NALED

Sweden Sverige

JAVNO JASNO EFIKASNO

Projekat za dobru upravu

Carbon Footprint and Sustainability of Primary Agricultural Production

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NALED

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Glossary

Abbreviation	Meaning
2020-2024 EU Action Plan on Human Rights and Democracy	European Commission, EU Action Plan on Human Rights and Democracy 2020-2024 (2020)
AMR	Antimicrobial resistance
CAP	EU Common Agricultural Policy - Common Agricultural Policy
CEAP	EU Circular Economy Action Plan (Commission Communication from the Commission to the European Parliament, the Council, the European economic and social committee and the committee of the regions, A new Circular Economy Action Plan For a cleaner and more competitive Europe, (2020)) - Circular Economy Action Plan
CSDDD	EU Corporate Sustainability Due Diligence Directive - Directive on due diligence attention and corporate sustainability
CSRD	EU Corporate Sustainability Reporting Directive (Council Directive (EU) 2022/2464 amending Regulation (EU) No 537/2014, Directive 2004/109/EC, Directive 2006/43/EC and Directive 2013/34/EU) - Reporting Directive on corporate sustainability
Green Agenda Declaration for Western Balkans	Council for Regional Cooperation, Sofia Declaration on the Green Agenda for Western Balkans, (November 2020)
EU Nitrates Directive	Council Directive of 12 December 1991 (91/676/EEC)
Sustainable Use Directive pesticide	EU Sustainable Use of Pesticides Directive Council directive 2009/128/EC establishing a framework for community action to achieve the sustainable use of pesticides, (2009) Official journal L 198, amended by Council regulation 2019/1243)
EEA	European Economic Area - European economic proctor
EF	Emission factor
EFRAG	European Financial Reporting Advisory Group - European Advisory Group financial reporting group
ESRS	European Sustainability Reporting Standards (Commission Delegated Regulation (EU) 2023/2772) - European standards for reporting on sustainability
EU Climate Pact	European Climate Act (Communication from the Commission to the European Parliament, the Council, the European economy and society committee and the committee of the regions, (2020))
EU Taxonomy	Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment, and amending Regulation (EU) 2019/2088

FADN	EU Farm Accountancy Data Network
FAO	Food and Agriculture Organisation of the United Nations
FaST	EU Farm Sustainability Tool
FSFS	EU Framework for Sustainable Food Systems
FSN Forum	Global Forum on Food and Nutrition Security
FtF	Farm-to-Fork
GAEC	Good agricultural and environmental conditions
GHG	Greenhouse gases
GILA	German, Italian and Latin American consortium for resource efficiency logistics hubs and transport
GMO	Genetically modified organism
GRI	Global Reporting Initiative
GWP	Global Warming Potential
Harmonized risk indicator	EU Harmonised Risk Indicators (Council directive 2019/782 amending Directive 2009/128/EC of the European Parliament and of the Council as regards the establishment of harmonised risk indicators (2019), Official journal L 127/4)
HNVF	High Nature Value Farmland
ICT	Information and communication technologies
Tamiš Institute	Tamiš Research and Development Institute Pančevo
IPARD	EU Program - Instrument for pre-accession assistance to rural development
IPCC	Intergovernmental Panel on Climate Change
IPEC	International Programme on the Elimination of Child Labour
IPM	Integrated pest management
ISSB	International Committee on Sustainability Standards
Commission	European Commission
UAL	Used arable land
LEADER	"LEADER" comes from the French phrase "Liaison Entre Actions de Development de l'Economie Rurale" which means "Links between activities for the development of the rural economy"
MPC	Maximum permitted concentration

MRL	Maximum residual level
Draft strategy	Environmental Protection Strategy of the Republic of Serbia for the period 2024-2033
NALED	National Alliance for Local Economic Development
NFRD	EU Non-Financial Reporting Directive (Council Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups (2014), Official Journal L 330/1)
NPK fertilizers	Fertilizers containing nitrogen, phosphorus and potassium
Water Framework Directive	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy
Authorized control organization	The authorized control organization is authorized by the Ministry of Agriculture, Forestry and Water Management for control and certification of organic production
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PFP	Processed food products
PPA	Energy purchase agreements
PPP	Primary agricultural products
Rulebook on control and certification in organic production and organic production methods	Rulebook on control and certification in organic production and organic production methods (Official Gazette of RS, No. 95/20 and 24/21)
Rulebook on the use of incentives for organic plant production	Rulebook on the use of incentives for organic plant production (Official Gazette RS, no. 31/2018, 23/2019, 20/2020, 44/2021 and 50/2022)
Rulebook on the conditions and method of exercising the right to incentives for organic plant production	Rulebook on the conditions and method of exercising the right to incentives for organic plant production, (Official Gazette of RS, no. 60/2023)
Rulebook on the conditions, method and procedure for exercising the right to a refund of paid excise duty on motor fuel used for agricultural purposes	Rulebook on the conditions, method and procedure for exercising the right to a refund of paid excise duties on motor fuel used for agricultural purposes (Official Gazette of RS, No. 115/2023)
Waste management program (2022-2031)	Waste Management Program in the Republic of Serbia for the period 2022-2031. (Official Gazette of RS, No. 12/2022)
REC	Renewable Energy Certificate
EU rules on producing and labelling organic products	Regulation (EU) 2018/848 of the European Parliament and of the Council of 30 May 2018 on organic production and labelling of organic products and repealing Council Regulation (EC) No 834/2007

Regulation on deforestation	EU Deforestation Regulation (Council Regulation 2023/1115, Official Journal L 150/206)
RZS	Republic Statistical Office
SCAP	Serbia Competitive Agriculture Project
SME	Small and medium-sized enterprises
FtF strategy	EU From Farm to Fork Strategy
Agriculture and rural strategy development (2014-2024)	Agriculture and Rural Development Strategy of the Republic of Serbia for the period 2014-2024 (Official Gazette of RS, No. 85/2014)
UNFCCC	UN Framework Convention on Climate Change
EU regulation on maximum residue levels of plant protection products on the market	Council Regulation (EC) No 1107/2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC, (2009), Official Journal L 309/1
Regulation on the distribution of incentives in agriculture and rural development for 2024	Regulation on the distribution of incentives in agriculture and rural development for 2024. ("Official Gazette of RS", no. 3/2024, 6/2024, 16/2024, 26/2024 and 32/2024)
Regulation on determination of hazardous child labour	Regulation on determining hazardous child labour (Official Gazette of RS, No. 53/2017)
Law on Organic Production	Law on Organic Production (Official Gazette of RS, No. 30/2010 and 17/2019)
Law on Incentives in Agriculture and Rural Development	Law on Incentives in Agriculture and Rural Development, (Official Gazette of RS no. 10/2013 and 101/2016)
Law on Agriculture and Rural Development	Law on Agriculture and Rural Development (Official Gazette of RS, No. 41/2009, 10/2013, 101/2016, 67/2021 and 114/2021)
Law on Agricultural Land	Law on Agricultural Land, Official Gazette of the RS, no. 62/2006, 65/2008 - new. law, 41/2009, 112/2015, 80/2017 and 95/2018 – new law
Law on Accounting	Law on Accounting (Official Gazette of RS, no. 73/19 and 44/21)
Labour Law	Labour Law (Official Gazette of RS, No. 24/2005, 61/2005, 54/2009, 32/2013, 75/2014, 13/2017 - CC decision, 113/2017 and 95/2018)
Law on Seeds	The Law on Seeds (Official Gazette of RS, No. 45/2005 and 30/2010 - new law)
Law on Plant Protection Products	Law on Plant Protection Products (Official Gazette of RS, No. 41/2009 and 17/2019)
Law on Soil Protection	Law on Soil Protection (Official Gazette of RS, No. 112/2015)

Introduction

ESG (Environment, Social, Government) criteria constitute a set of aspects, which include environmental, social responsibility and corporate governance issues. ESG represents the next step in sustainable business practices and is increasingly being integrated into regulatory frameworks worldwide, with the European Union (EU) leading the way as a pioneer in this field. The Republic of Serbia, as a candidate for EU membership, should proactively plan for the implementation of ESG regulations. Serbian companies and the broader economy must also prepare to align with EU regulatory requirements.

Agriculture is a key pillar of economic activity and growth in the Republic of Serbia, with agricultural land covering nearly half of the country's territory and contributing approximately 7% to Serbia's GDP. The agricultural sector employs 547,000 people, with 78.7% working in primary agriculture. This accounts for nearly 20% of total employment in Serbia. Agriculture accounts for 17.8% of Serbia's total goods exports, with a total export value of €4.8 billion and a trade surplus in agricultural and food products amounting to €1.6 billion. Within these exports, primary agricultural products (PAP) constitute 69% of the total, while processed agricultural products (PFP) make up 30.7%.[1]

Agriculture is also recognized worldwide as one of the sectors with the highest ESG impacts and risks. Serbia has a unique opportunity to develop and implement comprehensive ESG regulations in the agricultural sector. These regulations will impact both large enterprises and small agricultural producers, promoting economic growth while fostering sustainable business practices.

The development of this analysis was initiated by NALED's Food and Agriculture Alliance, within the project "Public Procurement and Good Governance for Greater Competitiveness", implemented by NALED with the support of the Swedish Agency for International Development and Cooperation (SIDA). The creation of this analysis is driven by the global advancement of ESG regulations and the objectives of the European Green Deal. Given all these factors, this analysis of the carbon footprint and sustainability in primary agricultural production is an ideal subject, addressing the critical issues of environmental protection and food production - key priorities for both the Republic of Serbia and the EU.

The objectives of this project are to review and analyse:

- ESG regulations in the Farm to Fork (FtF) chain in the EU and Serbia and making recommendations for harmonization,
- the current status in the FtF chain in Serbia and identifying critical areas for upgrading and growing local capacities on the topic,
- the financial effects of the transition to regenerative agricultural production,
- CO_2 emissions in primary agricultural production (PPP).

One of the topics of this project was the extent to which specific criteria for awarding contracts may represent ESG standards as aspects of public procurement,

[1] All 2022 data. Source: Green Paper of the Ministry of Agriculture, Forestry and Water Management - Report on the Situation in Agriculture in the Republic of Serbia in 2022.

enabling more offers from companies with sustainable practices (lower CO_2 footprint, use of renewable energy sources, established waste management systems, etc.) and socially responsible policies (workforce inclusion, effective complaint systems against violations of labour legislation, safety standards, etc.). Individual companies are likely to strive to meet the ESG criteria in the future, but the approach is relevant for entire supply chains, given that the food and agricultural sectors account for about 24% of total CO_2 emissions globally.

By gathering and combining the data that is currently accessible at the national level, detecting data gaps, identifying pertinent data from the global food business, and offering advice on decarbonisation strategies to the key players in the FtF chain, the goals are guaranteed to be met.

By taking part in studies on the extent of ESG criteria implementation, members of NALED's Food and Agriculture Alliance have also significantly aided in the project's execution. NALED's Food and Agriculture Alliance is made up of 58 members, including key large companies in the agricultural industry, transportation, logistics, and retail, as well as local governments, agricultural producer associations, agricultural faculties, and other academic community representatives, who work together to transform Serbia's food production and processing systems.

Research methodology

The analysis consists of several studies, as follows:

- Comparative legal examination of positive legal rules in the areas of ESG and agriculture in the EU and Serbia, with recommendations for enhancing existing legislation in these areas in Serbia.
- Exploration of business compliance with ESG criteria. This analysis was based on a questionnaire given to members of the NALED's Food and Agriculture Alliance.
- Analysis of potential economic effects of switching from traditional to regenerative agricultural production model. This analysis is based on information provided by the Tamiš Institute, historical data acquired from the Statistics Office of the Republic of Serbia (SORS) databases, and publicly available sources. It entails measuring the revenues, expenditures, and resulting gross margin connected with wheat production operations using both traditional and regenerative tillage methods, and then determining the difference in revenues, costs, and gross margin between the two methods. The analysis was carried out both at the level of a single manufacturing cycle and over a 10-year period. The analysis was performed for 1 hectare of arable land, in dinars. Item 5.1 of this research outlines a detailed approach.
- Carbon footprint analysis in Serbia's supply chain, from farm to fork. This analysis comprises carbon footprint studies in the following specific segments of the supply chain from Farm to Fork: (i) agricultural production, (ii) food processing (food production), (iii) transportation and storage, and (iv) retail of PPP and PFP. In this method, a full examination of the entire supply chain is offered, with an emphasis on the use of data accessible in Serbia (where possible), utilizing a list that includes pertinent surrogate data and recommendations to improve the accuracy and representativeness of the analysis in the future. The complete methodology of the research is provided in item 6.1. of this analysis.

- Analysis of CO_2 emissions and soil quality in primary agricultural production in Serbia. The Tamiš Institute conducted this research, which included: (i) a comparative analysis of different processing systems in terms of grain yields of the main arable crops on the experiment conducted at the Tamiš Institute Testing Site in Pančevo, and (ii) a survey on the territory of the Republic of Serbia that included 170 agricultural holdings on the basis of which the carbon footprint was calculated on the production lots of the holdings included in the survey, In accordance with the performed work operations in the technique of cultivating different crops. The detailed methodology of this research is outlined in Chapter 6 of this analysis

In addition to this analysis, a special short guide was created with practical tips for agricultural producers in the agricultural production sector, as well as researchers, agricultural advisors, and agricultural policymakers, on how to most effectively transform traditional agricultural practices into production using regenerative agriculture methods.

1. Key Conclusions and Recommendations

The goal of this analysis is to highlight the current state of business sustainability and carbon footprint in the from farm to fork supply chain in the Republic of Serbia, as well as to formulate clear and precise recommendations for all relevant factors, including state administration bodies, as well as companies and farmers participating in primary agricultural production and further steps of the supply chain, based on the established comparative analysis with best global practices in these issues.

The subject of this analysis includes:

- ESG regulations in the Farm to Fork (FtF) chain in the EU and Serbia and making recommendations for harmonization,
- the current situation in the FtF chain in Serbia and stress on key areas for improving and developing local capacities,
- the financial effects of the transition from conventional to regenerative agricultural production,
- CO_2 emissions in primary agricultural production (PPP).

For this analysis, the FtF chain was analysed in four steps:

1. Agricultural production - production of primary agricultural products (PAP);
2. Food processing – production of processed food products (PFP);
3. Transport and logistics – transport and storage of PAP and PFP through farms, processing facilities, warehouses and final points of sale (retail);
4. Retail – sale of PAP and PFP to end consumers.

In addition to this analysis, a Guide to the Transition to Regenerative Production Methods in Primary Crop Production has been prepared and published. In a clear and concise manner, the Guide proposed practical steps that each farmer can take to transition to a regenerative agricultural production system, as well as the economic and environmental consequences of such a shift in the short, medium, and long term.

1.1. Regulatory Framework

Serbian legislation has a strong tendency to align with EU regulations, particularly in agriculture, but there are some shortcomings and inconsistencies in terms of general ESG regulations. The main shortcomings observed during this analysis in the legislation of the Republic of Serbia include:

- Lack of an ESG regulatory framework defining the rights and obligations of economic operators with regard to non-financial reporting at the level currently in force in EU,
- Regenerative agricultural practices are not recognized in national strategic and planning documents for food and agriculture, as well as current legislation governing agriculture and rural development,
- Insufficient systemic and financial support for the transition from conventional to regenerative land treatment systems,
- Farmers' lack of familiarity with current systems and investment support options in agriculture,
- The current support systems for organic agricultural producers have a limited reach,
- Poor regulation and inadequate infrastructure in wastewater flows in the territory of the Republic of Serbia,
- Despite existing regulations that regulate and prohibit child labour, there are nearly 80,000 children working in agriculture today.

The proposed measures for harmonizing legislation in the field of agriculture and ESG with EU regulations include the following recommendations for the competent ministries, particularly the Ministry of Agriculture, Forestry, and Water Management.

Economic and financial measures

- Providing financial assistance through subsidies and other available tools in the transition of agricultural producers from conventional to regenerative agricultural practices, including incentives under rural development support measures and direct payments;
- Measuring the possibility that producers using regenerative farming practices are also subsidized within the framework of direct payments in primary crop production, in the same way that producers using organic farming methods are subsidized in relation to conventional production;
- Providing educational resources and financial incentives to help small farms adopt sustainable practices and improve their overall environmental performance, while also enhancing knowledge transfer and improving capacity of agricultural advisory and professional services;

- Assessing the possibility of increasing the financing of environmental initiatives within agricultural subsidies, including support for agro-ecology, biodiversity conservation, and soil health management;
- Work on domestic support programmes for agriculture and rural development, using the opportunities provided by programmes such as EU IPARD and SCAP to supplement national subsidies;
- Consider implementing environmental subsidies similar to those in the EU and encouraging farmers to adopt sustainable production practices;
- Introduction of support measures for farmers to buy certified organic seed, seed for cover crops, procurement of specific equipment and machinery;
- Determine financial resources for regenerative and organic agriculture research and development in order to improve existing production techniques, develop new soil fertility methods, and establish experimental fields and demo farms in collaboration with universities, research institutions, and other organizations.
- Supporting small producers who use regenerative farming practices and organic farming methods through incentives such as microcredits, access to land and infrastructure, and agricultural production training programmes.

Sustainable management

- Recognizing and incorporating regenerative agricultural practices into national strategic and programme documents and laws governing agriculture and rural development, such as the Agriculture and Rural Development Strategy, National Agricultural Program, National Rural Development Program, Law on Agriculture and Rural Development, Law on Incentives in Agriculture and Rural Development;
- Advocating legislation that supports the sustainable management of agricultural holdings, promoting practices that promote soil health, biodiversity, and water conservation;
- Encourage the implementation and further development of existing legislation to promote the integration of agricultural holdings as an instrument in the transition to sustainable and regenerative agricultural production;
- Simplification of the certification process for organic farmers - lower administrative barriers, additional financial assistance for certification fees, and technical assistance to meet certification standards.
- Facilitating market access for producers using regenerative and organic farming methods, by creating a dedicated market, providing marketing assistance and establishing standards for the labelling of products obtained through the use of regenerative and organic production practices, in order to reach a larger consumer base and achieve premium product prices;

- Implement existing land use policies that prioritize regenerative and organic farming practices, such as preserving agricultural land, limiting pesticide and fertilizer use, and promoting regenerative and organic agriculture in urban and suburban areas;
- Strengthening regulations and enforcement mechanisms to ensure compliance with national and international environmental standards, preventing market fraud and imposing harsher penalties for noncompliance, conducting regular and effective inspections, and establishing transparent reporting mechanisms for organic certification.

Waste water

- Promoting the further development of infrastructure for waste management and water treatment on agricultural holdings to reduce pollution and ensure compliance with environmental regulations;
- Regulating the emission limit values of water pollutants from agriculture in Serbia, by aligning national legislation with EU legislation on the subject. Support local governments in developing wastewater management projects and infrastructure.

Education

- Investing in farmer education and capacity building programmes that focus on sustainable agricultural practices and empower farmers with the knowledge and skills needed to adopt environmentally friendly agricultural methods;
- Implementing support programmes for agricultural producers during the application process for available national and EU funds to support agriculture and rural development;
- Launch a public awareness campaign to educate consumers about the benefits of regenerative and organic agriculture, as well as to encourage support for products made using these methods, via advertising campaigns, educational workshops, and collaboration with retailers.
- Assess the feasibility of expanding the educational programme of secondary agricultural schools and introducing a new subject, sustainable agricultural production, with a focus on precision, regenerative, and organic farming.

Child labour

- The adoption and application of laws and regulations that expressly prohibit child labour in all its forms, including hazardous and exploitative work;

- Developing a comprehensive national action plan specifically aimed at eradicating child labour—the action plan should contain measurable objectives, timeframes, and strategies for the prevention, protection, and rehabilitation of working children;
- Monitoring and implementing the allocation of sufficient resources to monitoring and enforcement mechanisms to effectively identify, investigate, and prosecute child labour cases, through cooperation with law enforcement authorities, labour inspectors, and civil society organizations to improve oversight and reporting mechanisms;
- Promoting the development of social protection programmes aimed at families at risk of resorting to child labour due to poverty, unemployment, or other socioeconomic factors, as well as providing financial assistance, food security, health care, and other basic services to vulnerable households;
- Raising household awareness through education and training on permitted forms of child labour in agriculture, in accordance with international ILO conventions, as opposed to prohibited child labour.

1.2. Carbon Footprint in Serbia's from Farm to Fork Supply Chain

Based on available data, the total **CO_2 footprint in the Serbian from Farm to Fork supply chain** is estimated to be **around 6 million tonnes of CO_2eq emissions.**

Agricultural Production • 4.35 million tonnes of CO_2eq emissions; • **66%** of total FtF emissions.	**Transportation and Storage** • Up to 308 thousand tonnes of CO_2eq emissions; • Up to 5% of total FtF emissions.
Processing Industry • 1.59 million tonnes of CO_2eq emissions; • **24%** of total FtF emissions.	**Retail** • Estimated 5% of total FtF emissions (based on the world average) • Approximately 312 thousand tonnes of CO_2eq emissions.

Emissions from agricultural production make up nearly half of the global FtF footprint (7.4 $GtCO_2$eq), while processing and logistics contribute roughly one-third (5.6 $GtCO_2$eq).

1.2.1. Agricultural production

Agricultural production generates 66% of total emissions in the FtF supply chain.

The proposed measures to reduce the carbon footprint in agricultural production include two major steps:

A. Increasing the carbon retention capacity of land (by adopting regenerative agricultural practices) - Regenerative agricultural practices are primarily responsible for increasing soil carbon levels (see section 6.4.3). "CO_2 Emissions in Serbian Agriculture") that successfully compensates for emissions from field work and natural processes. Combining regenerative agricultural practices with dedicated CO_2 reduction measures yields a cumulative positive effect.

> **Regenerative agriculture** is a set of principles and practices designed to restore natural resources like land, water, and biodiversity. Regenerative agricultural practices are an effective way to reduce carbon dioxide emissions into the atmosphere by binding it in the soil (known as sequestration).

The following steps have been proposed to implement regenerative agricultural practices:

- Determine the priority areas for regenerative agricultural production. This includes providing data on the risk of soil erosion in a given area, as well as information on soil and water quality in specific areas.
- Consider implementing a monitoring system for regenerative crop cultivation practices (control of agricultural practices such as leaving harvest residues on the soil surface, adequate crop rotation, cultivation of cover crops, and so on). This includes controlling CO_2 emissions by recording practices and measuring the total organic carbon matter in soil on the reported land lot every five years (SOM)
- Subsidizing the purchase of equipment, machinery, seeds for cover crops, and activities in the preparatory year of transition to regenerative agricultural practice, such as seedling procurement, use of subsoilers, graders in plot levelling, and so on.
- Investing in scientific research and education in the field of regenerative agricultural practices, such as organizing workshops, seminars, and conferences on regenerative agriculture, as well as setting up demo experiments to demonstrate regenerative agricultural practices.
- Investing in the education of agricultural advisors and agricultural producers in new soil cultivation systems and setting new directions in soil conservation;
- Incentives for certifying products obtained through the use of regenerative agricultural practices, as well as incentives for marketing products obtained through the use of regenerative agricultural production.
- Organizing promotions, fairs, and events focused on regenerative agricultural production.

B. Reduce greenhouse gas emissions from all sources, both natural and human.

Some measures to reduce CO_2 emissions in agricultural production include**:**

- Improving operations' energy efficiency by using more economical equipment, planning to minimize mechanized field work, or omitting some field activities (farming without tillage, not collecting plant residues after harvest, etc.).
- Use cover crops to reduce emissions from exposed off-season land.
- Nitrogen application should be minimized to reduce specific microbial activity that produces nitric oxide.
- Reduced the use of synthetic fertilizers.
- "Smart" agriculture can significantly increase efficiency, reduce fuel consumption, and result in significant emissions reductions. It is based on soil sampling, continuous sensor monitoring, GPS guidance for field work, and the use of drones to observe and precisely apply fertilizers, agrochemicals, and emergency irrigation.
- Replacing fossil fuels with alternatives such as biodiesel and biogas (if technically feasible).

1.2.2. Processing industry

Food processing is classified as a moderately energy-intensive sector, with the energy used to produce it determining most of its carbon footprint (i.e. electricity and fossil fuels used).

