan for Agriculture and Rural Development, Serbia should establish a national-level Agricultural Knowledge and Innovation System (AKIS) that supports farmer education, data-driven management, and the adoption of smart farming technologies. These systems are central to the EU's approach to resilient and modern livestock production [24], and their development is critical to facilitating knowledge transfer and innovation diffusion.

A historical perspective offers valuable insights into how effective strategic planning and institutional coordination once positioned Serbia as a regional leader in livestock exports. During the export boom of the former SFRY, Serbia leveraged a combination of forward-looking market intelligence, rapid adoption of state-of-the-art technologies, and a unified national export identity. Key drivers of this success included standardized veterinary sanitary protocols tailored to the specific needs of high-value markets, centralized quality control systems, and strict compliance with hygiene and infrastructure requirements. These strengths not only enabled market access but also established Yugoslav "baby beef" and lamb as high-quality products on the European market.

Today, Serbia lacks such cohesive strategic coordination and market alignment. While global and EU frameworks for sustainable livestock systems are increasingly built around innovation ecosystems and public-private collaboration, Serbia continues to operate within fragmented institutional structures, underutilized expert capacities, and insufficiently responsive support policies. Learning from this historical legacy is crucial—not as a call for return, but as a foundation for designing modern, market-oriented interventions that restore competitiveness and resilience in livestock production.

Breeding local livestock breeds in Serbia provides multiple benefits, combining sustainability, rural development, market competitiveness, and cultural heritage. Thanks to their adaptability to local conditions and natural resistance to diseases, these breeds require lower investments in feed and veterinary care, which reduces costs and promotes sustainable agricultural production with less pressure on natural resources. Their products are characterized by specific and recognizable quality, making them suitable for branding as products with geographic origin or traditional quality, which increases competitiveness on both domestic and international markets. At the same time, production based on local breeds creates opportunities for additional income through processing, marketing of value-added products, and rural tourism, thereby strengthening the rural economy and encouraging people to remain in villages. Beyond their economic

importance, local breeds also play a vital role in preserving cultural and national heritage, safeguarding tradition and identity, attracting consumers and tourists, and enhancing Serbia's image as a country rich in rural heritage.

Therefore, to effectively design such integrated reforms and prioritize interventions, it is crucial to systematically assess the sector's current internal and external environment. Ultimately, the sustainability of Serbia's livestock sector will depend on striking a balance between the strengths of local supply chains—offering resilience, reduced environmental footprint, and community-based value retention—and the necessity of meeting global market requirements through standardized production, adherence to international quality and safety benchmarks, and enhanced export competitiveness. The following SWOT analysis provides a structured overview of internal strengths and weaknesses, alongside external opportunities and threats affecting the livestock sector. Its purpose is to guide strategic decision-making by linking sector capacities with potential development pathways while identifying risks that must be mitigated.

The SWOT analysis provides a structured overview of internal strengths and weaknesses alongside external opportunities and threats affecting the livestock sector. Its purpose is to guide strategic decision-making by linking sector capacities with potential development pathways while identifying risks that must be mitigated. In the context of Serbian livestock production, the SWOT analysis (Table 3) highlights the urgent need to build on existing strengths, such as traditional expertise and favorable agro-climatic conditions [24,62], while addressing structural weaknesses, like farm fragmentation and low technological adoption. At the same time, opportunities such as EU market integration and technological modernization should be actively pursued to counter threats from climate change, rural depopulation, and market competition. Based on these insights, priority actions should focus on modernizing production systems, enhancing farmer education and organisation, improving biosecurity and animal welfare standards, and supporting demographic revitalization to ensure a resilient and competitive livestock sector that contributes sustainably to national food security and rural development.

Table 3. SWOT analysis of livestock production in Serbia.