The carbon footprint profile of PAP processing differs significantly from that of agricultural production. The main sources of emissions in agriculture are direct combustion of fossil fuels, bacterial processes (decay), fertilizer use, and limescale. However, in the processing step, the primary source of emissions is indirect, i.e. the generation of electricity for production processes.

Proposed measures to reduce the carbon footprint are:

- Improving energy efficiency can result in significant financial benefits and reduced CO_2 emissions. For example, switching to LED lighting, insulating buildings, and using "smart" electrical equipment can lead to significant energy savings and emissions.
- Introduction of self-generation of electricity from renewable sources (e.g., solar panels, wind turbines, biomass waste);
- Signing of a Power Purchase Agreement (PPA) or acquiring a Renewable Energy Certificate (REC);
- Replacing fossil fuels for heating with lower-carbon alternatives, such as biogas, natural gas, or LPG;
- Replacement of refrigerants with alternatives with lower GWP.

1.2.3. Transportation and storage

Goods in transit travel an average distance of 582 kilometres per journey. In Serbia, the average transport distance between food processing facilities and distribution centres is 135 kilometres. However, only two distribution centres are located in central Serbia: Nis and Velika Plana.

Fuel efficiency of vehicles in Serbia has been identified as the most important determinant that can be easily analysed and improved. In Serbia, the average fuel consumption in transportation is 35.2 litres per 100 kilometres. The fuel consumption of new trucks in the EU ranged from 23 to 34 litres per 100 kilometres, depending on the axle configuration and type. Vehicles better suited to local and regional deliveries all had an average fuel consumption of less than 31 litres per hundred. Vehicles' high fuel consumption and CO_2 emissions are primarily caused by their age due to technological differences. The average age of Serbia's cargo vehicles is 19 years[2]. In the EU, the average age of cargo vehicles ranges between 12 and 14 years for light commercial vehicles and trucks.

Recommended measures

- Implementation of financial support programmes for the modernization of Serbia's transport fleet via subsidies or other forms of financial assistance.
- Infrastructure development, including road networks and storage capacities in central Serbia, in order to achieve uniformity and shorten the length of goods transport, thereby lowering the carbon footprint and transportation costs.

1.2.4. Retail

Serbia is a developed economy/country, so it is reasonable to expect its retail system to consist primarily of modern forms of food retail, ranging from small stores or supermarkets to large stores. However, no publicly available information has been identified that would allow for a reliable calculation or estimate of Serbia's food retail sector footprint. Information on electricity consumption by sector is not publicly available, and an updated national refrigerant inventory could not be located.

1.3. Analysis of Potential Economic Effects of Switching from Traditional to Regenerative Agricultural Production Model

The potential economic effects of wheat planting and cultivation were examined per hectare of arable land. For the purposes of the analysis, the holding's basic level of technical equipment was assumed, as was the average transition period from traditional to regenerative production models of 5 to 7 years.

[2] 2022 statistics

The analysis revealed that the use of regenerative agriculture methods can result in slightly higher yields in the first 3 to 4 years of the transition compared to traditional soil cultivation (10% to 20% higher yields per hectare), followed by a period of stagnation and natural rest of the soil, during which yields can be the same or slightly lower than conventional production (by about 10%).

Cultivation costs in the regenerative production model are typically lower than in conventional production. The savings are primarily due to fewer agro-technical operations, lower fuel consumption, and working hours, as well as a reduction in the use of manure, NPK, and nitrogen fertilizers, which are completely eliminated after the transition from conventional to regenerative production, which occurs after 5 to 7 years. A simulation of a 10-year wheat cultivation cycle revealed annual savings in cultivation costs ranging from 10 to 47%.

2. Summary of ESG Regulations in the EU

2.1. The Farm to Fork Initiative Package

2.1.1. Introduction: farm to fork and the European Green Deal

The European GreenDeal[3] envisions Europe becoming the first climate-neutral continent by 2050, with the goal of achieving sustainable growth that benefits both the economy and society. Central part of this plan is the Farm to Fork Strategy (FtF Strategy) [4], which addresses the challenges of developing sustainable food systems while recognizing the interdependence of human health, social well-being, and environmental conservation. The FtF strategy is consistent with the United Nations Sustainable Development Goals and aims to ensure a fair transition for all stakeholders, particularly given the COVID-19 pandemic and economic downturn.

The COVID-19 crisis has highlighted the need for resilient food systems that would be able to provide access to affordable food in sufficient quantities under any circumstances. Furthermore, the link between human health, ecosystems, consumption patterns, and planetary boundaries was highlighted. The FtF strategy seeks to foster a positive environment for sustainable and healthy eating by empowering consumers to make informed choices and encouraging responsible practices throughout the food chain.

European food standards are already globally recognized in the field of safety and quality, but the FtF Strategy aims to further raise these standards by prioritizing sustainability and acknowledging the contributions of farmers and producers who have adopted sustainable

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[3] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, *A Green Deal Industrial Plan for the Net-Zero Age*, (2023)

[4] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and Committee of the Regions, *A Farm to Fork Strategy for a Fair, Healthy and Environmentally-Friendly Food System* (2020)

practices while encouraging others to follow suit. Furthermore, it emphasizes the importance of addressing the environmental impacts of food production and distribution, such as pollution reduction, greenhouse gas emissions, and biodiversity loss.

The FtF strategy is consistent with the objectives of the EU Climate Law, which aims to achieve climate neutrality by 2050 and proposes higher emissions reduction targets for 2030. It creates economic opportunities for food industry stakeholders by meeting consumer expectations and promoting sustainability as a competitive advantage.

However, transitioning to sustainable food systems necessitates changes in consumption habits, as well as addressing food insecurity, accessibility, and waste. Actions must also go beyond EU borders in order to ensure global sustainability standards and avoid exporting unsustainable practices.

In summary, the FtF Strategy supports the European Green Deal's commitment to sustainability by providing a comprehensive approach to transforming food systems for the benefit of both current and future generations.

2.1.2. The Farm to Fork Strategy's goal: sustainable food production

To achieve a sustainable food chain, all stakeholders, including agricultural producers, must quickly adapt to transformative production methods. The implementation of nature-based, technological, digital, and spatial solutions has the potential to improve climate and environmental outcomes while optimizing resource consumption. While these solutions require significant human and financial resources, they promise higher returns by increasing value and lowering costs. Carbon sequestration is an example of a green business solution. Stakeholders can help achieve climate neutrality by implementing agricultural practices that reduce CO_2 levels in the atmosphere.

The European Union recognizes the importance of establishing mechanisms to reward such behaviour. Currently, the Common Agricultural Policy (CAP) is a long-term programme to encourage carbon sequestration, as well as potential participation in public or private initiatives such as the carbon market. The introduction of a new carbon initiative under the EU Climate Pact will help to strengthen the EU's commitment to sustainability in the future. This initiative will provide farmers with an additional revenue stream while also promoting efforts to decarbonize the food chain. Furthermore, a set of EU requirements aimed at achieving sustainable agriculture is known as "good agricultural and environmental conditions," or GAEC in short. Maintaining a minimum level of maintenance, protecting and managing water resources, controlling soil erosion, retaining organic matter in the soil, and maintaining soil structure are all directly related to keeping soil in good agricultural and environmental conditions. European farmers receiving direct payments or a portion of rural development payments through the CAP must adhere to these standards.

Furthermore, as outlined in the Circular Economy Action Plan (CEAP), the European Commission will begin developing a regulatory framework for carbon certification. This framework will be developed to ensure the authenticity and integrity of carbon removal efforts. By establishing stringent verification and monitoring standards, the Commission hopes to boost confidence in carbon sequestration initiatives and improve their effectiveness in combating climate change.

Furthermore, the bio-based circular economy holds significant untapped potential for agricultural producers and cooperatives, providing a path to a climate-neutral European economy while encouraging job creation and innovation in primary production. For example, to reduce methane emissions from livestock production, farmers are encouraged to embrace renewable energy production through investments in anaerobic digesters. These digesters efficiently convert agricultural waste and residues, such as manure, into biogas, a renewable energy source. In addition, farms have the capacity to produce biogas from a variety of waste streams including those from the food and beverage industry, sewage, wastewater and municipal waste.

Solar energy is another option for improving farm sustainability. Farmhouses and barns are ideal locations for installing solar panels, which can significantly reduce energy consumption while lowering carbon footprints. These investments are consistent with future CAP strategic plans, which prioritize renewable energy infrastructure.

The Commission promises to help accelerate the market adoption of these energy-efficient solutions in the agriculture and food sectors. However, it is emphasized that investments must be made in a sustainable manner in order to maintain food security and biodiversity. This commitment is in line with clean energy initiatives and programmes aimed at fostering a resilient and environmentally conscious agricultural landscape.

The use of chemical pesticides in agriculture presents significant challenges, including soil, water, and air pollution, biodiversity loss, and potential harm to non-target plants, insects, birds, mammals, and amphibians. Recognizing these problems, the Commission has applied Harmonized Risk Indicators[5] to assess progress in mitigating pesticide-related risks, revealing a significant risk reduction of 20% over the last five years. The Commission aims to further reduce the overall use and

[5] Commission Directive 2019/782 amending Directive 2009/128/EC of the European Parliament and of the Council as regards the establishment of harmonized risk indicators (2019), Official Journal L 127/4

and risks associated with chemical pesticides by 50% by 2030, specifically targeting a reduction in hazardous pesticides by the same margin.

To ease the transition while protecting farmers' livelihoods, the Commission is taking a multi-step approach. This includes revising the Sustainable Use of Pesticides Directive to strengthen regulations, enhancing integrated pest management (IPM) provisions, and encouraging the use of safe alternative pest and disease control methods. IPM will be central to this effort, promoting the use of alternative control techniques such as crop rotation and mechanical weeding to reduce reliance on chemical pesticides, particularly those that pose a higher risk.

Given the importance of agricultural practices that promote reduced pesticide use, the Commission emphasizes the incorporation of such strategies into CAP and encourages Strategic Plans to reflect this shift while improving access to advisory services. Furthermore, the Commission will facilitate the introduction of pesticides containing biologically active substances while improving environmental risk assessments to ensure safety. Harmonization of the pesticide approval process by Member States, as well as proposed amendments to existing pesticide statistics regulations, will close data gaps and promote evidence-based policymaking in this critical area.

The increase in nutrients, particularly nitrogen and phosphorus, in the environment as a result of excessive agricultural application and inefficient plant absorption presents significant challenges, contributing to air, soil, and water pollution, as well as climate effects. This phenomenon has resulted in a decline in biodiversity in rivers, lakes, wetlands, and oceans.

To address these issues, the Commission intends to reduce nutrient losses by at least 50% while maintaining soil fertility.[6] This undertaking aims to reduce fertilizer use by at least 20% by 2030 through the comprehensive implementation and enforcement of relevant environmental and climate legislation. The Commission will work with Member States to identify necessary nutrient burden reductions, advocate balanced fertilization, and promote sustainable nutrient management practices.

In tandem, the Commission will develop an integrated nutrient management action plan with Member States to address nutrient pollution at its source and improve the sustainability of the livestock sector. This initiative will expand the adoption of precision fertilization techniques and sustainable agricultural practices, especially in regions characterized by intensive livestock production and recycling of organic waste into renewable fertilizers. Member States will integrate these measures into their CAP strategic plans, using tools such as the Farm Sustainability Tool

[6] As part of the Farm-to-Fork strategy, one of the European Green Deal's central pillars, the Commission aims to reduce nutrient losses by at least 50% by 2030 while maintaining soil fertility.

(FaST)[7] for nutrient management, investments, advisory services and EU space technologies such as Copernicus[8] and Galileo[9].

Furthermore, agriculture makes a significant contribution to EU greenhouse gas emissions, with the livestock sector accounting for nearly 70%.[10] Livestock production accounts for 68% of total agricultural land, resulting in emissions primarily from non-CO_2 greenhouse gases like methane and nitrous oxide. To reduce the environmental and climate impact of livestock production, prevent carbon leakage through imports, and promote the transition to more sustainable livestock farming, the Commission will encourage the use of sustainable and innovative feed additives. In addition, the Commission will revise EU regulations to reduce reliance on critical animal feed by promoting EU-grown plant proteins and alternative food sources such as insects, marine raw materials, and bio economy by-products.

The Commission will evaluate the EU's agricultural product promotion programme in order to strengthen its contribution to sustainable production and consumption while also aligning with nutritional development trends. In particular, when it comes to meat, the review will highlight EU promotional programmes that support the most sustainable and efficient livestock production methods. All joint support proposals in the strategic plans will be thoroughly reviewed to ensure that the overall sustainability goals are met.

Antimicrobial resistance (AMR), which is caused by the overuse of antibiotics in animal and human health, is a major public health issue in the EU/EEA, resulting in an estimated 33,000 human deaths each year and significant health-care costs. As a result, the Commission is implementing measures to address this issue, with the goal of reducing total EU antimicrobial sales for farm animals and aquaculture by 50% by 2030. The upcoming regulations on veterinary medicinal products and medicated feeds include a comprehensive set of measures designed to help achieve this goal while also promoting the holistic concept of "one health."

Recognizing the intrinsic value of improved animal welfare, which not only improves animal health and food quality, but also reduces the need for medicines and promotes biodiversity conservation, the Commission has pledged to review existing animal welfare legislation. This revision aims to align regulations with the most recent scientific evidence, expand their applicability, simplify enforcement mechanisms, and eventually raise animal welfare standards. In addition, the Commission will look into ways to implement animal welfare labelling to effectively transfer value throughout the food supply chain.

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7 FaST is an EU-supported digital service platform that provides farmers, EU Member States' paying agencies, farm advisors, and researchers with user-friendly access to opportunities for agriculture, environment, and administrative simplification.

8 Copernicus is the European Union's space program's Earth observation component, which monitors our planet and its environment for the benefit of all European citizens.

9 Galileo is the European Global Navigation Satellite System (GNSS).

10 European Court of Auditors, Special Report: Common Agricultural Policy and Climate, *Half of EU climate spending but farm emissions are not decreasing* (2021).

The growing organic food market is set to expand even further, emphasizing the importance of continuing to advocate for organic farming practices. Organic farming not only promotes biodiversity, but it also helps to create jobs and attracts young farmers. Consumer awareness and appreciation of its benefits reinforces its importance. While the existing legal framework serves as the foundation for the transition to organic farming, concerted efforts are required to make significant changes, including those affecting the marine and freshwater environments.

In addition to existing CAP measures such as eco-schemes, investments, and advisory services, the Commission is prepared to introduce an Action Plan aimed at promoting organic farming. This strategic initiative aims to increase both supply and demand in the organic market. The Action Plan will increase consumer confidence and demand by implementing targeted promotional campaigns and sustainable procurement practices. By taking this approach, the Commission hopes to meet its ambitious goal of designating at least 25% of the EU's agricultural land for organic farming by 2030.

2.1.3. Framework for Sustainable Food Systems (FSFS)

The regulatory Framework for Sustainable Food Systems, the FtF Strategy's flagship initiative, is intended not only to achieve specific sustainability goals, but also to incorporate sustainability into all EU policies. This undertaking necessitated the creation of new legal frameworks that would comprehensively govern future food policy and regulations. Definitions of sustainability, food labelling guidelines, and criteria for sustainable food production were among the proposed provisions. However, progress on this initiative has stalled. The proposal, which was originally scheduled for publication in the third or fourth quarters of 2023, was not carried out. It is not currently included in the Commission's work programme for 2024. As a result, the timeline for the FSFS proposal remains uncertain.

2.1.4. Deforestation regulation

Deforestation and forest degradation are major threats, accelerating climate change and biodiversity loss. This initiative aims to combat deforestation and forest degradation caused by EU consumption and production. It aims to reduce consumption and trade in products associated with deforestation or forest degradation, while increasing EU demand for and trade in legal goods and products that do not cause deforestation. This initiative will open up opportunities to promote trade in non-EU countries' deforestation-free products, fostering a fairer and more transparent market for suppliers committed to forest-friendly sustainable practices.

EU companies will be required to ensure that all products sold on the EU market are "deforestation-free" and comply with the country of origin's legislation. To facilitate this due diligence process, producers and exporters must provide specific geolocation information for individual production land lots as well as demonstrate legitimate land-use rights.

The deforestation regulation was adopted in June 2023, and the new rules will take effect in December 2024.

2.1.5. Amendments to current animal welfare legislation

The FtF strategy called for the Commission to conduct a comprehensive review of animal welfare legislation by the end of 2023. The Commission intends to revise several key laws, including the Directive on the protection of animals kept for agricultural purposes[11], as well as four directives that establish minimum welfare standards for laying hens[12], chickens[13], pigs[14], and calves[15]. However, because animal welfare is not a core component of this report, we will not delve into the specifics of this EU directive.

2.1.6. Sustainable use of pesticides

In June 2022, the Commission has proposed a new regulation focusing on the sustainable use of plant protection products, which is consistent with the farm-to-fork and biodiversity strategies' objectives. This proposal was part of a comprehensive package of measures aimed at reducing the environmental impact of the EU food system while also addressing the challenges of climate change and biodiversity loss. The proposal's key measures included establishing legally binding targets to reduce the use and associated risks of chemical pesticides by 50% by 2030, promoting environmentally sound pest control practices such as IPM, and implementing a ban on all pesticides in sensitive areas, including environmentally vulnerable areas designated for pollinator protection.

The proposed regulation focusses primarily on the use of plant protection products within the EU and does not include provisions for operators in non-EU countries. Nevertheless, it is expected that

[11] Council Directive 98/58/EC concerning the protection of animals kept for farming purposes (1998), Official Journal L 221/23

[12] Council Directive 1999/74/EC laying down minimum standards for the protection of laying hens, Official Journal L 203

[13] Council Directive 2007/43/EC laying down minimum rules for the protection of chickens kept for meat production (2007), Official Journal L 182/19

[14] Council Directive 2008/120/EC laying down minimum standards for the protection of pigs, Journal of Laws L47/5 (2008)

[15] Council Directive 2008/119/EC laying down minimum standards for the protection of calves, Official Journal L10/7 (2008)

potential changes in maximum residual levels (MRL)[16] in the EU limit the availability of plant protection products for use on crops intended for export to the EU market.

The European Parliament and the Council have discussed the Commission's proposal. In November 2023, the European Parliament rejected the commission's proposal. Despite this rejection, the EU Council can continue to refine the proposed regulation and possibly submit a revised text for Parliament to consider.

2.2. Corporate Sustainability Reporting Directive (CSRD)

The newly adopted CSRD aims to modernize and strengthen regulations governing how companies report social and environmental information. The CSRD was officially published in December 2022 and came into effect on January 5, 2023. The first group of companies required to comply with the new directive will begin reporting in fiscal year 2024, and the first reports will be published in 2025.

The CSRD replaces the previously applicable Non-Financial Reporting Directive (NFRD), which was supplemented by the Commission's adoption of European Sustainability Reporting Standards (ESRS). The ESRS, as part of the EU's sustainable financial agenda, provides a common framework for reporting on ESG issues. These standards, which are consistent with global reporting initiatives, address a wide range of sustainability issues such as climate change, biodiversity, and human rights. The ESRS aims to promote transparency and comparability in sustainability reporting, allowing investors to better understand companies' impact on sustainability, and making sustainability reporting the norm for large companies in the EU.

Companies subject to CSRD obligations will be required to disclose data on their impact on society and the environment, as well as report on governance, sustainability risks, strategy, capabilities, and climate change metrics in their own operations and across their product value chain.

Furthermore, CSRD applies to a broader range of companies that will be held more publicly accountable for the impact of their economic activities on ESG, affecting approximately 50,000 companies in the EU, up from 11,700 according to NFRD. All companies subject to CSRD must report on two mandatory cross-functional topics and determine which of the ten specific topics apply to their business. To do this, companies must follow a double materiality approach to assess

[16] The maximum residue levels are determined by Council Regulation (EC) No. 1107/2009 concerning the placing of plant protection products on the market and repealing Council Directives 79/117/EEC and 91/414/EEC, (2009), Official Journal L 309/1

financial and non-financial impacts of climate-related risks and opportunities on their business, i.e. justifying their finding of non-materiality for climate topics.

Companies already subject to NFRD are required to report in 2025 for the fiscal year 2024. Large enterprises will be required to submit 2026 reports for the financial year 2025. Small and medium-sized enterprises listed on stock exchanges will be permitted to postpone for two years before submitting declarations in 2027 for the fiscal year 2026. Furthermore, non-EU companies listed on stock exchanges with significant business in the EU (net turnover greater than EUR 150 million) will face new reporting requirements beginning in 2029 for the fiscal year 2028.

2.3. Corporate Sustainability Due Diligence Directive (CSDDD)

The Commission has adopted a proposal for a Corporate Sustainability Due Diligence Directive[17] (CSDD), with the goal of encouraging sustainable and responsible corporate behaviour in global value chains. Recognizing businesses as key players in shaping a sustainable economy and society, the CSDDD proposal directs them to identify and, if necessary, prevent, terminate, or mitigate the negative impacts of their operations on human rights (such as child labour and labour exploitation) and the environment (such as pollution and biodiversity loss).

The new obligations imposed on EU companies will strengthen their control over environmental and human rights impacts across all value chains that supply the EU market. While most non-EU entities are not directly subject to these obligations, they will be required to provide information to their EU customers to demonstrate that they follow the 'due diligence' principle in relation to these negative impacts, as well as implement measures to mitigate or eliminate them. Suppliers must provide additional information in accordance with the newly designed reporting mechanisms outlined in the proposal.

The Commission approved the CSDDD proposal on February 23, 2022. The EU Council and the European Parliament then engaged in negotiations, and on March 15, 2024, they reached a consensus with the required qualified majority on the revised text of the proposal. The core requirements from December 2023 remain in effect, which means that CSDDD enterprises must comply with regulations that promote ethical and sustainable business practices, as well as incorporate environmental and human rights concerns into corporate governance and operations.

CSDDD is currently awaiting final approval by the European Parliament. It will apply to:

[17] Proposal for a Council Directive on Corporate Sustainability Due Diligence and amending Directive (EU) 2019/1937, (2022)

- EU companies with, on average, more than 1,000 employees and more than EUR 450 million in global net turnover;
- Non-EU companies with more than EUR 450 million of net turnover in the EU;
- and companies that do not meet the above criteria but are the ultimate parent company of a group that meets those thresholds.

The CSDDD will be implemented in phases, with the first companies beginning to report at least two years after it is adopted. In particular, the implementation of the CSDDD will begin in phases.

i. enterprises with over 5,000 employees and a net turnover of EUR 1.5 million, beginning three years after the CSDDD's implementation (most likely in late 2027 or early 2028).
ii. enterprises with over 3,000 employees and a net turnover of EUR 900 million, beginning four years after the CSDDD's implementation (probably in late 2028 or early 2029).
iii. enterprises with more than 1,000 employees and a net turnover of EUR 450 million, beginning five years after the implementation of the CSDDD (probably in late 2029 or early 2030).

However, the harmonized text significantly reduces the directive's original ambitions. There are currently concerns about CSDDD's ability to promote basic due diligence procedures because it only covers businesses with more than a thousand employees and excludes certain high-risk industries. Regardless, Serbian companies, particularly those with extensive supply chains or activities, will still be required to address the directive's various sustainability issues, ranging from child labour to environmental pollution. The final changes to the CSDDD will most likely have a different impact on the Serbian market, potentially giving smaller companies more time to adapt. However, requiring a due diligence process for the environment and human rights within business value chains is a step closer to incorporating the UN Guiding Principles on Business and Human Rights into EU legislation.

2.4. EU Taxonomy Regulation

The EU Taxonomy Regulation creates a European classification system for sustainable economic activities, providing a common language for categorizing activities based on how they contribute to climate change mitigation and other environmental goals. As part of the EU Sustainable Finance Action Plan[18], both the Parliament and the EU Council have endorsed the EU taxonomy, which provides clear guidelines, evaluation criteria, parameters, and thresholds for defining environmentally sustainable activities. Taxonomy facilitates informed decision-making and comparability by providing transparent definitions that are consistent with the Paris Agreement, thereby encouraging investment in sustainable activities.

[18] Communication from the Commission to the European Parliament, the European Council, the European Central Bank, the European Economic and Social Committee and the Committee of the Regions, *Action Plan: Financing Sustainable Growth* (2018)

The EU Taxonomy consists of six environmental objectives: climate protection, adaptation to climate change, sustainable use and protection of water and marine resources, transition to a circular economy, pollution prevention and control, and biodiversity and ecosystem restoration. The EU Taxonomy aims to increase transparency about the environmental compatibility of economic activities by encouraging disclosure of information in non-financial statements and pre-contractual disclosure. Transparency extends to the level of the product or service, demonstrating the relationship between economic activities and sustainability goals using qualitative and quantitative data.

While the EU Taxonomy regulations are a significant step forward in promoting sustainability, they are still evolving, with uncertainties and accounting concepts that need to be clarified.

2.5. European Sustainability Reporting Standards (ESRS)

The European Sustainability Reporting Standards, mandated by the CSRD, are intended to provide a comprehensive framework for companies reporting on their ESG performance. The ESRS were approved by the Commission in July 2023. The ESRS addresses a wide range of sustainability issues, such as climate change, biodiversity, and human rights, and provides investors with basic information for assessing the sustainability impact of companies in which they invest. Furthermore, efforts have been made to ensure interoperability between EU and global standards, thereby avoiding unnecessary double reporting, through collaboration with international initiatives such as the International Sustainability Standards Board (ISSB) and the Global Reporting Initiative (GRI).

The implementation of these reporting requirements will be phased in for various types of companies, with the first wave expected to apply the standards in the fiscal year 2024, for reports published in 2025. This phased approach gives businesses enough time to adapt to new requirements, ensuring a smooth transition to comprehensive sustainability reporting. Furthermore, SMEs will be able to report using separate, proportionate standards developed by the European Financial Reporting Advisory Group (EFRAG), allowing for greater flexibility while maintaining the integrity of sustainability reporting practices. Currently, no such SME standards have been adopted.

When it comes to sustainable agriculture, implementing the ESRS provides a critical opportunity for smaller agricultural producers to improve their environmental performance and demonstrate their commitment to sustainability. Adhering to these standards allows agricultural enterprises to effectively measure, monitor, and report their greenhouse gas emissions, water use, soil health and other key sustainability indicators. This not only helps them identify areas for improvement, but it also ensures transparency for investors and stakeholders about their environmental impact. Furthermore, the phased implementation of reporting requirements gives smaller producers enough time to adjust to the new standards and effectively incorporate sustainable practices into their operations.

2.6. Organic Farming in the EU

Organic farming in the EU is defined by the EU Regulation on Organic Production and Labelling of Organic Products as a method of agricultural production that prioritizes organic practices and places a high value on environmental preservation, biodiversity preservation, and animal welfare in livestock production. Organic farming implies a comprehensive crop and livestock management system, with a focus on farm practices in relation to external outcomes. In this regard, this agricultural method prioritizes natural processes and substances while minimizing or eliminating the use of synthetic agents commonly found in conventional agriculture.

At its core, organic production aims to maintain the biological balance of the soil-plant-animal-human system, thereby protecting the health of humans, animals, and the broader agro-environment. Organic farming's key principles include rational resource use, the use of renewable energy sources, the preservation of natural diversity, and environmental protection.

Organic farming is distinguished by the use of few synthetic chemicals, such as fertilizers, pesticides (including fungicides, herbicides, and insecticides), additives, and veterinary medicines. Instead, organic farmers use cultural, biological, and mechanical methods whenever possible to improve soil health and fertility. Crop rotation, intercropping, and the use of nitrogen-fixing plants like clover all help to naturally increase soil fertility.

Furthermore, organic farming forbids the cultivation and use of genetically modified (GM) crops, as well as their incorporation into animal feed. Agriculture in the EU is classified as organic if it complies with Regulation 834/2007 of June 28, 2007 on organic production and labelling of organic products, as well as the detailed application rules outlined in Regulation 889/2008. These regulations establish stringent standards for organic farming practices, ensuring the authenticity and credibility of organic products on the EU market.

3. ESG Regulations in Serbia

3.1. Agriculture in Serbia: A General Overview

Because agricultural land accounts for nearly half of the country's territory, the agricultural sector is the backbone of the Serbian economy, shaping landscapes, supporting communities, and driving economic development. This section will look at the agricultural sector's critical role in Serbia, highlighting key trends, challenges, and strategies for sustainable development, as well as presenting the relevant regulatory framework.

Serbia's agricultural land covers 48.5% of the total territory, with arable land, vegetable gardens, and crofts accounting for the vast majority of used agricultural land. Over the last decade, there has been a significant increase in arable land and vegetable gardens, demonstrating the sector's flexibility and adaptability. However, challenges such as declining meadow and pasture areas, as well as urban development encroaching on agricultural land, pose serious threats to long-term sustainability.

3.1.1. The current state of agriculture in Serbia - data from the Draft Environmental Strategy 2024-2033

The Republic of Serbia's Environmental Strategy for the Period 2024-2033 (Draft Strategy) is an ambitious and comprehensive framework in the field of the environment, founded on the principles of justification, efficiency, and sustainability. This Draft Strategy focuses measures and activities on the Green Agenda for the Western Balkans[19], sustainable development, natural resource protection and pollution reduction, and improving the quality of life for all citizens. Measures and activities for further harmonization with EU regulations and standards are planned, as well as the creation of mechanisms to monitor the Strategy's implementation. This includes securing financial resources from European Union funds and other international sources to build the infrastructure and funds required to implement environmental protection measures.

This Strategy will define the directions of environmental development, in line with the objectives agreed upon by all six Western Balkan countries in the Sofia Declaration on the Green Agenda for the Western Balkans on November 10, 2020. The five pillars of the Green Agenda for the Western Balkans are: (i) climate, energy, and mobility; (ii) the circular economy; (iii) pollution reduction; (iv) sustainable agriculture and food production; and (v) biodiversity.[20]

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[19] The Green Agenda for the Western Balkans was adopted at the Western Balkans Summit in Sofia on November 10, 2020. The Sofia Declaration establishes the Green Agenda for the Western Balkans, which will serve as a blueprint for achieving climate neutrality and environmental sustainability by 2050. The five-pillar programme is consistent with the goals of the European Green Deal and is based on urgent regulatory reforms and significant investments.

[20] Regional Cooperation Council, Sofia Declaration on the Green Agenda for the Western Balkans (November 2020),

The Ministry of Environmental Protection is in charge of approving and adopting the Draft Strategy; the final draft was posted on the Ministry's website in 2023 but has yet to be adopted. In this regard, the following information about Serbia will be presented based on the findings and data presented in the Draft Strategy, which are representative of the current situation.

Agriculture in Serbia faces numerous challenges as a result of a lack of preparedness and progress in agricultural resource management. To effectively address these issues, new measures are considered necessary, with a focus on agro-environmental and climate practices, organic farming, and the implementation of local rural development strategies, as well as rural infrastructure investment.

One of the major issues identified is a lack of organic carbon in the soil, which is attributed to increased agricultural production and inefficient use of organic fertilizers. Changes in land use, such as pasture ploughing due to urban development, have resulted in erosion and loss of biodiversity. Although the land conversion fee is still in place, its effectiveness has been reduced due to disorganization, particularly on highly fertile land.

Serbia's agricultural landscape is divided into two parts: large, well-equipped farms in the north and numerous small and medium-sized farms with fragmented plots and basic machinery in the country's central and southern regions. This heterogeneity creates environmental risks and threats that are unique to each region and are determined by the type of farm and production direction.

Climate change, demographic change, accelerating rural depopulation, and low profitability all contribute to agricultural degradation, resulting in insufficient investment in environmental conservation measures. The absence of systemic integrated soil management, combined with insufficient infrastructure and irrational resource use, exacerbates degradation issues such as acidification, salinization, erosion, and organic matter loss.

While efforts like the IPARD programme seek to encourage environmentally sound practices through measures like agro-environment-climate and organic farming, there are still challenges in ensuring comprehensive compliance and implementation of the measures. Agriculture subsidies are not yet subject to standards and practices that are in line with EU regulations, highlighting the need for stronger regulatory frameworks and enforcement mechanisms in Serbia to promote sustainable agricultural practices and protect environmental health.

The Law on Plant Protection Products regulates the management of specific chemicals, such as fertilizers and pesticides, and identifies products and active substances that do not comply with its waste provisions.

3.1.2. Care for the environment

The intensification of agricultural activities, combined with rapid urbanization and industrial development, has resulted in environmental degradation across Serbia. Soil degradation, pollution, and erosion are some of the most pressing issues in agriculture. The conversion of agricultural land into urban infrastructure and industrial zones has resulted in permanent loss of productive land, exacerbating soil pollution and erosion. Inadequate soil management practices and uncontrolled chemical use have resulted in soil acidification, compaction, and a reduction in organic carbon content, jeopardizing soil fertility and agricultural productivity.

3.1.3 Soil quality and contamination

Soil pollution in Serbia endangers agriculture's long-term viability and public health. According to the 2018 Cadastre of Contaminated Soil[21], the Republic of Serbia recorded 709 potentially contaminated or polluted sites. 557 were officially registered, and 152 passed the assessment. Anthropogenic activities such as industrial emissions, improper waste disposal, and agricultural practices have resulted in the accumulation of pollutants in the soil, exceeding various elemental limit values. Municipal waste accounts for 45.48 percent of registered cases of local soil pollution, with industrial and commercial activities accounting for another 33.92 percent. Urban areas, industrial zones, and agricultural soils are especially vulnerable to contamination, with elevated levels of metals like nickel, copper, and zinc detected in soil samples. To protect soil quality and ecosystem integrity, soil pollution must be addressed through effective monitoring mechanisms, remediation efforts, and the implementation of sustainable agricultural practices. According to the first results of the most recent agricultural census from 2023[22] (final results will be published in 2024, at the time of writing this analysis were not available), the largest number of agricultural holdings (224 433) is located in the Šumadija and Western Serbia Region. However, when comparing the new statistics with the 2018 agricultural survey, the total number of holdings in Serbia decreased by 10%, while the area of used agricultural land decreased by 6.3% than in 2018 and now stands at 3,257,100 ha.

[21] Ministry of Environmental Protection of the Republic of Serbia, *Towards Soil Decontamination in the Republic of Serbia (2018)*

[22] 2023 Census of Agriculture, Statistics Office of the Republic of Serbia

The Region of Vojvodina has the most agricultural land used for farming, with 1,474,709 ha used out of 1,732,762 ha available land. In addition, Vojvodina has 111,884 registered holdings, with an average holding size of 13.2 hectares. According to the Green Agenda for Serbia 2023, Vojvodina, in particular, faces a significant threat from aeolian (wind) erosion, which endangers approximately 85% of its agricultural land. This is due to Vojvodina's extremely low forest cover, with only 6.4% of forested land, ranking among the least forested regions in Europe. Furthermore, the strategy's statistics show that 233,000 ha of agricultural land have been salted and alkalized, resulting in reduced soil productivity.

From 2002 to 2019, comprehensive soil quality monitoring was conducted throughout Vojvodina to ensure the integrity of agricultural land. This initiative examined 50 agricultural areas and discovered that the concentration of 29 heavy metals in soil samples remained below the maximum permissible concentration (MPC). Significantly, no traces of polychlorinated biphenyl (PCB) compounds were found, and the total concentration of polycyclic aromatic hydrocarbons (PAHs) in all samples was within acceptable limits.

The findings of this extensive research show that fertilization is frequently carried out in the studied areas without first conducting soil analysis. This agricultural industry practice has resulted in a wide range of soil nutrient content values, with a significant proportion of soil samples containing dangerously high levels of phosphorus, which may pose a toxicity risk. To address this issue, appropriate agro-technical measures must be implemented to regulate the concentration of phosphorus and potassium in Vojvodina's soil.

Efforts to address these issues must prioritize the implementation of land management practices, strict waste disposal regulations, and investments in sustainable infrastructure. By taking action, stakeholders can reduce risks to agricultural productivity, environmental well-being, and public health.

3.2. Regulatory Framework and Institutional Capacity

Non-financial reporting in Serbia is governed by legal obligations outlined in the Law on Accounting. This law requires large legal entities that are (i) public-interest enterprises and (ii) employ more than 500 people during the fiscal year to provide comprehensive reporting that goes beyond financial data and includes environmental, social, and governance factors. As part of the level reporting requirements, businesses must disclose information about their sustainability practices, environmental impact, social responsibility initiatives, and governance structures. These legal provisions emphasize the importance of transparency and accountability in corporate operations, in line with global trends towards sustainable development and business practices. By incorporating non-financial reporting into their operations, Serbian agricultural enterprises can boost their credibility, build stakeholder trust, and contribute to the country's long-term development goals.

The Republic of Serbia has yet to implement a comprehensive land protection planning framework. While some aspects are governed by existing strategies and laws, such as the Agriculture and Rural Development Strategy (2014-2024) and the Waste Management Programme (2022-2031), a comprehensive framework has yet to be developed. The Law on Soil Protection is a fundamental law that governs soil quality, but its full implementation at the state level has yet to be completed.

Existing laws, such as the Law on Agricultural Land, the Law on Agriculture and Rural Development, and the Law on Soil Protection, only partially comply with EU standards. Similarly, relevant by-laws, such as regulations governing hazardous substance quantities and soil pollution monitoring, must be further aligned with EU directives.

The Environmental Protection Agency plays an important role in establishing and maintaining the cadastre of contaminated soil, which is an essential component of Serbia's environmental protection framework. The Cadastre of contaminated soil allows for annual monitoring of the condition and quality of soil at contaminated sites, providing critical data on pollution sources for prevention or remediation measures.

Institutions throughout Serbia monitor soil quality in order to establish systematic quality control and create a centralized national database. The Law on Soil Protection, passed in 2015, laid the groundwork for systematic soil monitoring at the state and local levels, allowing for comprehensive reporting and the planning of remediation and protection measures.

Although progress has been made in soil protection efforts, further legislative harmonization and improved institutional coordination are required to establish a solid framework for land conservation and sustainable land use in the Republic of Serbia.

To summarize, the agricultural sector is a cornerstone of the Serbian economy, supporting livelihoods and stimulating economic growth. However, this sector faces numerous challenges such as environmental degradation, soil pollution, and unsustainable land management practices. To address these challenges, policymakers, stakeholders, and the larger community must work together to promote sustainable agriculture, preserve soil quality, and protect the environment for future generations. Serbia can pave the way for a resilient and environmentally sustainable agricultural sector by prioritizing land protection measures, investing in sustainable land management practices, and strengthening institutional capacity.

3.2.1. Agricultural cooperatives and agricultural holdings

The Law on Agriculture and Rural Development[23] defines agricultural holdings in Serbia as agricultural production units where a company, agricultural cooperative, institution, or other legal entity, entrepreneur, or farmer produces or processes agricultural products or engages in non-agricultural activities (rural tourism, old crafts, etc.).

During Serbia's accession to the European Union, its agricultural sector must adhere to a variety of regulations and standards, including those outlined in the Common Agricultural Policy. One such requirement is to establish a Farm Accountancy Data Network (FADN).

The FADN system conducts annual farm surveys to collect data on their structure, production, income, and expenditure, in accordance with European regulations and national requirements. This system allows for the year-round monitoring of business changes on agricultural holdings, assisting producers in managing their operations and policymakers in evaluating the measures put in place. The FADN system provides consistent data on agricultural holdings in Serbia, the region, and Europe, making it a reliable source for agricultural economic analysis. Its methodology allows for the extrapolation of economic data from a sample of agricultural holdings to the entire sector, allowing for comparison with indicators from other EU Member States.

The FADN system collects production, economic, and financial data from agricultural holdings that are divided into a representative sample based on economic size, type of agricultural production, and regional affiliation.

The Ministry of Agriculture, Forestry, and Water Management supervises and organizes the FADN system in Serbia, which requires several years of planning and coordination between various entities, including the Statistics Office of the Republic of Serbia, the Provincial Secretariat for Agriculture, Water Management, and Forestry of AP Vojvodina, the Institute for the Application of Science in Agriculture, Agricultural Advisory and Professional Services, and finally agricultural producers.

Founded in 2011, the FADN system initially surveyed 40 farms, with the sample size growing year after year. By 2022, the system had covered 1,761 farms, and data for 2023 is being processed. The EU Delegation to Serbia supported the establishment of the FADN system from 2011 to 2015 through a technical assistance project titled "Establishment of the Serbian Agricultural Accounting Data Network."

[23] Law on Agriculture and Rural Development, Article 2

Comparison to the EU

By 2020, the EU had 9.1 million farms. Romania, Poland and Italy have the highest percentage of agricultural holdings in the EU. Family farms account for the vast majority of farms in the EU, with an average farm size of 17.4 ha in 2020.

The vast majority of farms in the EU are family farms, which are defined as those where family members provide 50% or more of the regular agricultural workforce.

(94.8% in 2020). [24]

Recommendations

The Ministry of Agriculture, Forestry, and Water Management should take the following steps:

- Advocating legislation that supports the sustainable management of agricultural holdings, promoting practices that promote soil health, biodiversity, and water conservation;
- Encourage the implementation of existing legislation and the adoption of legal acts and strategies that promote the integration of farms as an instrument in the transition to sustainable agricultural production, because farms are often located in rural areas where they serve as economic foundations that encourage further growth and community vitality, and promoting responsible farming practices on farms can help the local community conserve natural resources, protect biodiversity and mitigate climate change.
- Promoting the installation of waste management and water treatment infrastructure on agricultural properties in order to reduce pollution and comply with environmental regulations.
- Providing educational resources and financial incentives to farms to help them adopt sustainable practices and improve their overall environmental performance, as farms encourage social interaction and cohesion among farmers, communities, and consumers.

[24] EuropeanCommission, *Farms and farmland in the European Union 2020 - statistics*, November 2022

3.3. Agricultural Subsidies

3.3.1. Agricultural subsidies in the Republic of Serbia

The Law on Incentives in Agriculture and Rural Development governs agricultural subsidies in the Republic of Serbia, while the Regulation on the Distribution of Incentives in Agriculture and Rural Development specifies the scope of funds, types, and maximum amounts for each type of incentive in agriculture and rural development for the budget year.

The Rulebook on the Manner of Exercising the Right to Basic Incentives in Plant Production and the Form of Requests for the Exercise of These Incentives (Rulebook) governs the implementation of basic incentives in primary plant production, along with the prescribed form of these incentives. This regulatory framework aims to directly support Serbian agricultural producers through financial incentives and assistance.

This Rulebook provides agricultural producers with incentives of RSD 18,000 per hectare for qualified plant production (a list of qualified crops can be found in the Plant Crop Codebook[25]). Furthermore, a special fee of RSD 17,000 per hectare is set aside for the purchase of certified seeds - seeds of known genetic origin and purity, whose production is regulated, and which have been tested, processed, and declared in accordance with the provisions of the law. The eligibility for these incentives is based on specific criteria:

a. Cultivation of areas entered in the appropriate register of plant crops, according to the Plant Production Code, except for natural meadows, pastures, and uncultivated land;
b. The maximum land area per producer is 100 hectares;
c. Soil processing must be done in the producer's personal name and for their own account.

Furthermore, the Rulebook on the Conditions, Manner, and Procedure for Exercising the Right to a Refund of Paid Excise Duty on Motor Fuel Used for Agricultural Purposes includes provisions for refunding excise duty. Producers can request a refund for up to 100 litres of oil and biofuel at a reduced price of RSD 179 per litre, subject to limitations based on cultivated area and fuel consumption for processing. The refund of excise duty on diesel can be up to RSD 5,000 (RSD 50 per litre), with a limit of 100 litres per hectare.

The Law on Incentives in Agriculture and Rural Development, as well as the accompanying Regulation on the Distribution of Incentives in Agriculture and Rural Development, define incentives as direct payments (premiums, production incentives, and subsidies), special incentives, and credit support. Furthermore, the same law prescribes incentives granted for the implementation of rural development measures, specifically to improve competitiveness, preserve and improve the environment and natural resources, diversify income, and improve the quality of life in rural areas,

[25] Plant Crop Codebook, Ministry of Finance of the Republic of Serbia, Treasury Department

preparation and implementation of local rural development strategies as well as measures to improve the system of knowledge creation and transfer.

Measures to support rural development include investment support for the purchase of machinery, equipment, and mechanization, facility construction and equipping, fruit plantation cultivation, and so on. These incentives are implemented on an annual basis, and they have an impact on production sustainability and competitiveness. In addition to these subsidies, agricultural producers can use subsidized loans from the Ministry of Agriculture, Forestry, and Water Management. Both natural persons, including owners of commercial family farms and entrepreneurs, as well as legal entities, are eligible for credit support for loan amounts between RSD 6,000,000 and RSD 18,000,000[26]. This subsidy includes agricultural loans for the purchase of livestock and fodder, agricultural development, fruit and vegetable growing, viticulture, and flower production, as well as investments in new agricultural machinery and equipment.

3.3.2. SCAP Project

The Serbia Competitive Agriculture Project (SCAP) is run by the Ministry of Agriculture, Forestry, and Water Management in collaboration with the World Bank. This project was first implemented in 2021 and will be valid until the end of 2024. It uses the 50:40:10 financing method (50% non-refundable, 40% bank loan, and 10% borrower share). The percentage amount of support is 50% of the total value of the investment (including VAT), of which 40% is financed by loans from commercial banks with only 10% of the beneficiary's share. Eligible investments include preparatory costs, machinery, equipment, and processing capacities, as well as investments in professional and technical support and borrower training for grant use.

This project is aimed at family farms, agricultural cooperatives, entrepreneurs, and micro, small, and medium-sized businesses, with a particular emphasis on vulnerable groups such as women farmers and young farmers in underdeveloped municipalities. The primary goal is to empower small agricultural producers and businesses that want to learn, improve, and develop their capacities while transitioning from a traditional agricultural to an entrepreneurial approach. As a secondary goal, this project aims to assist agricultural institutions in the Republic of Serbia with capacity improvement and cost reduction through the development of information and communication technologies (ICT).

[26] Rulebook on Requirements and Manners of Exercising the Right to Credit Support: 48/2017-75, 88/2017-156, 84/2018-41, 23/2019-22, 27/2020-36, 36/2021-46, 102/2021-31, 130/2021-144, 127/2022-6, 144/2022-110, 21/2023-96, 8/2024-79

3.3.3. IPARD Programme

The Instrument for Pre-Accession Assistance for Rural Development (IPARD) is an EU-funded programme aimed at assisting rural development and agricultural sectors in EU candidate countries such as Serbia. These programmes aim to encourage countries to align with EU standards and the EU Common Agricultural Policy (CAP). The previous IPARD II programme began in 2018 and provided EUR 175 million in investment support for measures 1, 3, and 7, which are the same as the new IPARD III programme. The European Commission has budgeted EUR 288,000,000 for this Programme from 2021 to 2027. IPARD III measures 1, 3, and 7 have already been made public, with measures 4 and 6 in the works.

IPARD Measure 1 encompasses investments in physical assets of agricultural holdings. This assistance is strategically planned to help beneficiaries increase productivity and competitiveness in primary agricultural production. These advancements are made possible by technical upgrades and investments in new machines, equipment, machinery, facility construction and equipping, and technology development. Furthermore, farms are encouraged to align their production practices not only with national standards, but also with EU regulations on environmental protection and animal welfare.

IPARD Measure 3 directs investments to modernize agricultural and fish processing capacities. Strengthening these processing capacities is expected to significantly improve the overall performance of key sectors such as milk and dairy products, meat and meat products, fruit and vegetables, cereal, egg, and wine products. These investments are ready to help businesses comply with EU standards while also increasing productivity and competitiveness in specific sectors. Furthermore, it is expected to simplify market positioning and increase export opportunities.

IPARD Measure 7 emphasizes farm diversification and business development. This initiative seeks to generate new opportunities for rural tourism development and employment in rural areas, reducing reliance on agriculture while improving the quality and availability of basic services and infrastructure.

IPARD measures 4 and 6 are still being developed and await accreditation. Measure 4 covers agriculture, environmental protection, climate, and organic production. The primary goal of this measure is to implement EU methodologies and practices in the agricultural sector. Measure 6 will address the improvement of public infrastructure in rural areas. Measure 6 distinguishes itself by focusing on LGUs as the ultimate recipients of assistance.

These subsidies and incentives are critical mechanisms for promoting growth, sustainability, and competitiveness in the agricultural sector, thereby contributing to the overall development of Serbian agriculture.