Strengths	Weaknesses
<p>Existing capacities in the dairy and meat sectors with long-standing tradition and expertise.</p> <p>Favorable geographic and agro-climatic conditions for livestock production.</p> <p>Potential for integration into EU value chains.</p> <p>Presence of indigenous breeds suitable for geographical indications (GI) and traditional branding.</p>	<p>Highly fragmented farm structure with economically non-viable smallholdings.</p> <p>Low productivity, e.g., average milk yield per cow of 3500–4500 L/year vs. >7000 L in the EU.</p> <p>Outdated housing systems and insufficient technological modernization.</p> <p>Limited adoption of Precision Livestock Farming technologies, AI, IoT, and robotics.</p> <p>Weak market organisation with few producer groups and clusters.</p> <p>Lack of a dedicated livestock development strategy aligned with EU CAP Strategic Plans and the Green Deal.</p> <p>Insufficient implementation of biosecurity and animal welfare standards.</p>
Opportunities	Threats
<p>Alignment with EU Farm to Fork Strategy, Green Deal, and CAP Strategic Plans.</p> <p>Potential for harmonization with EU CAP green architecture (eco-schemes, environmental conditionality) could</p>	<p>Ongoing rural depopulation and an ageing farming population reducing available labor and innovation capacity.</p> <p>Climate change impacts, including droughts and heat stress, reducing forage yields and pasture productivity.</p>

facilitate access to future funding and enhance farm sustainability.	Geopolitical and macroeconomic instabilities affecting feed costs, exchange rates, and market competitiveness.
Utilization of IPARD and other EU funds for farm modernization and digital transformation.	Increased risk of transboundary animal diseases (e.g., African Swine Fever, Avian Influenza) with insufficient biosecurity.
Development of GI-certified and traditionally branded products for domestic and export markets.	Rising imports of cheaper animal products due to real appreciation of the dinar.
Implementation of AI, IoT, precision feeding, and robotics to increase productivity and sustainability.	Lack of adaptation to EU sustainability standards and delayed digital transformation may widen the competitiveness gap with EU livestock sectors.
Growing demand for high-quality animal products within the EU and regional markets.	

4. Conclusions

The analysis confirms that Serbia's livestock sector is under prolonged structural and economic pressure, with declining animal numbers, low productivity, and reduced competitiveness. Overcoming these challenges requires a clear strategic focus on modernizing production systems, strengthening farmer organizations, and adopting advanced technologies to improve efficiency, sustainability, and market integration. Enhancing farmer education, biosecurity, animal welfare standards, and environmental management is essential for aligning with EU requirements. Implementing these measures will not only revitalize the sector and enhance its role in national food security and rural development but also ensure environmental sustainability in line with the EU Green Deal, Farm to Fork Strategy, and CAP Strategic Plans.

In addition to these operational priorities, strategic policy action is crucial to providing the enabling framework for sectoral revitalization. Future policies should prioritize closer alignment with EU sustainability objectives, targeted financial and institutional support for producers, regionalization of production, and stronger incentives for the development of value-added livestock products. Moreover, preserving and promoting local breeds should be recognized as a component of sustainable development, contributing to biodiversity, resilience, and product differentiation. Together, these strategic measures would strengthen resilience and create more-favorable conditions for the long-term growth and competitiveness of the Serbian livestock sector.

Author Contributions: Conceptualization, D.M. (Dragovan Milićević), L.S., M.L. and D.M. (Dragan Milićević); methodology, D.M. (Dragovan Milićević) and D.M. (Dragan Milićević); investigation, D.M. (Dragovan Milićević), L.S., M.L. and D.M. (Dragan Milićević); resources, D.M. (Dragovan Milićević), L.S., M.L. and D.M. (Dragan Milićević); data curation, D.M. (Dragovan Milićević), L.S., M.L. and D.M. (Dragan Milićević); writing, D.M. (Dragovan Milićević) and D.M. (Dragan Milićević); visualization, D.M. (Dragovan Milićević) and D.M. (Dragan Milićević); All authors have read and agreed to the published version of the manuscript.

Funding: The results of this research were financed under the Contracts concluded between the Ministry of Science, Technological Development and Innovation of the Republic of Serbia and the following institutions: the Institute of Meat Hygiene and Technology (Contract No. 451-03-136/2025-03/200050, dated 4 February 2025) and the Institute for Animal Husbandry (Contract No. 451-03-136/2025-03/200022, dated 4 February 2025).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

Conflicts of Interest: The authors declare no conflicts of interest.

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