Comparison to the EU

The EU recognizes that agriculture is a critical industry in all Member States. The EU has allocated EUR 386.6 billion to support agriculture in the 2021-2027 budget. Of this, EUR 291.1 billion is set aside for the European Agricultural Guarantee Fund, which provides direct payments to farmers, and EUR 95.5 billion for the European Agricultural Fund for Rural Development, which provides funds for rural development, climate action, and natural resource management.

With the most recent agricultural reforms in 2021, the EU has prioritized improving the environmental performance of the agricultural sector, which is estimated to account for approximately 10% of the EU's greenhouse gas emissions. To achieve environmental and climate goals, the EU has implemented eco-schemes that reward farmers who use sustainable agricultural practices, even if this does not correspond to actual market values. This includes techniques like organic farming, precision farming, and carbon sequestration. Beginning in 2023-27, 25% of direct payments will be allocated to eco-schemes; implementation of this system is mandatory for all member states but optional for farmers.

In Serbia, the Ministry of Agriculture, Forestry, and Water Management has allocated RSD 119 billion in 2024 for direct assistance, rural development, and subsidized agricultural loans. However, Serbian subsidies noticeably lack a focus on promoting improvements in environmental performance or ensuring the sustainability of the sector. Subsidies for organic production and the preservation of plant genetic resources, totalling RSD 1.05 billion from the annual republic budget, are Serbia's only form of environmental subsidy. The EU IPARD programme, which has a budget of RSD 6.3 billion for 2024, supplements Serbia's agricultural subsidies for farmers and businesses. IPARD measures are the primary support mechanism for improving the sustainability of agricultural practices. In order to benefit from them, farmers must demonstrate compliance with the relevant CAP standards. SCAP also promotes environmental values by providing loans for agricultural modernization.

Recommendations

Given the current state of agricultural subsidies in Serbia and the growing importance of environmental actions, it is critical to work on aligning incentives with environmental goals and modern agricultural practices.

In the near future, the Ministry of Agriculture, Forestry, and Water Management should consider the following measures:

- Measuring the possibilities of increasing funding for environmental initiatives within agricultural subsidies, including support for agro-ecology, biodiversity conservation and soil health management.

- Measuring the possibility that producers using regenerative farming practices are also subsidized within the framework of direct payments in primary crop production, in the same way that producers using organic farming methods are subsidized in relation to conventional production;
- Investing in farmer education and capacity-building programmes that focus on sustainable agricultural practices and empower farmers with the knowledge and skills needed to adopt environmentally friendly agricultural methods.
- Implement a programme to assist agricultural producers with the application process for available IPARD and SCAP funds.
- Work on domestic programmes to support agriculture and rural development to supplement national agricultural subsidies. Alignment with EU standards not only simplifies access to additional funding, but also boosts Serbia's competitiveness in the European agricultural market.
- Consider implementing eco-schemes similar to those in the EU that encourage farmers to use sustainable practices. Allocating a portion of the subsidy budget to eco-schemes has the potential to promote widespread adoption of environmentally friendly agricultural practices.

3.4. Organic Farming in Serbia

The Law on Organic Production defines organic farming in Serbia as the production of agricultural and other products using organic production methods at all stages of production, excluding the use of genetically modified organisms and products derived from genetically modified organisms, as well as the use of ionizing radiation.

To be considered organic producers, agricultural producers must obtain a written certificate from an authorized control organization confirming that the organic product was produced in accordance with the Organic Production Law and its accompanying acts (Authorized Control Organization). The Ministry of Agriculture, Forestry, and Water Management has granted the Authorized Control Organization permission to perform organic production control and certification activities.

Based on the reports on the controls performed, the Authorized Control Organization issues a certificate stating that the product or production process complies with the law. Food, animal feedstuffs, processing aids, plant protection and nutrition products, soil conditioners, and reproductive material cannot be used to produce organic plants.

Microorganisms or animals that are GMOs or represent GMO-derived products, as well as ionizing radiation, cannot be used in the processing of organic food or animal feedstuffs. Organic plant production methods include plant species and varieties selection, crop rotation, soil cultivation, fertilization, soil fertility maintenance, plant disease, pest, and weed control, and wild species collection from natural habitats in accordance with organic production laws.

Agro-technical measures used in organic plant production should avoid or reduce environmental pollution. Hydroponic production is not an option in organic plant production.

The Law on Incentives in Agriculture and Rural Development and the Rulebook on the Use of Incentives for Organic Plant Production establish a system of incentives for organic agricultural production.

In 2020, amendments were made to the Ordinance on control and certification in organic production and methods of organic production, which is harmonized with Regulation (EU) 834/2007 and Regulation (EU) 889/2008, while the annexes related to fertilizers, soil protection and plant nutrition products, plant protection products, feed additives, products and substances for use in the production of processed organic food, yeast and yeast products, and products and substances approved for use or addition to the sectors of organic wine products were prepared in accordance with the Implementing Regulation (EU) 2021/1165.
According to the certification procedure, Serbia has two types of organic farmers: (i) individually certified producers and (ii) members of the group who are not physically certified but work for a company that oversees farmers and holds a certificate, thus forming part of a "cooperative." They are listed as producers in the Certificate Annex. In this type of production, farmers are typically brought together by an export-processing corporation that also regulates the internal control structure and has contractual obligations to farmers.[27]

Organic agriculture in Serbia increased by 12.2 percent compared to 2021, but its representation remains below the EU average. In 2021, the number of organic producers increased from 6,109 in 2020 to 6,421[28], with 616 certified organic producers cultivating 23,527.03 ha of land. In the same year, the number of cooperatives increased, and 54 of the total number of certificate holders now engage in group production with 5,805 subcontractors.

High nature value farming (HNVF) land accounts for approximately 19% of farming land and 13% of Serbia's total territory. These lands consist primarily of

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[27] EkoConnect and the German Ministry of Food and Agriculture, Report on the State of Organic Agriculture and Industry in Serbia 2022 (2022)
[28] *Ibid.*

grasslands resulting from deforestation. However, only type 1 HNVF is considered in these assessments, with the caveat that the actual area may be greater.

3.4.1. Drawbacks and challenges

Rural areas in Serbia face significant challenges, such as depopulation, declining economic activity, and inadequate utility infrastructure. Climate change exacerbates these issues, particularly as it impacts rural ecosystems and livelihoods. Inadequate infrastructure, especially in mountainous areas, contributes to water quality issues and insufficient waste management.

To address rural infrastructure gaps, efforts have primarily focused on including modest legal provisions to support funding, as well as initiatives such as the IPARD III programme by 2027.[29] Priorities for rural infrastructure management include waste management, water collection and treatment, road infrastructure, and energy supply, all with the goal of improving the resilience and sustainability of Serbia's rural communities.

When it comes to biodiversity and ecosystem efforts in Serbia, the goal is to halt biodiversity loss and restore ecosystems through comprehensive management systems. This necessitates ongoing efforts to conserve habitat and species, manage protected areas, and implement an integrated monitoring system. Continuous monitoring, regulatory changes, and timely information collection should be prioritized in order to determine the extent of the impact of environmental changes on various groups of organisms.

Efforts have been made to complete the mapping of protected species and habitats within NATURA2000[30], while also promoting and raising awareness and strengthening protection measures. Given the anticipated increase in droughts and extreme weather events, steps are being taken to prevent further degradation of forest and fish stocks.

When it comes to sustainable agriculture, Serbia is working to align its strategies with the EU Green Agenda in order to transform the agricultural sector while ensuring affordable and healthy food for both citizens and export markets. The most common priorities are to increase organic production, reduce reliance on synthetic fertilizers and pesticides, and align national regulations with EU standards.

To achieve these goals, Serbia must place emphasis on promoting organic and sustainable agriculture, investing and adopting new technologies, and making systemic efforts in

[29] IPARD II is a rural development-specific instrument within the Instrument for Pre-Accession Assistance II. The Republic of Serbia can expect to receive EUR 175 million in investment support from this instrument between 2014 and 2020.

[30] The Birds and Habitats Directives provide a general legal framework for the protection and management of Natura 2000 sites.

improving inspection and sanitary control throughout the production chain. As a result, collaboration with scientific, educational, and economic entities is critical to facilitating the transition to new and innovative technologies, as well as the implementation of methods and measures to promote sustainable agriculture.

Finally, encouraging investment in renewable energy sources is critical for lowering operating costs and alleviating pressure on the traditional energy system. Investment in rural infrastructure, waste reduction measures, and the implementation of the LEADER approach through the IPARD programme are key financing mechanisms for such initiatives.

To summarize, all of these efforts help to promote sustainable agricultural practices, support rural community development, and contribute to Serbia's overall environmental and economic goals.

Comparison to the EU

Unlike Serbia, the EU's FtF Strategy includes ambitious targets for organic farming. By 2030, the EU plans to cultivate at least 25% of its agricultural land using organic methods. Since 2020, the EU has made significant progress, with 14.7 million hectares dedicated to organic farming, a significant increase of 5.3 million hectares since 2012, or more than half (55.7%). In 2021, there were nearly 380,000 organic producers in the European Union.

Organic farming's share of total utilized agricultural area also increased significantly, rising from 5.9% in 2012 to 9.1% in 2020 in EU Member States. Almost 60% of the total EU organic area in 2020 was concentrated in just four Member States: France, Spain, Italy, and Germany. These countries have played an important role in driving the expansion of organic farming in the EU, reflecting the different levels of adoption and application of organic farming practices across the Member States.

EU Regulation 2019/1009 establishes rules for the marketing of EU fertilizing products, including product requirements and limit values for contaminants found in fertilizers from various Product Function Categories.

Recommendations

To improve organic agriculture in Serbia, the Ministry of Agriculture, Forestry, and Water Management should take the following measures:

- The implementation of financial incentives or subsidies for the purchase of certified organic seeds, equipment, and the use of organic techniques.
- Simplify the certification process for organic farmers by lowering administrative barriers, providing financial assistance for certification fees, and offering technical assistance to meet certification standards.
- Launch public awareness campaigns to educate consumers about the benefits of organic farming and to encourage them to buy organic products, using advertising, educational workshops, and collaboration with retailers.
- Determine funding for organic farming research and development to improve farming techniques, develop organic pest control methods, and organically improve soil fertility through collaborations with universities, research institutions, and agricultural organizations.
- To reach a larger consumer base and achieve premium product prices, help organic farmers gain market access by establishing organic product labelling standards, creating a dedicated organic market, and providing marketing assistance.
- Implement existing land use policies that prioritize organic farming practices, such as reserving agricultural land for organic farming, limiting synthetic pesticides and fertilizers, and encouraging organic farming in cities and suburbs.
- Provide assistance to small organic farmers through microcredits, access to land and infrastructure, and organic farming training programmes.
- Strengthening regulations and enforcement mechanisms is required to ensure compliance with national and international environmental standards, prevent organic market fraud, impose harsher penalties for noncompliance, conduct regular and effective inspections, and establish transparent reporting mechanisms for organic certification.

3.5. Water, Wastewater and Agriculture in Serbia

3.5.1. General overview

Given the important links between water, soil, climate change, ecosystems, biodiversity, energy, agricultural sub-sectors (crop and livestock production, forestry, fisheries and aquaculture) and food security, there is a growing need for improved water management in agriculture.

Growing water demand in all sectors requires greater investment in infrastructure and efficient management, stronger capacity and adaptability, improved information and science, innovation and technology, and multi-stakeholder dialogues to understand trade-offs and distribution of water. Increased competition for drinking water can exacerbate already serious disparities in access and inefficiencies in use if effective and inclusive management is not in place.

Wastewater originating from agricultural activities is a significant concern at the global level, with the agricultural sector being the largest consumer of water in the world, primarily for irrigation purposes. The growing demand for food due to population growth has led to increased use of pesticides to increase crop yields, exacerbating the problem. Developing countries in particular struggle with the consequences of pesticide/herbicide overuse with 4,000,000 tons of pesticides applied annually worldwide. This widespread use of pesticides has resulted in high concentrations that exceed limit values in water bodies, which pose serious risks to human health, ecosystems and the aquatic environment. To mitigate these negative effects, there has recently been a move towards the adoption of biodegradable and biocompatible pesticides, heralded by eco-friendly solutions. However, adoption of bio-pesticides remains limited by factors such as cost and slower efficacy compared to synthetic counterparts. Furthermore, the interaction between pesticides and water and soil constituents can lead to the formation of intermediates with different physical and chemical properties. Mechanisms such as diffusion, dispersion, and permeation facilitate the transfer of pesticides to solid matter and water, often prolonging natural degradation processes.

To address these challenges, efforts are being made to develop new technologies and environmentally friendly pesticide formulations aimed at reducing water contamination. Mathematical models are used to stimulate and predict the fate of pesticides in water resources, highlighting the importance of innovation and sustainable practices in preserving water quality and ecosystem health.

3.5.2. Agricultural waste water in Serbia

The Republic of Serbia is one of the biggest polluters of the Danube River with nitrogen and phosphorus.[31] Problems concerning environmental protection arise due to the inappropriate use of chemical agents in agricultural production; farmers use them unprofessionally and thus large amounts of pollutants reach the soil, surface and underground water. The use of chemical agents is necessary, but it is necessary to use them at the right time and at the appropriate concentration.

Modern technological achievements help in various ways. One of the long-term problems that Serbia faced was the disposal of pesticide packaging. The Law on Plant Protection Products and the corresponding bylaw[32], were adopted, providing a regulatory context for dealing with hazardous waste from pesticide packaging. When it comes to mineral nutrients, a soil analysis campaign was conducted in Serbia based on which

[31] Decision on establishing the National Environmental Protection Program, Official Gazette of RS, number 12/10, *Paragraph. 6.4 Agriculture*

[32] Rulebook on the content of the declaration and instructions for the use of plant protection products, as well as specific requirements and markings of risks and warnings for humans and the environment and the way of handling empty packaging from plant protection products. Official Gazette of RS, number 89/2014 and 97/2015

expert services can provide information to farmers about the type and amount of mineral fertilizer that must be used.

Pursuant to the Law on Plant Protection Products, the rules for classifying and determining the quality of plant nutrients, nutrient content deviations and minimum and maximum values of permitted nutrient content deviations, as well as the content of the declaration and the way plant nutrients are labelled, are established by a separate by-law.[33] It is interesting to note that this complementary regulation does not set limit values that determine the maximum concentration of pollutants in fertilizer.

Although it is not the subject of this analysis, it is important to note that major nutrient pollution of waterways comes from livestock farms and slaughterhouses, where manure is often dumped in unprotected areas, contaminating groundwater and waterways, leading to algal blooms and disrupting ecosystems. In order to mitigate this type of pollution, it is recommended to process liquid manure in biogas plants for environmental protection, but only a few farms in Serbia have such facilities in use.

The prescribed fines for exceeding the waste water discharge limits are significantly lower compared to the costs of maintaining the plant, because legal entities can be fined from 500,000 to 3,000,000 dinars. In addition, there is a noticeable lack of enforcement regarding non-compliance with regulations in practice. It is imperative to help farmers develop nitrogen and phosphorus management plans and raise awareness of pollutant impacts to facilitate better understanding and reduction of nutrient and pesticide impacts.

The implementation of the "code of good agricultural practice" is crucial to prevent further pollution of ground and surface water resources.[34]

In Serbia, only 55% of the population has access to sewage systems, with most wastewater treatment plants using outdated technologies, reflecting the country's middle development level concerning sewage infrastructure, but lagging behind in wastewater treatment. Moreover, only 26 out of 47 cities and municipalities with wastewater treatment plants are operational, exacerbating water supply challenges, including source water pollution, inadequate access to clean drinking water, significant losses in water networks, and impending privatization of utilities. Groundwater depletion, particularly severe in Vojvodina, represents a significant threat exacerbated by overexploitation and pollution, without feasible means for restoration. Large-scale sand and gravel mining, together with the planned construction of reservoirs, poses additional risks to groundwater reserves and existing reservoirs, which is further exacerbated by the consequences of climate change such as droughts and floods, illegal construction, poor anti-erosion measures, discharge of agricultural wastewater and inadequate waste management. Encroachment on reservoir banks exacerbates these issues, highlighting the absence of effective institutional responses.

[33] Rulebook on the conditions for classifying and determining the quality of plant nutrition products, nutrient content deviations and minimum and maximum values of permitted nutrient content deviations, and on the content of the declaration and the method of labelling plant nutrition products. Official Gazette of the RS, no. 30/2017 and 31/2018

[34] Rulebook on the Code of Good Agricultural Practice, *Official Gazette of the RS,* no. 23/2023;

Comparison with the EU

The average nitrate concentration in European groundwater has fluctuated around the same level since 1992 and there is no clear trend. Shorter but more representative time series starting in 2000 and ending in 2021 closely follow the longer ones. Agricultural activities, such as excessive use of fertilizers, are the main driver of nitrates in groundwater.[35] The average concentration of nitrates in European rivers decreased continuously during the period 1992-2009, but has levelled off since then. Since 2000, the level of concentration has been lower. Agriculture remains the main contributor to nitrogen pollution, but the EU Directive on nitrates and national measures contributed to lower concentrations.[36]

When it comes to the presence of phosphates in European rivers, concentrations more than halved in the period 1992-2011. From 2011 onwards, concentrations have levelled off and increased over the last five years, indicating the need for further measures.[37] The overall reduction of river phosphate can be related to measures introduced by national and European legislation, e.g. Urban Wastewater Treatment Directive. Also, switching to phosphate-free detergents contributed to lower phosphate concentrations. Since 1992, there has been a gradual decrease in the average total concentration of phosphorus in European lakes, although the concentration has stabilized since 2015. The concentration level is slightly higher in the period from 2000 to 2021.[38] As the treatment of urban wastewater has improved, phosphorus from detergents has decreased, and many wastewater discharges were diverted from the lake, phosphorus from point sources became less significant. However, diffuse runoff from agricultural land is still the main source of phosphorus in European lakes. Furthermore, phosphorus stored in the sediment can maintain high concentrations in the lake despite decreasing input.

In the EU, the maximum permitted levels of nutrients in water are regulated primarily by the EU Water Framework Directive and the EU Nitrates Directive. These directives set general quality standards for various parameters to ensure the protection of human health and the environment. The maximum allowed concentration of nitrates in freshwater bodies is set at 50 mg/L in order to protect against nitrate pollution and eutrophication. However, there are no specific levels for phosphorus and ammonium, although they are common pollutants from agricultural runoff, these pollutants may be indirectly regulated by other specific local laws. The EU is currently considering raising standards for the monitoring and management of surface and groundwater pollutants

Recommendations

[35] European Environment Agency, Freshwater Nutrients in Europe, published on 14 December 2023.

[36] Ibid.

[37] ibid.

[38] ibid.

Currently, there are no set limits for water pollutant emissions from agriculture in Serbia. In order to solve this, it is recommended to regulate the limit values of emissions of water pollutants from agriculture in Serbia, by harmonizing the national legislation with the EU legislation on this topic.

Moreover, considering that groundwater pollution from agriculture is mainly caused by the use of fertilizers, the legislation should prescribe precise limit values of pollutants present in fertilizers, as well as mechanisms that enable effective inspection and sanctioning for non-compliance with standards.

3.6. Social and Governance Factors of ESG in the Agricultural Sector

3.6.1. Social factors

In the agricultural sector of Serbia, the social factors of sustainability require a comprehensive approach to ensure the well-being of those who are engaged in it. This includes guaranteeing the right to work, ensuring fair wages and benefits and fair working conditions for all agricultural workers.

In this sense, safety and health at work is regulated in Serbia in order to ensure a safe working environment. The agricultural sector must address the unique challenges facing rural communities, such as limited access to quality education and health care, which are essential for sustainable development. Promoting gender equality and empowering vulnerable groups, including young and older farmers, are also key steps towards building a more inclusive farming community. Improving the social sustainability of agriculture in Serbia includes supporting small and family farms, preserving rural traditions and strengthening local food systems.

By focusing on these social aspects, Serbia can improve rural life, ensure food security and contribute to the overall socio-economic development of the country.

In the EU, addressing the social factors of sustainability within the agricultural sector is essential to promote equitable and inclusive growth. This includes protecting workers' rights, ensuring fair labour practices and ensuring fair wages. It is crucial that agricultural businesses across the EU commit to improving the well-being and professional development of their workforce, recognizing the important role of farmers and agricultural workers in society. This includes promoting rural development, supporting small farm owners and providing access to education and training opportunities to facilitate innovation and sustainable farming practices.

Social responsibility in the EU is regulated by international conventions and declarations, as well as various directives and regulations adopted by the EU. The CSRD calls for disclosure of labour practices, respect for human rights and community engagement through the ESRS, while the CAP envisages economic measures that include socially inclusive elements such as redistributive rewards and assistance for small farms. By aligning with the already adopted EU regulations and seeing that Serbia already applies a large part of the provisions that are in force in the EU, Serbia can easily close the gap that exists today and improve its own standards.

3.6.2. Governance factors

Effective corporate governance is of great importance for the promotion of sustainable development in the agricultural sector of Serbia. This includes implementing transparent, accountable and participatory governance structures that ensure equitable distribution of resources and support the rights of all stakeholders, including small and family farms.

Strong governance requires the establishment of clear regulatory frameworks that promote sustainable agricultural practices, protect land rights, and facilitate access to markets and financial services.

It is also essential to fight corruption, increase the efficiency of public spending in agriculture and ensure that agricultural policies are evidence-based and aligned with national sustainability goals and international standards.

Moreover, engagement with a wide range of stakeholders, including farmers, agribusinesses, non-governmental organizations and local communities, is essential to ensure that governance mechanisms are responsive to the needs and challenges of the sector.

3.7. Child Labour in Serbia

3.7.1. General overview

The latest global estimates [39] show that 152 million children – 64 million girls and 88 million boys – are in child labour, which is almost 1 in 10 of all children worldwide. Child labour in agriculture is a complex challenge that undermines the principles of sustainability within the sector. Defined as work that deprives children of their childhood, potential and dignity, and at the same time endangers their physical and mental development, it represents a gross violation of human rights and ethical standards. The agricultural sector harbours the majority of child workers worldwide, accounting for 70 percent of all cases.[40]

[39] International Labour Organization (ILO), Global Estimates of Child Labour: Results and Trends, 2012-2016, Geneva, 2017

[40] International Labour Organization, Ending Child Labour by 2025 (2018)

Between 2012 and 2016, an additional 10 million children worldwide were involved in child labour in the agricultural sector. While the number of children in child labour has declined by 94 million since 2000, the pace of progress has slowed significantly between 2016 and 2021.[41] This trend not only underscores the persistence of the problem, but also underscores the need for targeted interventions and sustainable solutions.

The main causes of child labour in agriculture are multiple, with household poverty and food insecurity appearing as the primary drivers.[42] It is important to note that IPEC noted that child labour is a cause and effect of poverty, inequality, discrimination, social exclusion and lack of access to education. Nevertheless, although child labour is a serious violation of human rights and the right to education, it is important to remember that not all work performed by children should be classified as child labour.

Families struggling with economic hardship and inadequate access to food often resort to involving their children in agricultural activities as a means of survival. This reality highlights the intricate links between poverty, food security and child labour, highlighting the need for holistic approaches that address systemic issues at their core.

Findings from the Global Forum on Food Security and Nutrition (FSN Forum), as well as insights from the Food and Agriculture Organization (FAO), shed light on the complex interplay of socioeconomic factors that shape the prevalence of child labour in agriculture. As stakeholders in the pursuit of sustainability, it is imperative that we face reality head-on, devising strategies that not only protect the rights and well-being of children, but also foster resilient agricultural systems that prioritize the equality and dignity of all actors involved.

3.7.2. Development in the EU

CSDDD and child labour

The EU has improved its stance on forced labour and environmental sustainability within corporate supply chains by requiring large companies operating in the EU to not only identify, but also take corrective action if their operations involve the use of child labour or contribute to environmental harm. Such measures underline the EU's commitment to combating child labour and environmental degradation, in line with broader initiatives outlined in the EU Action Plan on Human Rights and Democracy 2020-2024.[43]

While supply chain due diligence is not a new issue, CSDDD adds another layer of responsibility. Under this regulation, companies based in the EU will be held accountable for adverse impacts on human rights and the environment throughout their value chains, including child labour.

Prohibition of products made by forced labour

41 Ibid.

42 FAO UN, FAO Framework to End Child Labour in Agriculture (2020)

43 European Commission, EU Action Plan on Human Rights and Democracy 2020-2024 (2020)

The European Union has taken steps to combat forced labour, including child labour, by adopting strict regulations aimed at banning products made with forced labour from the EU market. This complements existing legislative frameworks and underlines the EU's commitment to respecting human rights and protecting workers' rights.

The proposal for a Council regulation banning products produced with forced labour on the Union market, submitted by the Commission to the European Parliament and the European Council in June 2022 (not yet in force), provides a legal basis for preventing products produced with forced labour from entering the EU market or exporting from the EU. Banning products made with forced labour is expected to contribute significantly to international efforts to eradicate such practices and protect the rights of workers and children. For businesses, compliance with these regulations not only promotes social sustainability, but also increases public trust and credibility among customers. All businesses operating in the EU market or exporting products from the EU are subject to these new rules, providing a comprehensive approach to tackling forced labour in all supply chains. The new rules apply to EU agriculture, a sector known for its heavy reliance on child labour and seasonal migrant labour for the hardest and lowest paid jobs in agriculture.

3.7.3. Child labour in Serbia

The Labour Law stipulates that a child of at least 15 years of age can work, if a contract has been concluded (i) with the consent of the parents and (ii) if such work does not endanger his health, morals and education. The Labour Law also prohibits employees under the age of 18 from working in jobs:

- which include particularly difficult physical tasks, work underground, under water or at a great height;
- which include exposure to harmful radiation or agents that are toxic, carcinogenic or cause hereditary diseases, as well as health risks from cold, heat, noise or vibration;
- which, based on the findings of the competent health authority, could adversely affect their health and life with increased risk, considering their psychophysical abilities.

The regulation on determining hazardous work for children, which has been in force since 2018, has determined the dangerous jobs that children should not engage in under any circumstances. Hazardous activities include, but are not limited to, mining, logging, gambling and betting. Children are prohibited from working in those areas.

On October 22, 2022, the Government of Serbia adopted the General Protocol on the Protection of Children from Violence.[44] In this sense, Serbia harmonized its definition of child labour abuse with the Convention on the Worst Forms of Child Labour, defining child labour abuse as psychologically, socially and morally dangerous and harmful to the child and which affects the child's education by preventing the child from attending school, requiring the child to leave school early or forcing the child to attend school under extremely difficult conditions, including the worst forms of child labour. Serbia

[44] Decision of the RS Government no. 560-826/2022-2 dated 02/10/2022 adopting a new General Protocol for the Protection of Children from Violence

ratified other key conventions dealing with child labour, setting the minimum working age at 15 and identifying hazardous activities prohibited for children.

The survey on child labour in Serbia for 2021[45] shows that almost one in ten children, aged 5 to 17, is involved in child labour, which includes work that threatens their physical and psychological well-being. This equates to a child labour rate of 9.5%. Moreover, more than 61,000 young children are engaged in child labour, some engaged in hazardous work even though they are too young for economic activities. A significant finding is that one in ten children above the minimum working age is involved in dangerous activities, which pose a risk of injury or illness.

Exposure to workplace hazards is prevalent among working children, with many exposed to dust, dangerous machinery, extreme weather conditions and awkward physical positions. Boys are disproportionately affected by child labour and hazardous work compared to girls and suburban and rural areas show significantly higher rates of child labour than urban areas. The age structure reveals that the rate of child labour increases with age, with the 12-14-year-old group being the most vulnerable. Boys are more likely to be engaged in child labour than girls, and rural areas have a significantly higher prevalence compared to urban areas.

Agriculture appears as the primary sector employing child labour, followed by industry and the service sector. Most children who engage in child labour do so to supplement family income or gain skills, highlighting socioeconomic pressures and the need for support systems.

The survey also highlights the impact of work and housework on children's education, with older children spending significantly more hours on work and housework, potentially affecting their academic performance.

Overall, the findings underscore the urgent need for concerted efforts to address child labour in Serbia, focusing on improving social protection, access to education, and economic opportunities to protect children's rights and well-being.

Recommendations

In order for the Government to address the issue of child labour, it should consider the following measures:

- enact and implement laws and regulations that explicitly prohibit child labour in all its forms, including hazardous and exploitative work;
- ensure that national legislation is in accordance with international standards and conventions;
- develop a comprehensive national action plan specifically aimed at eradicating child labour. This action plan should contain measurable goals, timelines and strategies for the prevention, protection and rehabilitation of working children;
- improve monitoring and enforcement by allocating sufficient resources to mechanisms

[45] International Labour Organization, Survey on Child Labour in Serbia for 2021, July 2023

monitoring and enforcement for effective identification, investigation and prosecution of child labour cases, through cooperation with law enforcement authorities, labour inspectors and civil society organizations in order to improve monitoring and reporting mechanisms;

- promote the development of social protection programs aimed at families at risk of resorting to child labour due to poverty, unemployment or other socio-economic factors, as well as to provide financial assistance, food security, health care and other basic services to support vulnerable households;
- raising the awareness of households through education and training on the permitted forms of child labour in agriculture, all in accordance with international conventions of the ILO, compared to prohibited child labour.

4. Analysis of the Potential Economic Effects of the Transition from a Conventional to a Regenerative Model of Agricultural Production

4.1. Methodology and Prerequisites

The analysis presented below and the measurement of potential economic effects are based on several key assumptions:

- Given the method and complexity of crop cultivation, crop rotation and challenges in the multi-year stimulation of agricultural production, for the purpose of simplification, this analysis is exclusively focused on the sowing and cultivation of wheat. All agro-technical operations and associated revenues and costs listed in this analysis primarily relate to wheat production and may not necessarily be the same for other types of crops.
- The farm has the following equipment: tractors, fertilizers spreaders and sprayers. The mentioned equipment is used both in the traditional and in the regenerative model, and represents the basic mechanization needed for agricultural production. Based on the information provided by the Tamiš Institute, it can be assumed that the majority of farms already own the mentioned equipment.
- The agricultural holding does not own a seed drill or a harvester.

- The agricultural holdings pay for land preparation services (ploughing, pre-sowing preparation, rolling), sowing and harvesting.
- Depreciation of machines is not included in the analysis due to the different age of the machines in the average agricultural farm in Serbia. In addition, depreciation is a non-monetary expense that as such does not affect the gross margin of agricultural production.
- The cost of the agricultural producer's salary is not included in the analysis due to the fact that the agricultural producer's salary as the owner of the farm is reflected through the calculated gross margin.
- The cost of acquiring the necessary mechanization for the transition from a conventional to a regenerative model is not included in the analysis, but the service engagement of the equipment needed for those operations (sowing and harvesting) is foreseen.

The analysis is based on information provided by the Tamiš Institute, historical data collected from the databases of the Republic Statistical Office (RSO) as well as publicly available sources. Please note that during the analysis, we did not perform independent checks or verification of information and data obtained from the RSO, as well as verification of data collected from publicly available sources.

The analysis includes the measurement of income, expenditure and the resulting gross margin associated with wheat production processes using conventional and regenerative tillage methods, after which the difference in income, costs and gross margin between these two approaches has been determined. The analysis was performed at the level of one production cycle as well as for a period of 10 years. The analysis was done for 1 hectare of arable land, in dinars.

4.2. Profit

The total profit was determined by calculating the yield and price of crops. In the case of wheat, based on the data of the Tamiš Institute, as well as the historical ten-year average in Serbia, the assumption of an average yield level of 4.7 tons/ha was adopted.

In general, the full process of transitioning from a traditional tillage model to a regenerative one involves a period of 5 to 7 years during which yield volatility is present, after which stabilization occurs. The application of regenerative agriculture methods can result in slightly higher yields compared to traditional tillage in the first 3 to 4 years from the moment of transition from the traditional to the regenerative model (10% to 20%). After that, a period of stagnation lasting 2 to 4 years is expected, during which yields in the regenerative model fall to the level of traditional production or slightly below that level (by about 10%).

In the long term, in the period after 5 to 7 years, the yield level is similar or higher compared to the traditional model, with additional benefits of long-term preservation of soil quality.

Depending on the agricultural season, the price of the crop can vary significantly between years. Based on 10-year historical data on the average prices of wheat (not taking into account the year 2022, in which the price was significantly higher due to market disruptions caused by the war between Russia and Ukraine), the expected price of wheat is around RSD 18/kg. According to the information provided by the Tamiš Institute, the price of wheat is the same in the case of conventional and regenerative production. This stems primarily from the fact that, in practice, individual farms do not follow the origin of raw materials and finished products (wheat), and do not store their crops produced by conventional method separately from those produced by regenerative methods of tillage.

4.3. Variable Costs (Production Costs)

The presented costs of wheat production are based on the information provided by the Tamiš Institute as well as on the basis of publicly available data on historical yields, crop prices and seed prices.

- Seeds - on the basis of 12 different samples (different types and producers), the average price of seeds was calculated at RSD 64/kg. The same type and species of seed are used in both conventional and regenerative production models.
- Fertilizers - Based on information obtained from the Tamiš Institute, the same three types of fertilizers are used in both models of agricultural production, but in different quantities:
    - Manure - in the classic model of production, the use of around 20 t/ha is foreseen, while in the regenerative model of production this amount is half of that, i.e. 10 t/ha. The use of manure is expected every 3 to 4 years, in both production models,
    - NPK fertilizers (fertilizers containing nitrogen, phosphorus and potassium) - expected use during sowing in amounts of around 300 kg/ha in the classic production model, while consumption is expected to be 30% to 50% lower in the regenerative model. Regenerative production is also characterized by the fact that it strives to completely remove NPK fertilizers in the period after 5 to 7 years,
    - Nitrogen fertilizers - it is expected to be used for the purpose of nourishment both in the traditional and in the regenerative model in quantities of around 200 kg/ha. Regenerative production is characterized by the fact that it strives to completely remove nitrogen fertilizers in the period after 5 to 7 years.
- Pesticides - in both models of agricultural production, the use of pesticides is expected for protection against weeds as well as protection against wheat diseases (fungicides).
- Agro-technical operations - regenerative production essentially excludes a significant number of operations related to mechanical soil cultivation. With that and with the previously mentioned prerequisites concerning the level of technical

equipment of an average agricultural holding, the costs of the following operations are calculated in this category:

  - for the conventional model - ploughing, pre-sowing attachment (with seed drill), rolling, sowing, harvesting and stubble processing.
  - for the regenerative model - sowing and harvesting.

- Fuel costs - consumption of about 30 l/ha is expected in the classic production model, while in the regenerative model, due to the reduced number of agro-technical operations, consumption of about 15 l/ha is expected. Additional savings in fuel for agricultural farms are expected in the period after 5 to 7 years, when the aim is to completely eliminate artificial fertilizers and supplements.
- Cover crops - a cost that is characteristic only for the regenerative method of production. The total amount of cover crop seeds is about 80 kg/ha and is a mixture of two varieties of plants. Taking into account the dynamics of planting small grains, this cost was included every two years.
- Other costs - include machine maintenance costs, transport costs and crop insurance costs. These costs are estimated at a fixed amount in each of the years and are expected to be at the same level in both the conventional and regenerative production models.

4.4. Key Conclusions

In the projected period of 10 years (9 growing cycles), the savings in production costs in the regenerative compared to the conventional model ranges from 10% to 47% annually. With the end of the transition period from the conventional to the regenerative soil tillage model (from the 7th year), there is an additional noticeable drop in the level of costs in the regenerative model, primarily as a result of the absence of NPK and nitrogen fertilizers as well as reduced fuel consumption.

The benefits for agricultural producers are essentially twofold - on the one hand, they imply a significant reduction of costs in the long term, while on the other hand, they ensure the long-term preservation of soil quality, which can result in increased yield and income stability over the years.

The lower absolute level of costs in the first and last year of the projected period refers to the fact that in the first year the transition to the regenerative model is assumed to begin, and the costs associated with soil preparation and wheat planting are shown, while the last year of the projected period includes costs associated with harvesting and completion of the last breeding cycle.

Volatility in production costs in the regenerative model comes primarily from the costs associated with planting cover crops every two years.

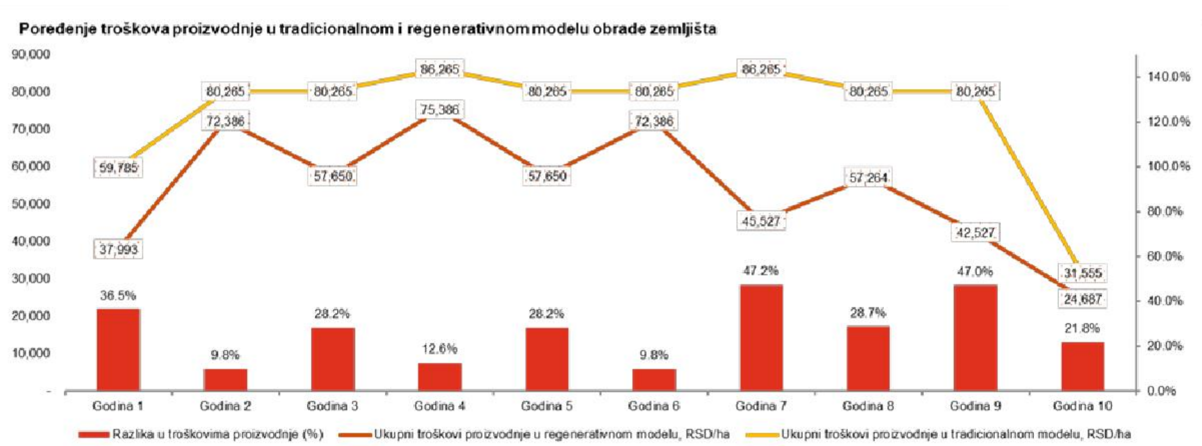

Figure 1: Comparison of production costs in conventional and regenerative model of land cultivation

Additionally, taking into account the volatility of yields and prices of agricultural products, the analysis also included an examination of the sensitivity of the gross margin per hectare to changes in yields and prices, for the regenerative model of soil cultivation. The shown volatility of the gross margin refers to the period from the first 5 to 7 years, when the use of fertilizers is still present in production and the maximum level of savings has not been achieved.

Prinos po ha (kg)	Otkupna cena (RSD/kg)				
	14.1	16.1	18.1	20.1	22.1
4230	(10,871)	(2,411)	6,049	14,509	22,969
4,700	(4,225)	5,175	14,575	23,975	33,375
5170	2,422	12,762	23,102	33,442	43,782
5640	9,068	20,348	31,628	42,908	54,188

Figure 2: Sensitivity analysis of gross margin in regenerative production model (RSD/ha) *

It is also necessary to emphasize that systemic measures could create benefits in agriculture, by providing incentives to agricultural producers to switch to a new way of production. The development and digitization of tools intended for keeping records of production and costs (recording of work operations, costs and yields) could contribute to strategic insight into the transition process in domestic agriculture. On the other hand, it can also contribute to agricultural producers in the scope of planning and monitoring the efficiency of farms.

5. Carbon Footprint in the Field to Fork Supply Chain in Serbia

5.1. Access and Restrictions

5.1.1. Overview

This analysis includes the cultivation of primary agricultural food products (e.g. grains, vegetables, fruits, etc.), their processing into finished and semi-finished consumer products (groceries) and their subsequent offer to final consumers (in retail stores). Transportation and logistics along the FtF chain are also considered. The impact of food waste and the choice of retail packaging is not considered due to the specific technical nature of these topics, which requires separate research and detailed analysis. The scope of the project also does not include livestock breeding, production of animal products and products of animal origin (e.g. meat, milk and milk products, animal fat, etc.), as well as processing of primary agricultural products (PPP) into non-food final products (such as are beverages, alcohol and tobacco products). As much as the available data allows, the focus of the analysis is still on locally produced agricultural products for domestic consumption. Imported raw and processed goods and agricultural production for export are excluded from data collection and analysis, wherever possible (i.e. when specific data are available). Finally, the scope of this paper excludes the examined food products after retail sale, i.e. consumer use, post-sale losses, as well as end-of-life packaging and food waste.

The analysis, its results and derived conclusions are significantly limited by the available data for Serbia. Data from reputable sources are very limited available at any level (national, regional or local), so in many cases, data that are not fully representative of Serbia (i.e. EU or world benchmarks) are used as a substitute. Depending on the specific data available, this limitation can have a significant impact on the accuracy and representativeness of the analysis. In an effort to mitigate this effect, data sources have been carefully selected to provide at least an indication of the actual situation in Serbia. Furthermore, a list including relevant data gaps and suggestions for future improvement of the accuracy and representativeness of the analysis can be found at the end of each chapter.

5.1.2. Data collection

Reputable sources at the European and/or national level are a priority when collecting data. When data were not available from institutional sources (Eurostat, Republic Statistical Office, UN communication), they were primarily obtained from publications in peer-reviewed journals, industry reports or from widely used and reliable data repositories and information platforms (see the Sources section).

Where emission factors representing national or regional products or economic activities were not available (in most cases), they were substituted by European emission factors with priority. In cases where European emission factors were not available or would make the results extremely unrepresentative for the Serbian context, global averages were used. In some cases, (e.g. for specific processing examples) approximately representative emission factors for non-European countries were also used. All emission values - calculated or from literature sources - represent the carbon dioxide equivalent of all primary greenhouse gases on the IPCC list (carbon dioxide, methane, nitrous oxide, halocarbons, etc.), unless otherwise stated.

GWP values for refrigerants are based on data from the latest IPCC reports (AR5 and AR6)

All primary data on land cultivation, agricultural products, transport, etc. for Serbia were obtained from the Republic Statistical Office. Geographic data (distances and routes) were obtained from Google Maps, using its routing tools.

All statistics are representative of 2022, unless otherwise stated.

All data on emission factors used in the study were estimated (based on subject and date of publication) and considered to be temporally representative.

5.2. From Field to Fork: Global and National Value Chain

5.2.1. An overview of the field-to-fork supply chain – including activities, causality and carbon footprint implications

For the purposes of this report, and in accordance with best practice in the specialized literature, the FtF chain was analysed in four steps:

1. Agricultural production - production of primary agricultural products (PPP);
2. Food processing - production of processed food products (PFP);
3. Transport and logistics – transport and storage of PPP and PFP through farms, processing facilities, warehouses and final sales points (retail);
4. Retail - sales of PPP and PFP to end consumers.

Globally, emissions from agricultural production (Step 1) account for almost half of the global FtF footprint (7.4 GtCO_2eq), while processing and logistics contribute about one third of emissions (5.6 GtCO_2eq). It is noticeable that in Europe processing and logistics (steps 2 and 3) contribute the most on average - 53% (1.1 GtCO_2eq) of total FtF emissions on the continent. (2020). Similarly, other economically developed countries show a higher share of processing and logistics in their FtF emissions (e.g. Japan - 57%, USA - 55%, South Korea - 58%). This phenomenon is mainly a consequence of the strongly developed and complex supply network of the food sector and the relatively higher consumption of processed food. In less developed countries, a step from the entrance to the farm ("land-based" in the image below) represents the majority of FtF emissions, as the production and supply chain is much shorter, subsistence farming is much more prevalent and larger share of food consumption was obtained directly from farmers or not industrially processed.

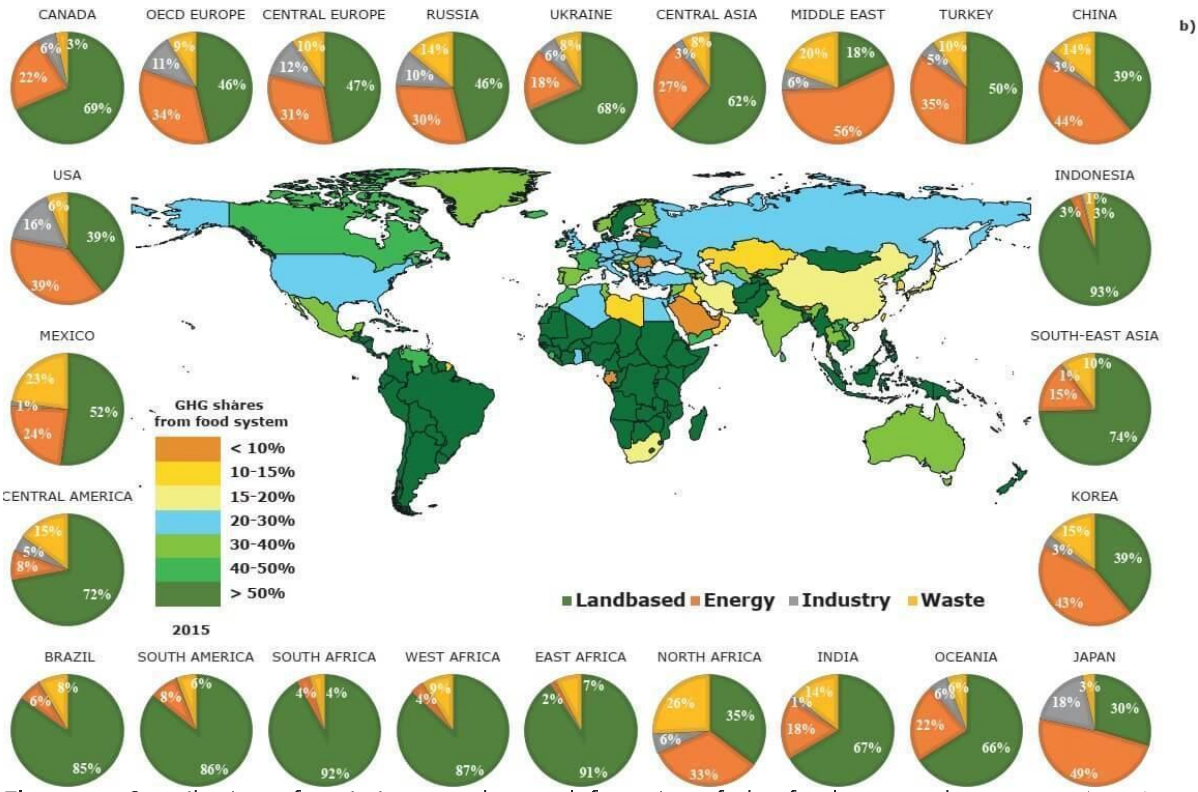

Figure 3: Contribution of emissions to the total footprint of the food system by country (2015). Contribution of different sectors of the food system (land, energy, industry and waste) to the total emissions from the corresponding national food system (FtF chain) are shown through pie charts. The map shows the share of GHG emissions from food systems in total national emissions.

Source: EDGAR - Global Database on Food Systems Emissions

https://edgar.jrc.ec.europa.eu/edgar_food#data_download

The evidence shows that Serbia is a middle ranked country in the global context. The agricultural sector is the main part of the Serbian economy (6% of GDP, 14.8% of total employment, 41% of the territory is under arable land), which indicates a significant amount of emissions related to land. However, there are several large producers of processed food in the country (food production accounts for 3.5% of total employment) and a large part of the population lives in cities (57%), relying primarily on retail establishments for food consumption.

There is no precise analysis of carbon emissions along the Serbian FtF chain. Data from the Second Biennial Update Report of the Republic of Serbia to the UN Framework Convention on Climate Change offer a limited and fragmented insight into the potential carbon footprint of the Serbian agricultural and food system. Out of a total of 64 mils. tons of CO_2eq emitted in 2020, 4.6 million. tons (7.2%) come from activities related to land use, which include agriculture, but also forestry and animal husbandry. The "energy sector" as a general category (including both electricity and fuel production) is responsible for 50.7 million tons (79.2%) of all GHG emissions, however it covers a wide range of activities such as the use of fuel for transport (road transport - 10 .3% or 6.6 million tons of total emissions) and electricity production (53.3% or 34.1 million tons of total emissions). The footprint of the logistics and transport (step 3 of the FtF) is contained in the national road traffic emissions, while the unknown part of the electricity production emissions represents the largest part of the processing and retail footprint (steps 2 and 4) in the Serbian FtF. Due to the required categorization for UNFCCC reporting purposes, information on national FtF emissions cannot be reliably inferred from available data. Therefore, adopting a UNFCCC-based top-down approach to establishing Serbia's FtF footprint is expected to yield very approximate results. Such results would likely be an unreliable and potentially misleading basis for planning decarbonisation measures and footprint reduction pathways.

Considering various data and resource limitations, a segmented bottom-up approach was applied for this analysis. This approach enables a more credible assessment of the carbon footprint of some processes along the entire FtF chain, within a limited time frame. Key processes and steps in the FtF chain (for which data are more available) were analysed in detail and used as an indication of the overall situation in Serbia. Carbon footprint results calculated in this way can serve as a sustainable basis for planning decarbonisation efforts for specific production facilities and at the national level.

A complete and detailed inventory of the carbon footprint of the FtF chain is a very valuable asset for any related decarbonisation initiative. However, creating such an inventory requires considerable effort. In case this effort is repeated every year, the CO_2 emission dynamics of the FtF chain can be monitored, which has additional benefits. Ultimately, however, compiling an exhaustive and regular inventory is not critical to the initial stages of decarbonisation planning. Instead, it is more practical to gain general-level insight in the form of key facts and build initial capacity on the subject.

In this regard, the carbon footprint of any national FtF chain depends on a limited set of factors and consists of similar elements. Therefore, even a general understanding of all these factors and elements will benefit future decarbonisation efforts at any level.

5.3. Key Outputs

Based on the available data, **the CO_2 footprint in the Serbian supply chain** from the field to the fork is estimated at a total of **approximately 6 million tons of CO_2eq emissions**. In terms of individual links in the FtF chain, we came to the following results:

1. Agricultural production:
    - 4.35 million tons of CO_2eq emissions;
    - 66% of total FtF emissions.

2. Processing industry:
    - 1.59 million tons of CO_2eq emissions;
    - 24% of total FtF emissions.

3. Transport and storage (logistics):
    - Up to 308 thousand tons of CO_2eq emissions;
    - Up to 5% of total FtF emissions.

4. Retail:
    - Estimated 5% of total FtF emissions (based on world average)
    - Approximately 312 thousand tons of CO_2eq emissions.

The presented estimates should be considered purely indicative and illustrative, because their accuracy is significantly limited by the unavailability of data specific to Serbia and the limited availability of relevant (in the context of Serbia) European and global data. They also depend on the chosen methodology and approach, which is clearly described in the section.

Nevertheless, the analysis provides a basis for future efforts to compile a more detailed and accurate national inventory of FtF emissions. Furthermore, it provides relevant information on the primary sources of emissions throughout the food chain, relevant in both European and national contexts. The proposed measures to reduce the carbon footprint are applicable both to individual companies and to the sectoral level. Overall, the analysis can easily serve as an actionable capacity-building resource for stakeholders in the entire farm-to-fork ecosystem in Serbia.

5.4. Agricultural Production (Step 1)

5.4.1. Primary data collection

The data collected and analysed in this part is largely based on the primary study of agricultural holdings in the Republic of Serbia conducted by the Tamiš Institute, for the needs of this project. Most of the agricultural farms analysed, grow corn, followed by wheat, soybeans, barley and rapeseed. Based on the obtained primary data, an indicative calculation of the CO_2 footprint was made for each land plot and operation in the production of a given agricultural crop.

5.4.2. The processes involved in this step, details about the CO_2 footprint and the main sources of emissions

- Emissions from fuel combustion by agricultural equipment - necessary for practically all modern mechanized agricultural activities. Smaller agricultural holdings probably have a lower share of such emissions. The fuel used is mostly diesel.
- Emissions from the production and use of fertilizers and pesticides/herbicides. Synthetic fertilizers and agrochemicals require large amounts of energy and materials to produce – usually in the form of steam, electricity and chemical raw materials of fossil origin;

- Emissions from soil manipulation - disturbance of organic soil and management of plant residues leads to significant emissions of greenhouse gases, due to oxidation of organic matter and microbial activity;
- Emissions due to the change in land use – emissions resulting from the disruption and destruction of natural carbon reserves as a result of the conversion of natural habitats. In the context of the FtF chain - these emissions are mostly applicable to developing countries, where forests, savannahs and other types of undisturbed natural habitats are continuously being destroyed and converted into agricultural land. These emissions are not part of the scope of this analysis, but are expected to have a share of national FtF emissions, which is significantly lower than the global average (~28%). This is due to the fact that Serbia has a stable and long-lived agricultural sector.

5.4.3. CO_2 emissions in Serbian agriculture

For all analysed crops, except soybeans, the highest CO_2 emissions are generated from fertilizers applied to the land (from 339.11 kg CO_2/ha for rapeseed to 451.57 kg CO_2/ha for corn). These emissions occur during the production of fertilizers in a given factory. Only in the case of soybeans, the use of energy in the field (200.96 kg CO_2/ha) contributes more to CO_2 emissions than the applied fertilizer (156.55 kg CO_2/ha). This is due to the fact that soy is a legume and a nitrogen fixer, and has less need for nitrogen, which is why farms use less fertilizer in the production of this crop.

CO_2 emissions that occur during crop management (i.e. chopping or ploughing) range from 23.02 kg CO_2/ha in rapeseed production to 165.89 kg CO_2/ha in corn production.

The application of crop protection measures (i.e. herbicides and pesticides) is estimated to contribute the least to CO_2 emissions, partly because the CO_2 estimate for this process is based on the most abundant active substances in each product and the corresponding amount of that product per hectare. CO_2 emissions from crop protection measures ranged between 3.73 kg CO_2/ha in corn production and 6.34 kg CO_2/ha in soybean production.

Total CO_2 emissions per hectare, expressed as kg CO_2/ha, represent the CO_2 emission value of all operations carried out in the production of a given field crop. The largest total emission of CO_2 is represented in the production of corn and amounts to 1428.48 kg CO_2/ha. The total emission of CO_2 in the production of wheat is 1314.46 kg CO_2/ha, while the production of barley generates 1290.45 kg CO_2/ha. The total CO_2 emission for the production of rapeseed and soybeans is significantly lower and amounts to 883.31 kg CO_2/ha from 606.5 kg CO_2/ha.

By combining the collected data on emissions from the research of the Tamiš Institute and the information on the area cultivated by a certain crop, an indicative total carbon footprint is obtained from the agricultural production of corn, wheat, soybeans, barley and rapeseed.

In addition to the data collected by the Tamiš Institute, data on the sale and purchase of various agricultural products were also used in order to obtain an overall impression of the steps of agricultural production in the national FtF chain. Since information on emissions and carbon footprint for cultivation on the territory of Serbia was not available, emission factors were collected from other (EU and world average) sources.

The total indicative CO_2 footprint of agricultural production is estimated at 4.35 million. tCO_2eq, which is equivalent to about ⅔ of the total CO_2 footprint in FtF emissions in Serbia in 2022.

The table below presents a detailed overview of the calculated results.

Table 1 - Estimated carbon footprint for primary agricultural products, 2022[46]

Category	Cultivation area (ha)	EF ($kgCO_2eq/ha$) [47]	Estimated emissions (tCO_2eq) [48]	Relative total contribution
Wheat	639,566	1,314	840,684	19.3%
Barley	102,125	1,290	131,787	3.0%
Corn for grain	900,048	1,428	1,285,701	29.6%
Rapeseed	45,575	883	40,257	0.9%
Soybean	196,903	607	119,422	2.7%
Category	**Sold (t)**	**EF ($kgCO_2eq/kg$)**	**Estimated emissions (tCO_2eq) [49]**	**Relative total contribution**
Oat	1,401	1.87	2,626	0.1%
Other grain	10,020	1.87	18,777	0.4%
Sugar beet	1,196,000	0.54	640,785	14.7%
Sunflower	509,000	2.10	1,068,289	24.6%
Potato	33,281	0.19	6,382	0.1%
Beans	145	1.12	163	0.0%
Onion	18,084	0.22	3,903	0.1%
Cabbage	15,991	0.23	3,678	0.1%
Tomato	14,131	0.71	9,969	0.2%
Peppers, fresh	16,306	1.32	21,524	0.5%
Other vegetables	131,096	0.18	23,250	0.5%

[46] The total CO_2 footprint (in tCO_2eq) for this step is based on the collected data for the area cultivated (in ha) and the amount (in t) of PPPs sold.

[47] Emission factors originally from "Environmental Impacts of Food Production" by Hannah Ritchie, Pablo Rosado and Max Roser, https://ourworldindata.org/environmental-impacts-of-food and CONCITO (2024): The Big Climate Database, version 1.1 https://denstoreklimadatabase.dk/en/international

[48] It is calculated by multiplying the cultivated area (in ha) for each product category with the relevant emission factor (in $kgCO_2eq/kg$).

[49] It is calculated by multiplying the quantity (in t) of PPP for each product category with the relevant emission factor (in $kgCO_2eq/kg$).

Plums, fresh	38,947	0.14	5,453	0.1%
Apples	134,040	0.20	26,388	0.6%
Pears	9,160	0.16	1,466	0.0%
Cherries	49,732	0.75	37,299	0.9%
Raspberries	46,465	0.74	34,498	0.8%
Other fruit	47,461	0.50	23,712	0.5%
Grape, edible	212	0.74	157	0.0%
Total	4,155,689		4,346,169	100.0%

*(Wheat and corn for sowing are excluded)

** (excludes tobacco, sowing seeds and other industrial crops)

***(Grape for processing are excluded)

Source: Domestic trade statistics 2018-2022 Annual statistics of the Republic of Serbia 2023, analysis by the Tamiš Institute.

For sources of emission factors - see Section "Sources".

5.4.4. General principles of decarbonisation in agricultural production

There are two practical approaches to reducing the overall carbon footprint of agricultural production:

1. Increasing the soil's carbon capturing, sequestration capacity (through the adoption of regenerative agricultural practices);
2. Reduction of greenhouse gas emissions generated from all sources - natural and anthropogenic.

The increase of carbon in the soil is mainly achieved by regenerative agricultural practices (see section 6.4.3. "CO_2 emissions in Serbian agriculture") and when successful, acts as the main compensation for emissions from field work and natural processes. In short, regenerative agriculture reinforces the role of soil as a sink for CO_2. This approach increases the amount of CO_2 that is absorbed by plant photosynthesis and stored as organic matter first in the plant itself, and later - in the humus of the soil.

The use of regenerative agricultural practices is best combined with dedicated measures to reduce CO_2 emissions, which helps to achieve a cumulative positive effect. Measures to reduce CO_2 emissions in agricultural production include**:**

- Improving the energy efficiency of operations - mainly by using equipment that is more economical, planning to minimize mechanized work in the field or omitting some field activities (no-till farming, no collection of plant residues after harvest, etc.);
- Using cover crops to reduce emissions from exposed soil during the off-season;

- Minimizing nitrogen to reduce specific microbial activity that leads to nitrous oxide (a potent greenhouse gas) from the soil - can be achieved either by an absolute reduction in the amount of nitrogen fertilizer applied or by more targeted fertilizer use. Reduced use of synthetic fertilizers also reduces the carbon footprint of agricultural production;
- "Smart" agriculture can significantly increase efficiency, reduce fuel use and result in significant reductions in emissions. It is based on soil sampling, continuous monitoring with sensors, GPS guidance for field work and the use of drones for observation and precise application of fertilizers, agrochemicals and emergency irrigation.
- Replacing fossil fuels with alternative ones - biodiesel, biogas (if technically feasible). Using electric farm equipment is another alternative to using fossil fuels, but is currently only applicable for smaller equipment and smaller farms, as the equipment relies on battery technology with limited range. Nonetheless, it will increasingly be a viable commercial alternative to traditional ICE farm equipment.

5.5. Food Processing - Production of Food Products (Step 2)

5.5.1. The processes involved in this step[50], details of the CO_2 footprint and the main sources of emissions

In this step of the FtF chain, the PPPs are processed in the PFP. Typical processes in this step include washing, cutting, baking, drying, freezing, grinding, mixing, etc. Most of these processes are mechanized, especially in commercial and industrial facilities.

Since most raw materials and some of the PFPs are perishable - food processing plants maintain a highly controlled environment, especially in terms of temperature. Therefore, regardless of the need for cooling, freezing, and/or refrigeration for PFP production, refrigerants are commonly used for climate control systems in processing plants.

Food processing is considered a moderately high energy-intensive sector and its carbon footprint is primarily determined by the energy used for production (i.e. electricity and fossil fuel use).

The carbon footprint profile of PPP processing differs significantly from that of agricultural production (step 1). In agriculture, the main sources of emissions are direct - combustion of fossil fuels, emissions from bacterial processes (rotting), emissions from the use of fertilizers and scale. However, in the processing step, the main source of emissions is indirect, that is, the production of electricity needed for production processes. Electricity production is categorized

[50] The transport of raw PPP from the farm gate to the processing and storage facilities takes place before the processing step, however in the structure of this report all transport and logistics activities are discussed in section 6.6. Transportation and storage of fresh and processed agricultural products.

as an indirect source of emissions, because in most cases the user (food processing plant) is not directly responsible for the amount of emissions produced. Therefore, if a certain food processor does not rely on its own energy production, the intensity of the emission of electricity used depends exclusively on the type of energy facilities that actively contribute to the national or local power grid (the so-called "electricity mix"). In short, electricity generation plants are practically responsible for CO_2 emissions, while food processing plants can only regulate the amount of electricity consumed, within practical operating limits.

Direct emissions in the PPP processing industry are associated with specific processes and usually account for a smaller share of the total CO_2 footprint for this step. Such processes usually involve intensive heating - for drying, cooking or concentration by evaporation. These processes require the combustion of natural gas, LPG or, in some cases, biomass. Combustion of fossil fuels is usually cheaper and more efficient compared to using electric heat sources for such operations. Relevant examples include the production of sugar, thermal drying of spices and vegetables and the production of chips (baking in an oven).

Another source of direct emissions, which could have a significant share in the CO_2 footprint in the processing, are the air conditioning and cooling systems of the processing facilities. Although they operate as closed systems, virtually all air conditioning and refrigeration units emit some of their refrigerants during their life cycle, particularly during installation, maintenance, repair and/or removal. Depending on the refrigerant used, even small amounts of fugitive emissions can have a significant impact on the overall carbon footprint of a processing plant. Typically, a kilogram of refrigerant emitted into the atmosphere is equivalent to thousands of kilograms (i.e. several tons) of CO_2 in terms of its impact on climate change. This effect is represented by the so-called global warming potential value (Global Warming Potential - GWP).

5.5.2. CO_2 emissions in the Serbian food processing industry

The contribution of direct emissions from food processing (i.e., fugitive emissions of refrigerants and fuel combustion) to the total carbon footprint is similar in many ways across countries. When it comes to cooling systems, the key difference could be the choice of cooling agents, which mostly depends on the type and brand of cooling systems used. No recent data on the use of refrigerants in Serbia have been identified, however, available historical data[51] for 2015 suggest that mostly modern refrigerants are used throughout the country. In particular, any variation in efficiency between the equipment used (e.g. Western Europe compared to Serbia) will be reflected in the electricity consumption and its share in emissions and will not affect the share of direct emissions from refrigerants. All in all, no significant deviations are expected for Serbia in the share of emissions from the use of refrigerants compared to the world/European average.

Fossil fuel burning and the related contribution to the CO_2 footprint are also similar around the world. Burning a certain amount of natural gas or diesel fuel will result in a fixed amount of carbon emissions, regardless of the technical context or location. The only significant variable in the

[51] Survey of consumption, distribution and uses of various alternatives to ODSs for the Republic of Serbia October, 2016 UNIDO Project ID: 150204; Grant No.: 2000003110

country would be the efficiency of the equipment (e.g. water heater, heating system, oven). As equipment efficiency is directly related to operating costs, it is assumed that most facilities using such equipment focus on its timely improvement or replacement, similar to businesses across Europe. For some processing facilities in Serbia, it is possible that the use of old heating equipment (for both food processing and space heating) may increase the total share of emissions in fuel consumption. However, it is unlikely that such cases would have a significant impact on the total CO_2 footprint for the processing step in Serbia.

Unlike direct emissions, the emission intensity of electricity production largely depends on the local and national energy infrastructure. Compared to EU countries (on average 0.251 kgCO_2eq/KVh), Serbia has a high carbon dioxide share of electricity – 0.582 kgCO_2eq/KVh for 2022. Moreover, the CO_2 footprint of electricity in Serbia is also higher than the global average (0.437 kgCO_2eq/KVh). Therefore, the relative share of CO_2 emissions derived from electricity used for food processing would be higher than the global average. Serbia's relatively lower energy efficiency in the area of food production processes, including refrigeration and air conditioning equipment, would also contribute to overall electricity consumption and the corresponding carbon footprint. All in all, it is expected that the used electricity will have the largest share in CO_2 emissions for the food processing step in Serbia.[52]

Despite great efforts to collect information on total emissions from food processing in Serbia, such information is difficult to find. Apparently, there is not a sufficiently detailed (publicly available) record that discusses the electricity, fuels and coolants used specifically by the food industry.

Given the above, the table below shows the total amount of PPPs sold on the Serbian market, which are most likely to be processed into PFPs. Potential CO_2 emissions from the processing of the full amount of sold PPPs (by type)[53] were calculated based on the available emission factors for the produced PPPs.

Table 2: Estimated carbon footprint for PPP to PFP processing, 2023[54]

[52]Source of emission factors is Our World in Data, https://ourworldindata.org/grapher/carbon-intensity-electricity

[53]100% conversion is assumed for simplicity, excluding processing losses and by-products. This approach is likely to result in a limited overestimation of total emissions from the processing process. The available emission factors represent mainly EU countries with a less CO_2 energy network than Serbia. Therefore, the effect of overestimation on the final emission processing is probably compensated by the effect of the applied emission factors.

[54]The total CO_2 footprint (in t CO_2eq) for this phase is based on the collected data for the amount (in t) of PFP processed in Serbia, based on the amount of PFP transported internally

PPP processed for production PFP	Total (t)	EF for processing ($kgCO_2eq/t$) [55]	Estimated emissions (tCO_2eq) [56]	Estimated relative contribution to total emissions of the sector
Wheat, rye flour	1,361,000	0.109	148,349	9.61%
From corn to the grain corn into canned food	1,350,000	0.15	202,500	12.77%
Sugar beet into sugar	1,196,000	0.39	466,440	29.41%
Sunflower into sunflower oil	509,000	0.67	341,030	22.10%
Rapeseed into rapeseed oil	80,745	2.44	197,018	12.42%
Soybean into soy oil	272,578	0.57	155,370	9.80%
From potatoes to the chips (baked)	33,281	1.39	46,261	2.92%
Cherries - frozen	49,732	0.15	7,460	0.47%
Raspberries - marmalade	46,465	0.460	21,374	1.35%
Total	4,898,801		1,585,801	100.00%

Source: Domestic trade statistics for 2018-2022 Statistical Yearbook of the Republic of Serbia 2023

In total, the included PPPs represent approximately 90% of all PPPs sold on the internal national market (according to data from the Statistical Office). The emission from their processing amounts to more than 1.59 mil. tons of CO_2eq. Actual emissions are likely to be higher than the

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[55] This emission factor takes into account direct emissions from food processing, incl. use of refrigerants and fossil fuels, as well as indirect emissions from the use of electricity. Emission factors originally from CONCITO (2024): The Big Climate Database, version 1.1 https://denstoreklimadatabase.dk/en/international, More sustainable vegetable oil: Balancing productivity with carbon storage opportunities https://doi.org/10.1016/j.scitotenv.2022.154539, Life cycle assessment of the production of beet sugar and its by-products - https://doi.org/10.1016/j.jclepro.2022.131211, A Comparative Study on Carbon Footprints between Wheat Flour and Potato in China Considering the Nutrition Function of Foods https://doi:10.1088/1755-1315/726/1/012004

[56] Calculated by multiplying processed PPP (in t) for each product category with the relevant emission factor (in $kgCO_2eq/kg$)

above estimate due to the limited relevance of available emission factors and the incomplete PPP inventory. Factors of emissions can have a significant impact as even small amounts of PPP can have a large contribution to processing emissions, depending on the actual process. This fact is evident from the contribution of rapeseed oil production to the total refining footprint (~2% of total PPP tonnage responsible for more than 12% of total refining emissions).

The total indicative CO_2 footprint of PPP and PFP processing is estimated at 1.5 million tCO_2eq, which is about ¼ of the total CO_2 footprint in FtF emissions in Serbia.

5.5.3. Examples

Several PPPs, which are usually processed in Serbia, were selected in order to provide a more detailed overview of CO_2 emission sources in food processing. The CO_2 footprint data and analysis presented below are derived from available academic and other publications, with a special emphasis on reviewing data relevant to Serbia.

- **Flour production:** Wheat goes through a multi-stage cleaning process, refining, scrubbing, sifting and grinding before it is turned into flour. All steps are highly mechanized and the process generally involves many different types of equipment (e.g., vibrating screens, magnetic separators, and air aspirators for the cleaning step only). All these machines are mostly powered by electricity. As with most processes that require intensive equipment in a confined space, some form of cooling (or heating) of the space is usually required, depending on the season (outside temperature). The process itself does not require dedicated cooling of wheat or flour. Therefore, emissions in the processing process mainly come from the electricity consumed by the grinding equipment, and only a small part arises as a result of the electricity needs of the climate control system (i.e., due to potential refrigerant leakage). Emissions from fuel combustion represent only a very small proportion (if any) and are associated with on-site transport and the potential use of backup (i.e. diesel) electricity generators.

  The processing of wheat into flour is on average responsible for about 40% of the total CO_2 footprint of flour, while the remaining share is mainly related to wheat production. Of the 40% share related to processing, about 75% (or 30% of total emissions) can be attributed to the consumption of electricity used for the flour milling process. Some sources indicate that as much as 97% of emissions from processing could be derived from electricity consumption, depending on the carbon intensity of the grid.

  Globally, the footprint of processing 1 kg of wheat flour ranges from 0.017 $kgCO_2e$ (Sweden) to 0.109 $kgCO_2eq$ (China), depending on the origin of the wheat and the location of the processing plant. The CO_2 footprint of Serbian flour is expected to be closer to the upper limit of this range due to the high CO_2 footprint in the electricity mix in the country u zemlji.[57]

- **Production of sunflower oil:** In order to obtain sunflower oil, the seeds are first planted clean and then (usually) peeled. The peeled seeds are ground into coarse flour and crushed into uniform fine particles. This fine meal is heated and then pressed in expellers to obtain virgin oil. The process may involve continuous heating during pressing (hot pressing) or not (cold pressing). Virgin oil is filtered to remove all solids and can be used directly for consumption or can be further refined through several chemical and physical processes.

  The rest of the expelled flour retains some residual oil, which can be extracted using a solvent (usually food grade hexane). The oil-solvent mixture is purified (the solvent is evaporated) to yield desolventized sunflower oil and meal. This oil is further processed to remove unwanted components and impurities. The process includes alkaline refining, degumming, bleaching, dewaxing and deodorization.

  The initial process of cleaning and crushing the seeds involves equipment that is usually powered by electricity (e.g. centrifugal beaters or dehullers, hammerers, grooved rollers), while the later stages of oil production (hot pressing, solvent removal and refining) require heating and involve the use of steam. The open spaces of the process facility must be maintained at adequate temperatures, especially in rooms with heated equipment (expeller, desolventized, etc.). The process itself does not require dedicated cooling. Any equipment cooling is most often performed with cooling water, not coolants, therefore process cooling likely contributes only indirect electrical energy emissions to the overall machining process. Therefore, the emissions from the processing will mainly come from the electricity consumed by the grinding equipment and only a small part will be the result of the electricity needs of the climate control system and potential refrigerant leakage. Emissions from fuel combustion for steam/heat production will also be a major contributor to the hot pressing process, and in particular to the production of refined sunflower oil.

  The total FtF CO_2 footprint ranges between 1.1 and 4.2 kg CO_2eq per 1 kg of sunflower oil produced. This includes all stages of growing, harvesting, pressing and refining the seeds to produce pure vegetable oil, as well as its packaging. Processing is responsible for as little as 0.07 kgCO_2eq (Chile) to as much as 0.67 kgCO_2eq (Greece) of emissions.

[57] Data and emission factors originally from A Comparative Study on Carbon Footprints between Wheat Flour and Potato in China Considering the Nutrition Function of Foods https://doi:10.1088/1755-1315/726/1/012004, Carbon Footprint Analysis for Energy Improvement in Flour Milling Production http://dx.doi.org/10.1007/978-3-642-19692-8_43, Comparison of Carbon Footprint Analysis Methods in Grain Processing—Studies Using Flour Production as an Example https://doi.org/10.3390/agriculture14010014

This amount corresponds to a share of 8% (Chile) to 41% (Greece) of the total carbon footprint of the respective oil production.

Similar to flour production, the CO_2 footprint of Serbian sunflower oil production is expected to be closer to the upper limit of the range with a significant share of processing emissions due to the high CO_2 footprint of Serbian electricity production.[58]

- **Production of sugar from beets:** The beets are first washed and separated from contaminants. Then cut into small pieces, soak in hot water and stir to extract the sugars. Once the extraction is complete, lime and CO_2 are added to the sugar water (raw juice) to purify it. The resulting mixture is filtered and concentrated by evaporation to give the so-called "thick juice". The thick juice is then boiled under vacuum and seeded to crystallize the sugar - this process is repeated several times. The resulting sugar is finally dried with the help of air drying (heat).

  This multi-step process includes several electricity-intensive operations (cutting, mixing, drying), but is dominated by heat-intensive operations (wetting in hot water, evaporation, boiling) that mainly rely on the use of fossil fuels (e.g. gas, LPG, fuel oil).

  The production of lime and CO_2 (used for the sugar refining sub-process) often takes place in the lime kiln of the processing plant and contributes direct CO_2 emissions to the overall footprint. In the context of these operations, any emissions from refrigerant leaks would have a very small contribution. In Serbia, the CO_2 footprint related to electricity is expected to be very significant due to the high intensity of CO_2 emissions from the grid. Therefore, emissions from heating with fossil fuels and from the consumption of electricity would completely obscure the trace of the use of refrigerants.

  In the EU, the total footprint of beet sugar ranges from 0.24 $kgCO_2eq$ to 0.7$kgCO_2eq$ with as much as 56% (0.13 $kgCO_2eq$ – 0.39 $kgCO_2eq$) of the footprint attributable to sugar production (processing stage) depending on emission intensity of the local population, electrical network and efficiency of heating equipment. The use of fossil fuels accounts for the largest share of emissions from processing (up to 53% of total emissions). This is in line with the current reality of industrial heating, which, unlike electricity generation, does not have many low-emission alternatives. Finally, the CO_2 footprint in beet sugar processing in Serbia is expected to be at the upper limit of the above-mentioned range, potentially even exceeding it, as it currently has a higher emission intensity of electricity production compared to most EU countries (except Poland).[59]

[58] Data and emission factors originally from More sustainable vegetable oil: Balancing productivity with carbon storage opportunities https://doi.org/10.1016/j.scitotenv.2022.154539, A harmonised systems-wide re-analysis of greenhouse gas emissions from sunflower oil production https://doi.org/10.1101/2020.06.19.161893

[59] Data and emission factors originally from The Product Carbon Footprint of EU beet sugar (Part I) https://doi.org/10.36961/si12784, Life cycle assessment of the production of beet sugar and its by-products - https://doi.org/10.1016/j.jclepro.2022.131211

- **Biscuit production:** This is a relatively complex PFP, which consists of a series of pre processed ingredients (flour, sugar, fat, optional additives). The CO_2 footprint of biscuits is also related to CO_2 emissions resulting from the final processing of this product
  – mixing and baking.

  The carbon footprint of several types of biscuits (UK) was found to be from 1.27 kg CO_2 eq. to 1.81 kg CO_2 eq. per 1 kg of biscuits depending on the ingredients added. Biscuits with chocolate and/or milk powder had a larger footprint than simpler recipes based solely on flour, sugar, oil and water. In particular, the production of raw materials was identified as the primary focus (41%–61% of total CO_2 emissions), followed by the manufacturing process(es) (24%–38%). Baking was identified as the process with the highest emissions (accounting for 10%–19% of the total CO_2 footprint for biscuits).

  Other analyses point to a potentially higher CO_2 footprint for the production of biscuits (between 3.30 kgCO_2eq and 5.29 kgCO_2eq), mainly due to the higher emission intensity of the electricity used and less efficient production. However, the relative share of raw material and processing CO_2 emissions remains largely unchanged.
  To summarize, using ingredients from Serbia to make biscuits is likely to result in a relatively higher CO_2 footprint of the final product. Given the electrical intensive operations (mixing and baking) required to obtain the final product, the carbon footprint of Serbian biscuits is expected to be particularly high. In other words, it is expected that the total processing footprint of Serbian products will be at the upper limit of the above-mentioned range, and could even exceed it. [60]

5.5.4. General principles of decarbonisation in the processing industry

Improving energy efficiency leads to significant financial benefits and reductions in CO_2 emissions. Any action that allows a certain amount of PPP to be processed using less electricity and fossil fuels falls into this category. Each industry, and even each facility, could consider which processes are the most energy-intensive and which could be most effectively improved - both through technical solutions and through internal reorganization. For example, converting on-site lighting to LED can result in significant savings, in some cases reducing associated costs and CO_2 emissions several times, depending on the initial lighting technology (e.g. incandescent, halogen, etc.). Building insulation and "smart" control of electrical equipment are additional measures that can also lead to significant energy and emissions savings in certain cases.
The introduction of own production of electricity from renewable sources (e.g. solar panels, wind turbines, biomass waste) can also be beneficial - both financially and to reduce CO_2 emissions. Electricity produced from renewable sources has a much smaller carbon footprint compared to fossil-based generation (e.g. grams of CO_2 per KWh compared to hundreds of grams from fossil sources). In fact, the CO_2 footprint of renewable energy is almost non-existent, so entering into a Power Purchase Agreement (PPA) or

[60] Data and emission factors originally from Evaluation of environmental sustainability of biscuits at the product and sectoral levels https://doi.org/10.1016/j.jclepro.2019.05.095

renewable energy certificates (REC) are also a sustainable way to decarbonize food processing in Serbia.

Replacing fossil fuels used for heating with lower carbon alternatives, e.g. biogas or even hydrogen (when the latter becomes widely available) is another possible means of reducing the processing footprint. Currently, only the use of biogas has been proven on a wide commercial scale and is not necessarily a viable alternative for all food processing facilities and businesses. In addition, replacing less efficient and carbon-intensive fossil fuels (such as coal and heating oil) with natural gas or LPG can also have a significant effect on reducing plant emissions. Using waste biomass or agricultural waste for combustion (instead of fossil fuels) can also greatly reduce the carbon footprint of food production.

Finally, replacing refrigerants with lower GWP alternatives (e.g. CO_2 - GWP of 1) is likely to have a limited impact on the annual CO_2 emissions of food processors, unless the latter rely heavily on cooling and refrigeration equipment for their production. The reduction in footprint will mainly come from the higher efficiency of modern systems using low GWP refrigerants. In any case, improving the cooling equipment and/or replacing the appropriate refrigerants would lead to a significant reduction in CO_2 emissions related to possible refrigerant leaks.

5.6. Transportation and Storage of Fresh and Processed Agricultural Products (Step 3)

5.6.1. Transportation in Serbia

PPP and PFP transport is an integral part of modern FtF chains, especially in developed countries. Hotspots of food consumption (urban centres) are usually tens to hundreds of kilometres away from farms and processing facilities. Furthermore, larger processing facilities cannot rely solely on the production of nearby farms to maintain sufficiently high utilization levels. Finally, several stages of transportation, transhipment and storage are required to "move" PPPs and PFPs through the FtF chain to end consumers.

Serbia is no exception - the largest food processing capacities in the country are distributed along the northern part of the country (Figure 4 below), where the largest part of agriculture is concentrated. At the same time, most major distribution centres for retailers are located more centrally, closer to large population centres. Considering the spatial distribution of key facilities in Serbia, transport represents a significant part of FtF CO2 footprint.

The shortest transport distance between the food processing facilities marked on the map and the distribution centre is 5 km, and the longest is 437 km. The average transport distance between two such locations is 135 km. Similarly, the shortest transport distance between the nearest larger city and distribution centre is 5 km, and the furthest is 334 km, with 146 km between the two locations, on average.

As for retail locations (shops) - they are evenly distributed in accordance with population density. Therefore, the transportation distance from distribution centres to stores would vary widely within the constraints of country borders (generally from tens of km to ~500 km).

All in all, road freight is practically the only mode of PPP and PFP transport in Serbia and would be the dominant contributor to the carbon footprint of this step of transport. Thus, all distances for transportation via the road network are provided.

PPP and PFP railway transport amounted to only 1,000 tons in 2022 [61]. The reported volumes via rail are insignificant, compared to road transport tonnage (<0.0006% of total PPP and PFP transport). There is no record of transport and distribution centre is 5 km, and the furthest is 334 km, with 146 km between the two locations, on average of PPP and PFP by waterways.

According to statistical data for Serbia, the average fuel consumption in a transport vehicle per 100 km is 35.2 l (29.4 kg), assuming that the fuel mix is 100% diesel. The value of fuel consumption corresponds to 0.937 $kgCO_2eq$ emitted per kilometre of freight transport in Serbia. At the moment, information on fuel consumption and CO_2 footprint specific to PPP and PFP transport is not available in Serbia. Thus, the compound average value of [62] is used to calculate the country's FtF transport emissions.

Table 3: PPP and PFP transported on the territory of Serbia and their estimated emissions of transport (road transport), 2022 [63]

Type of goods	Total transported quantity (tons)	Average distance travel (km)	Ton kilometres	Emissions (tCO_2eq)
Grains	1,218,209	405	493,597,000	34,007
Potato	85,351	1,245	106,274,000	7,322
Sugar beet	82,224	767	63,045,000	4,344
Other fresh fruit and vegetables	357,595	849	303,568,000	20,915
Others products	121,014	569	68,916,000	4,748

[61] According to the data of the Republic Institute of Statistics

[62] Average EU data for 2022 was used as a proxy for average cargo weight

[63] The transport footprint (in t CO_2eq) is calculated by multiplying the total amount of long-distance freight (in tkm) by the relevant emission factor (in $kgCO_2eq$), dividing the result (in $kgCO_2eq$/km of travel) by the average freight load for the EU (13.6 tonnes for national transport - 2022, Eurostat). The emission factor was obtained from the average reported fuel consumption for transport (statistical data for Serbia), the average density of diesel according to the EU EN 590 standard and data on diesel emissions from the literature - 2.66 $kgCO_2eq$/l.

of veg. origin				
Fruit and vegetables, processed and canned	159,934	750	120,015,000	8,269
Oils and fats of animal and vegetable origin	110,266	867	95,549,000	6,583
Flour, processed cereals, starchy products and food for animals	377,184	377	142,115,000	9,791
Others food products, which are not listed elsewhere (excluding services packaging and grouping)	163,829	719	117,860,000	8,120
Various food and tobacco products (with packaging, grouping)	230,216	788	181,318,000	12,492
Total	**2,905,822**	**582**	**1,692,257,000**	**116,592**

* Calculation of emissions is based on the assumed diesel consumption of 100%.

Based on 2022 data, a total of 2.9 million tons of PPP and PFP were transported on average 582 km per trip. It is estimated that PPP and PFP transport is responsible for 116 thousand tons of CO_2 emissions[64], which gives an indication of the size of transport emissions in the Serbian FtF chain.

Compared to agricultural production and food processing, the CO_2 footprint of transport is considered significantly smaller.

[64] This estimate is based on using EU data for cargo size (13.6 tonnes). Since the EU has a better developed logistics system, this figure could underestimate the actual CO_2 emissions in Serbia.

5.6.2. General principles of decarbonisation in road transport

For road transport, the main source of emissions is the combustion of fossil fuels (usually diesel) in vehicles with internal combustion engines (ICE) - trucks, tractor- trailers, light commercial vehicles, etc. The key factors that determine the carbon footprint of transport at the national level are:

1. total distance travelled – depends on national-geographical specifics, road network and distribution of various facilities (as already discussed);
2. tonnage of transported cargo - mainly in terms of cargo loading efficiency (% empty space, prevalence of empty return trips);
3. fuel efficiency of used vehicles - primarily depending on their age and brand.

As stated above, the distance travelled depends to a large extent on the geography and demography of Serbia. Any radical improvements would require major capital investment in infrastructure such as improved roads and railways.

Loading efficiency, on the other hand, can be improved at the company level and at relatively low cost. Increasing the load factor and better route planning to avoid empty journeys could bring financial benefits to the business in addition to ensuring a reduction in the CO_2 footprint. However, improving transport loading efficiency consistently enough to affect emissions nationally would be a challenging and uncertain task. The key metric used to calculate transport CO_2 emissions is the sum of every single freight transport journey in a country. The amount of cargo carried in a single vehicle is generally dictated by specific commercial and economic circumstances and there are currently no proven universal measures to improve it on a country-wide basis. Moreover, since there is practically no data available for Serbia at the moment, it is very difficult to estimate traffic emissions and the need for improvement in the area of loading efficiency. For EU countries the average for national transport is 26% empty trips, but this includes all sectors, not just the FtF chain. This makes the number largely unrepresentative, as some common industrial activities (e.g. construction) inherently involve a large proportion of empty journeys and as a result – lower loading efficiency.

Given the above, vehicle fuel efficiency in Serbia has been identified as a major determining factor that can be easily analysed and reliably improved. Compared to the average Serbian fuel consumption of 35.2 l/100km [65], the basic fuel consumption of a 40 ton European 4×2 tractor trailer used for international long-distance transport is 33.1 L/100 km. This is lower than the national average in Serbia, although the national average should only include regional deliveries and should also include vehicles that are much less intensive. A truck that is more suitable for local and regional food deliveries in Serbia is 21.4 L/100 km (significantly lower than the Serbian average).

In 2020, the fuel consumption of new trucks in the EU ranged from 23l/100km to 34l/100km, depending on axle configuration and type. Vehicles that were more suitable

[65] In 2015

local and regional deliveries, all had average fuel consumption below 31l/100. As stated earlier, due to different technological characteristics, the age of vehicles is the main determining factor for their high fuel consumption, i.e. high CO_2 emissions.

The average age of trucks in Serbia is 19 years [66]. In the EU, the average age of goods vehicles ranges from 12 to 14 years for light commercial vehicles and for trucks. The average difference of 5 to 7 years is quite significant as it represents an entire generation gap in the vehicle. This is particularly significant when considering the interval between the publication of new EURO emissions standards (4-5 years). Although they cover pollutant emissions, they are the main drivers of overall ICE efficiency improvements for European and global car manufacturers. Therefore, owning a vehicle, on average one standard older than the EU, probably significantly affects the overall profile of emissions in the freight transport sector in Serbia and vice versa, the transport step of the national FtF chain. Moreover, not all trucks in Serbia comply with EU standards and regulations because not all are manufactured in the EU, which probably also contributes to the increased footprint in transport since the EU has the strictest standards for emissions and efficiency in the world.

Overall, getting more efficient freight vehicles with fewer emissions is the single most comprehensive and most important measure to reduce the CO_2 footprint of PPP and PFP transport. The positive effects of this measure will be both for the transport-intensive FtF chain in Serbia and for the national transport sector as a whole.

5.6.3. Warehousing in Serbia

The information about the storage and the causality between types of operations and potential emissions are based on analyses that are part of the global storage initiative by the German, Italian and Latin American Consortium for Resource Efficient Logistics Hubs and Transport (GILA). It covers 843 logistics hubs from 51 countries around the world. 43 countries are located in Europe. Footprint calculations in the analyses were based on annual information on energy consumption, refrigerant charge, flow and indoor logistics area, all provided by the operators of their hubs. Average national emission factors were used to calculate the emission contribution of electricity to the carbon footprint. Overall, the analysis represents one of the best sources available for real and accurate information on the European storage sector.

5.6.4. Specific details of the carbon footprint during storage

European warehouses generally rely on electricity for most of their operations – lighting, electrified internal transport, ventilation and refrigeration. Electricity use, as well as processing, is often the main factor contributing to the carbon footprint. Consumption is particularly high in refrigeration facilities because the cooling and refrigeration systems are powered exclusively by electricity. The emission intensity of the local/national grid is the main determining factor for the size of the carbon footprint. Some buildings require space heating, depending on their location and local climate.

[66] Statistical data for 2022

The use of fossil fuels for heating could be another major contributor to the overall carbon footprint of storage, especially in harsh climates or for buildings with poor insulation. It was found that the main energy source used for heating in European buildings is natural gas, which contributes to lower emissions per calorific value compared to fuel oil or solid fuel. Non-electrified internal transport (material handling forklifts) can be another source of carbon emissions from fossil fuels as they most often use diesel or LNG or LPG. However, its contribution to the carbon footprint is usually minimal.

The most common refrigerant types used by study participants were R-717 (ammonia, GWP of 0), R-404A (GWP of 3922 kgCO_2eq/kg), and R-410A (GWP of 2255.5 kgCO_2eq/kg). Facilities using R-717 would see no refrigerant emission contribution to their carbon footprint, regardless of any leakage. The remaining plants likely have a limited portion of their annual carbon footprint derived from fugitive refrigerant emissions.

It was found that the average carbon footprint of cargo during the storage step is highly dependent on the type of storage facility handling it. This would also be applicable to PPP and PFP as well as any other type of cargo in storage.

It was found that ambient (as opposed to refrigerated) transhipment facilities without dedicated storage have, on average, the smallest footprint both per ton of cargo processed and per area (0.6 kgCO_2eq/and 16.7 kgCO_2eq/m2 respectively). They specialize in quick loading and unloading of cargo and operations do not include servicing, maintenance and organization of any storage areas. Transhipment facilities with dedicated storage have a significantly larger carbon footprint, due to the need to maintain and service a larger total space and all additional operations related to storage, organization and internal transport of cargo. Transhipment and storage facilities, on average, have a carbon footprint of 2.1 kg CO_2eq/t or 28.0 kgCO_2eq/m2. Dedicated warehouses were found to have an even higher footprint per tonne of cargo processed (17.5 kgCO_2eq/t) as most of their operations are related to cargo maintenance in storage rather than high throughput (tonnes processed per day). However, due to the effects of storage scale and specialization on overall operational efficiency – warehouses were found to have a smaller footprint on average. The capacity to process frozen or chilled cargo (mainly food), with ambient storage and transhipment can increase the footprint of facilities more than 3 times per ton of cargo processed (for transhipment facilities). On average for warehouses the footprint increase is ~80%. This is largely due to the additional energy consumption of refrigeration equipment and potential refrigerant leaks, which are much more significant in the case of large warehouse refrigeration systems, compared to other FtF chain facilities.

No country-specific information on the carbon footprint of storage and storage could be obtained for Serbia. State statistics do not include a breakdown by sector for total energy consumption (fuel and electricity) or for electricity consumption. Site-level data on currently operating storage and distribution facilities, such as fossil fuel use, electricity or refrigerant consumption, could not be obtained and are likely not publicly available.

Nevertheless, based on the analysis discussed in the previous section, rough estimates can be made for the potential range of the national FtF warehouse footprint. Assuming that all 2,905,822 tons of PPP and PFP transported on the territory of Serbia were processed through two warehouses/transhipment facilities (once before processing and once before retail), the carbon footprint of the storage ranges between 3.487 tCO_2eq and 191.784 tCO_2eq. The large spread depends on the type of assumed storage/transhipment facility and the appropriate choice of emission factor. Regardless of the difference from the actual footprint, the data suggests that the warehouse has a secondary/minimal contribution to Serbia's total FtF footprint. The storage footprint is estimated to be negligible, compared to the carbon footprint of the cultivation step (1246 to 23 times smaller), minimal compared to processing (454 to 8 times smaller) and potentially similar to the transport step (33 times smaller to 1.6 times larger). Following the conservative approach to estimates adopted for this analysis, only the highest total emission value – 192 thousand tons of CO_2eq emissions – is taken into account for the FtF inventory.

Table 4: Potential types of logistics operations and estimated total emissions associated with handling PPP and PFP in Serbia, 2022[67]

Assumed type of logistical operations	EF only for storage on ambient temperature ($kgCO_2eq$/t of goods)[68]	Print only for storage on ambient temperature (tCO_2eq)	EF for temperature ambient and cooled storage ($kgCO_2eq$/t of goods)[69]	Print for Temperature of the environment and chilled warehouse (tCO_2eq)
Only terminal for reloading X2	0.6	3,487	2.2	12,786
Terminals for storage and reloading X2	2.1	12,205	4	23,247
Storage and processing only X2	17.5	101,703	33	191,784

The footprint of the storage step (in tCO_2eq) is calculated by multiplying the relevant emission factors ($kgCO_2eq$/t of processed cargo) with the total amount of PPP and PFPs sold on the territory of Serbia, whereby the result is multiplied by a factor of two (representing two processing iterations). This calculation was made for each available emission factor for different types of storage/transhipment facilities from literature.

[67] The study covers almost all European countries (even outside the EU) and is expected to be at least partially representative of warehouses in Serbia.
[68] Emission factors originally from "Emission intensity factors for logistics hubs" by Kerstin Dobers (Fraunhofer IML), Sara Perotti (Politecnico di Milano) i Andrea Fossa (GreenRouter) https://reff.iml.fraunhofer.de/dl/AverageEmissionIntensityValues_sites_2023.pdf
[69] *Ibid.*

5.6.5. General principles of decarbonisation in storage

Since a reliable emission inventory of FtF storage facilities in Serbia cannot be compiled with the available information, no country-specific decarbonisation recommendations can be made.

However, the general principles for decarbonisation in this part of the FtF chain are still applicable. There are also significant similarities between the general sources of emissions between storage and processing and therefore – similarities between measures to reduce.

- All options available to increase the efficiency of equipment and processes that consume electricity, such as lighting, ventilation, air conditioning and refrigeration, conveyor belts, etc. would contribute to the reduction of produced emissions.
- The introduction of on-site electricity generation from renewable sources (e.g. solar panel) will offset the effect of the high-emission national grid.
- Replacing indoor transportation (e.g. light vehicles, forklifts) that relies on fossil fuels with electrified alternatives can lead to overall reductions in emissions, especially when combined with on-site renewable energy production.
- Upgrading refrigeration equipment to run with low-carbon refrigerants (lower GWP) would greatly reduce emissions from equipment maintenance and accidental releases.
- Reducing empty storage space and improving plant utilization will indirectly affect the overall efficiency of the storage step and likely lead to a reduction in its carbon footprint.

5.7. Retail PPP and PFP (Step 4)

The last step of the FtF chain within this paper covers the retailing of all food (raw or processed) grown and produced in the previous steps.

Globally, retail is responsible for approximately 5% of FtF emissions, but this share is expected to grow rapidly with the spread of modern retail practices in Serbia. An indication of this is the fact that currently global CO_2 emissions from retail trade are 3 times higher than in 1990.[70]

5.7.1. Details of the carbon footprint in retail

As the retail in the FtF chain includes some elements of storage and processing, it also has a similar emission profile. The main factor contributing to its carbon footprint is electricity consumption, with its carbon footprint largely dependent on the national electricity mix (as

[70] Data based on https://news.un.org/en/story/2021/03/1086822 and EDGAR-FOOD: A global emission inventory of GHGs and air pollutants from the food systems https://edgar.jrc.ec.europa.eu/edgar_food

previously described). The use of fossil fuels (mainly natural gas) has a smaller contribution, depending on the choice of heating technology for commercial spaces and the presence of "hot" food within retail locations. Emissions from refrigerant use are highly dependent on the volume of chilled and frozen food supply and the age of the refrigeration system (dictated by the type of refrigerant).

Processes primarily responsible for retail electricity and fuel consumption and conversely for its carbon footprint include:

- Heating/cooling of business premises - either by electricity consumption or emissions from direct combustion of heating fuel (natural gas, LPG, heating oil, etc.);
- Cooling of the storage space - mainly done through air conditioning and ventilation, mostly relying on electricity for operation;
- Lighting - both indoor (storage and commercial areas) and outdoor areas (parking lots, building facades) in the retail sector require constant lighting, consuming a significant amount of electricity;
- Product cooling – estimated to be responsible for almost half of global retail emissions, electricity consumption is the dominant contributor to the footprint with refrigerant emissions playing a secondary role;
- Cooking/preparation of hot products - some retailers offer a range of products that are cooked or heated on site, using mainly natural gas or electricity in the process, overall this is only a secondary contribution to the overall retail footprint.

Additional sources of emissions attributable to the retail sector are food waste (approximately 13% of food waste in Europe is attributable to the retail sector) and packaging – are estimated to be responsible for up to 5% of emissions in the global food chain. Due to the specific technical nature of the topic, which requires separate research and detailed analysis, food waste and packaging are not included in this study.

Globally, retailing can be done at several levels of complexity and vice versa – energy demand and carbon footprint. Serbia is a developed economy/country, so it can be assumed that its retail system will include mostly modern forms of food retailing - through shops or supermarkets/large stores. Regardless, no publicly available information has been identified that could enable a reliable calculation or assessment of the footprint of the food retail sector in Serbia. Information on electricity consumption by sector is not publicly available, and an updated national inventory of refrigerants could not be found either. Data on the number and size of retail businesses were collected, however, without technical data on floor space, average electricity, cooling and/or heating, any estimates derived would be highly unreliable.

For the purpose of analysis, the global share of emissions in the food chain was used as a proxy for the retail sector in Serbia - it was assumed that 5% of the national FtF carbon footprint belongs to retail, which is approx. 312 thousand tons of CO_2eq emissions.

5.7.2. General principle of decarbonisation in retail

Basic measures:

- Energy efficiency of equipment for cooling, lighting, heating and other equipment in stores. Specific measures include:
    - Modernization of the cooling system, introduction of closed cold displays to minimize heat exchange;
    - Introduction of LED lighting both indoors and outdoors;
    - "Smart" control of ventilation, air conditioning and heating for optimization energy consumption;
    - Dimming/"smart" lighting control, depending on the work time to optimize energy consumption;
- Absolute reduction of electricity consumption by reducing excessive lighting (especially outdoor surfaces), turning off lighting for advertisements outside of working hours, minimizing non-essential cooling displays (e.g. for bottled drinks), automating closing and opening doors to prevent unnecessary heat exchange;
- Climate-neutral refrigerants, such as CO_2 (GWP of 1) to minimize the footprint of unavoidable fugitive emissions and reduce the effects of potential large-scale refrigerant releases due to accidents;
- Own renewable energy production - rooftop solar panels are the most common addition to supermarkets and larger stores. Especially profitable for a significant reduction of the carbon footprint in stores, considering the high emission intensity of the electricity grid in Serbia;
- Alternative fuels for heating or reducing the use of fossil fuels - using biogas for heating can significantly reduce its carbon footprint because the combustion of biogas is considered climate neutral, the electrification of heating (e.g. heat pumps) can also greatly reduce the carbon footprint if powered by renewable energy sources (e.g. rooftop solar energy).
- Reducing waste and single-use packaging - although not covered in detail in this report, reducing food waste, packaging waste and single-use packaging as a whole can significantly reduce the overall footprint of the retail sector.

6. CO_2 Emissions and Soil Quality in Primary Agricultural Production in Serbia

6.1. General Overview

Agriculture in the Republic of Serbia is characterized by large differences in terms of soil quality, agricultural production systems, and the level of development between the developed rural areas of Vojvodina and the marginalized mountainous rural areas of central and southern Serbia. On the other hand, the natural characteristics of the land, the availability of water resources and the suitability of the climate provide wider frameworks for the structuring of agriculture, which could be profitable and sustainable on such grounds.[71] According to the data of the Republic Statistical Office[72] (2018), Serbia has 564,541 agricultural farms. The largest number of agricultural holdings is represented in the region of Šumadija and Western Serbia (242,636), while the lowest number of agricultural holdings was recorded in the Belgrade region (30,033).

The average economic size of agricultural holdings in Serbia is 8,610 euros, which is four times less than the EU average. Compared to the EU countries, only Romania has a smaller average economic size of the agricultural holding (3,537 euros), which places Serbia in the II group of countries. Observed according to the organizational and legal form, family farms in Serbia make up 99.6% of the total number of farms, while entrepreneurs and legal entities are represented by 0.4%.

The physical size of the farm, analysed through the used agricultural area, amounts to 6.4 ha and is almost three times smaller compared to the EU average. In Serbia, there has also been an increase in the average area of used land in the last few years, which is a consequence of the decrease in the number of farms and the concentration of land in the hands of a smaller number of producers.[73]

The agriculture of the Republic of Serbia is characterized by a high participation of small farms, that is, those that carry out agricultural production on an area of less than 5 hectares (72%). The share of small farms in the total number of farms is higher compared to the EU 28 average (63.5%).

Table 5 Basic characteristics of agricultural farms in Serbia

[71] Roljević et al., (2017)

[72] Survey on the structure of agricultural holdings, 2018 – Poljoprivredna gazdinstva prema tipu proizvodnje i ekonomskoj veličini.Republic Statistical Office, Belgrade, 2019

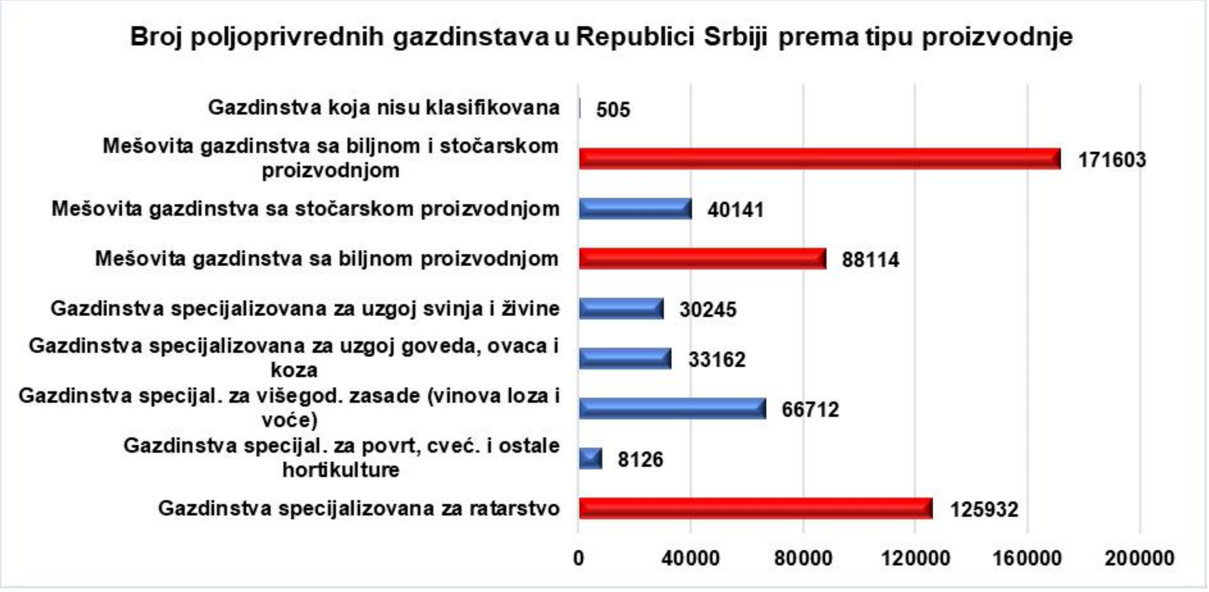
[73] Paraušić et al., (2021)

Characteristic	Value
Total number of farms	564,541
Average SO (EUR)	8,610
Used agricultural land per farm (ha)	6.2
Farms with less than 5 ha, % of total	71.7
Farms with more than 100 ha, % of total	0.3
Specialized in farming, % of total	46.8

Source: RSO, Survey, 2018

Taking into account all the previously mentioned characteristics of farms in Serbia, the dominant representation of farms engaged in mixed agricultural production is expected and is significantly higher compared to all member states as well as to the average for the entire EU (22.4%). In addition to farms with mixed crop and livestock production (30%), the most represented are farms specialized in arable farming (22%) and mixed farms with crop production (15,6%), chart 1.

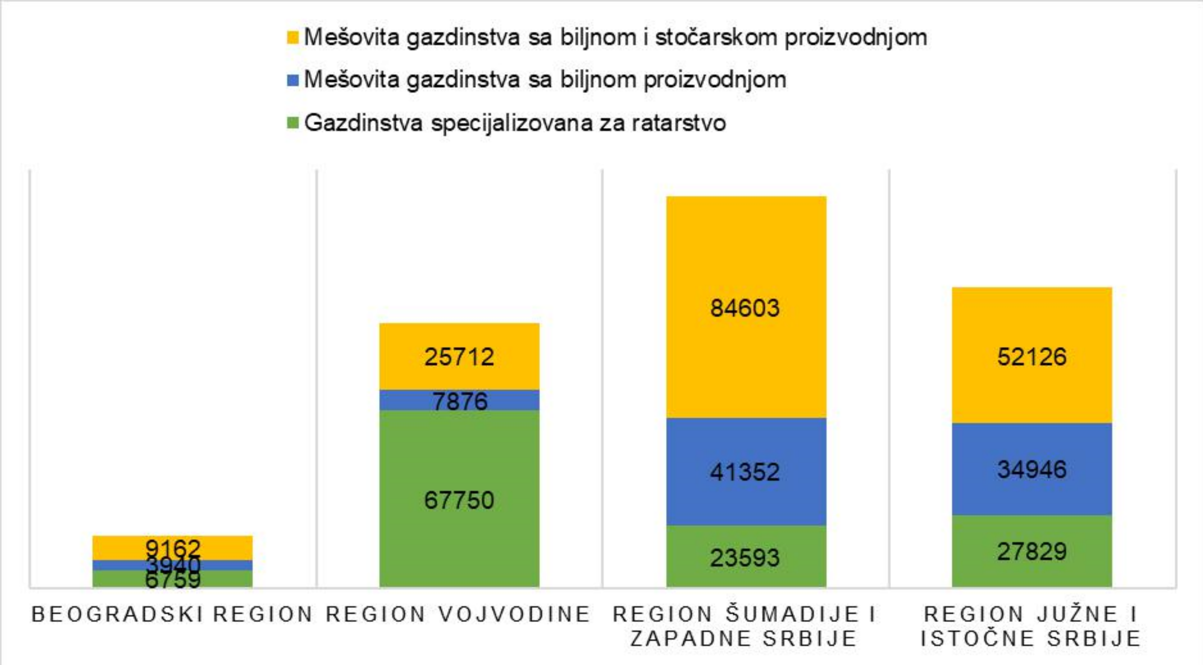
Figure 4. Number of agricultural farms in the Republic of Serbia by type of production



Source: RSO, Survey, 2018

The largest number of farms specialized in arable farming are represented in the region of Vojvodina (67,750), and the least in the region of Belgrade (6,759). Mixed farms for plant represented in Šumadija and Western Serbia (41,352), and the least in the Belgrade region (3,940). There are the most mixed farms for crop and livestock production in the region of Šumadija and Western Serbia (84,603), and the least in the region of Belgrade (9.162), chart 2.

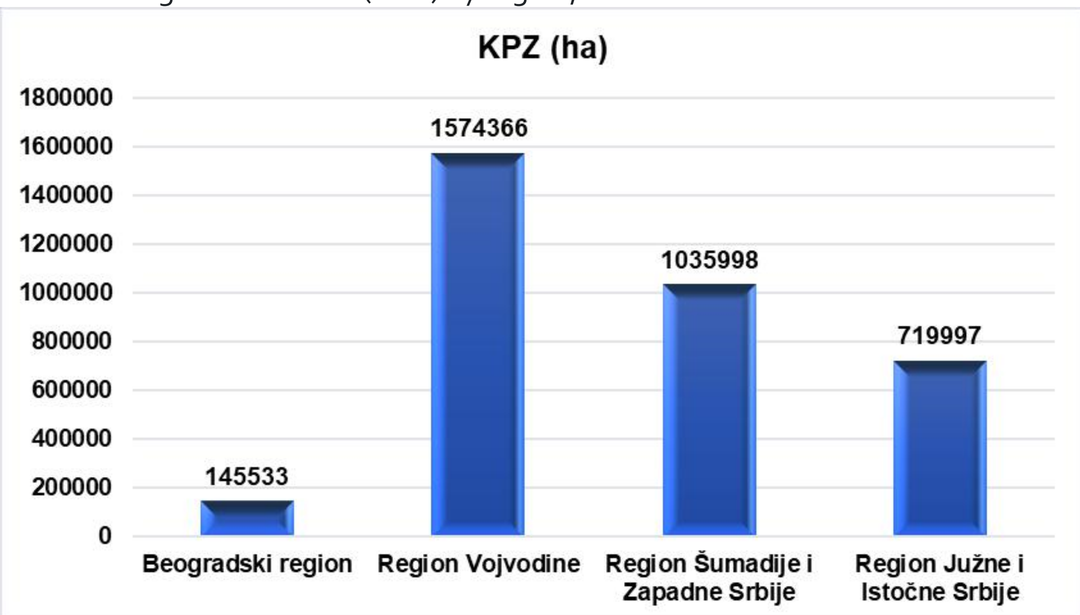
Figure 5: Number of agricultural farms by region of the Republic of Serbia by type of production on which agricultural production takes place.



Source: RSO, Survey, 2018

The used agricultural land (UAL) in the Republic of Serbia covers 3,475,894 ha. From the aspect of regional distribution, it is noticeable that the largest part of the UAL is located in the region of Vojvodina (45%), and the least in the region of Belgrade (4,2%).

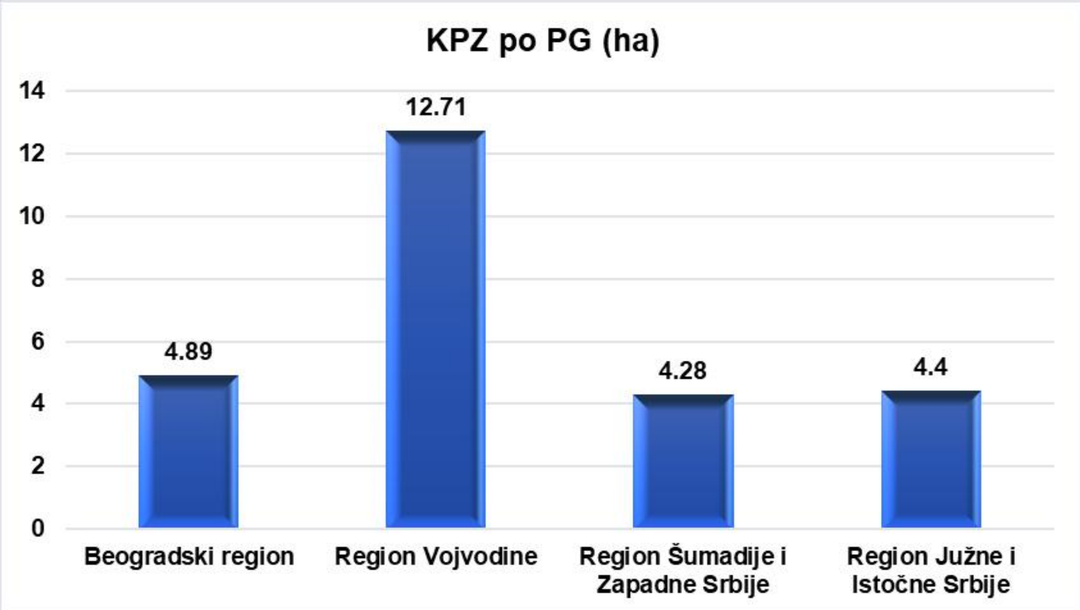
Figure 6. Used agricultural land (UAL) by region, 2018 census



Source: RSO, Survey, 2018

The average size of agricultural holdings in the Republic of Serbia is 6.2 ha/agricultural holding of UAL. The largest farm size in terms of UAL is in the Vojvodina region (12.71 ha/agricultural farm), while in the other three regions the average farm size is smaller than the national average. (Figure 8)[74]

Figure 7. Used agricultural land (UAL) by agricultural holding, by regions, 2018 census

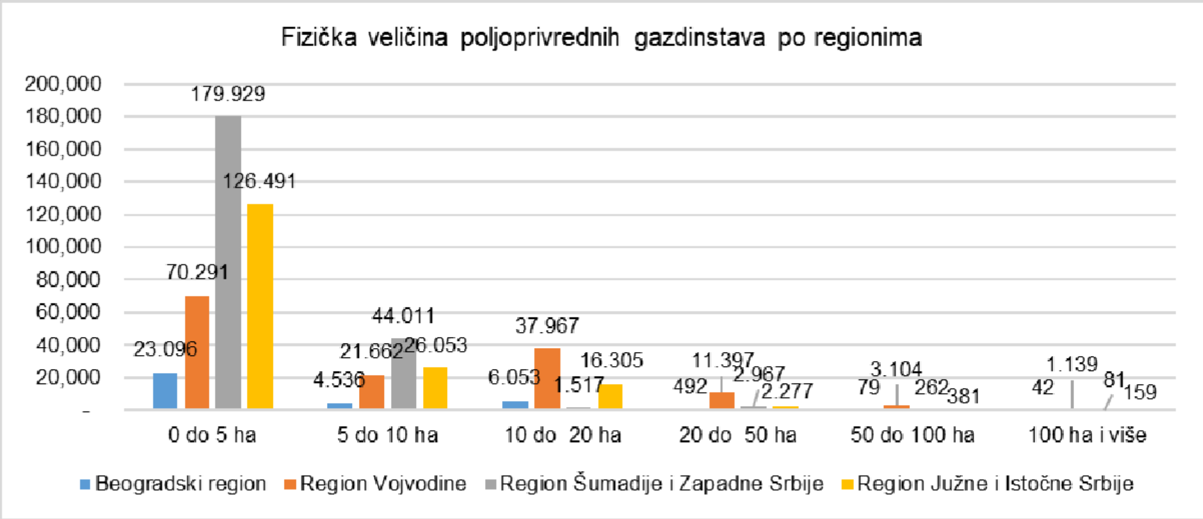


Source: RSO, Survey, 2018

However, the key characteristic of agriculture in Serbia is the fragmentation of land holdings. Over 70% of the total number of agricultural holdings have an area of UAL up to 5 ha. The majority of such farms are located in the region of Šumadija and Western Serbia (Figure 9).

Figure 8. Number of agricultural holdings by size by region

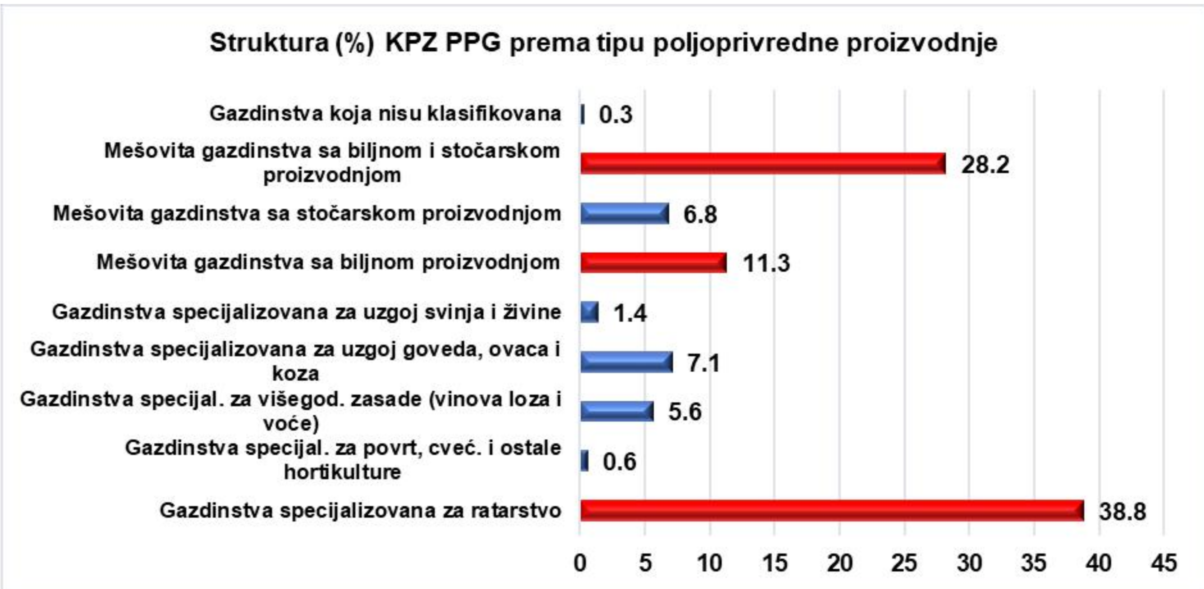
[74] Survey on the structure of agricultural holdings, 2018 - Land. Statistical Office of the Republic of Serbia, Belgrade, 2019.



Source: RSO, Survey, 2018

Farms specializing in arable farming have the largest percentage of UAL family agricultural farms (38.8%), and the smallest percentage, excluding unclassified farms, have farms specializing in vegetable growing, flower growing and other horticulture (0.6%) (Figure 10).[75]

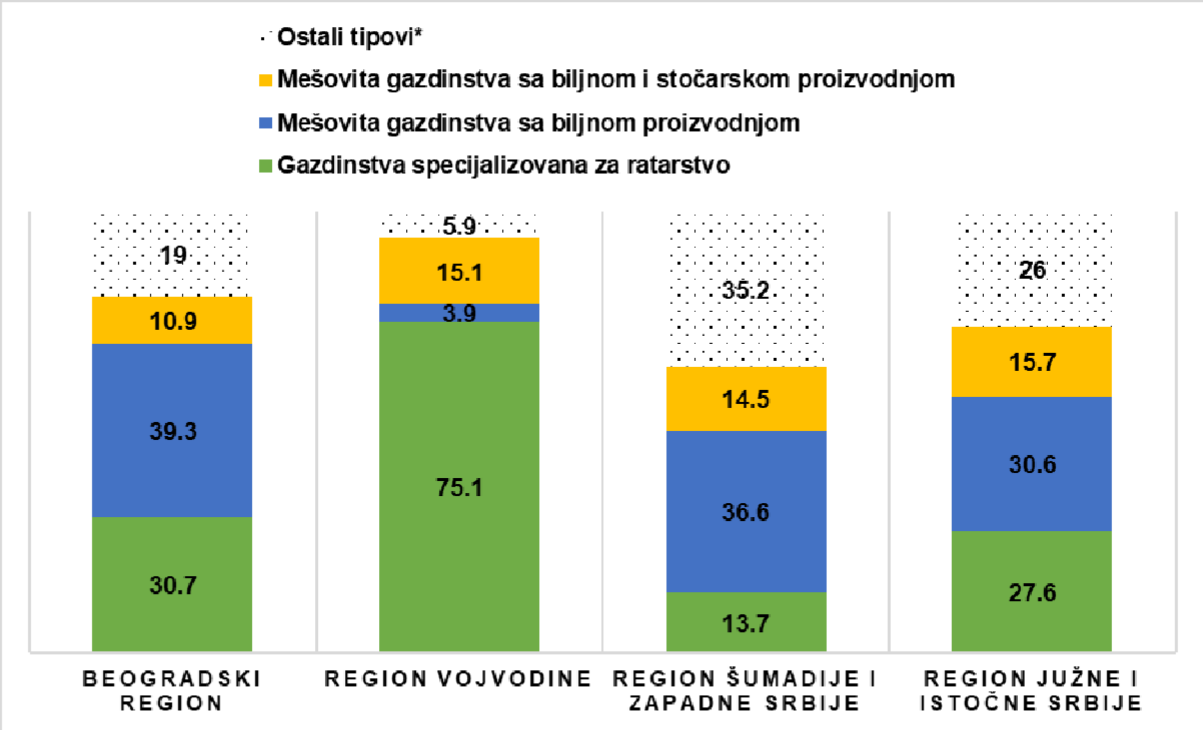
Figure 9. Structure of UAL of family agricultural holdings according to type of agriculture production in the Republic of Serbia, 2018 census



Source: RSO, Survey, 2018

Figure 10. Structure of UAL by type of agricultural production by region, 2018 census

[75] Publication "Poljoprivredna gazdinstva prema tipu proizvodnje i ekonomskoj veličini" Survey on the structure of agricultural holdings, 2018



Source: RSO, Survey, 2018

**Other types: farms specialized in vegetable growing, flower growing and other horticulture; farms specialized in perennial crops; farms specialized in breeding cattle, sheep and goats; farms specialized in raising pigs and poultry; Mixed farms with livestock production; farms that are not classified*

The analysis of the share of used areas in the production of the main agricultural crops found that, in all the regions covered in the Republic of Serbia, the largest share of the total used areas of arable land and gardens is grain production (from 61.36% in Vojvodina to 72.66% in the region of South and Eastern Serbia). Observed individually by crop, wheat and rye have the largest share in the used areas of arable land and gardens (over 20% share) in all regions covered by the research. The largest share of areas under potatoes is in the region of Šumadija and Western Serbia (3.07%), and the smallest in Vojvodina (0.27%). The largest share of areas used for the production of sugar beet, oilseed rape, sunflower and soybeans is represented in the region of Vojvodina, and the smallest in the region of Šumadija and Western Serbia (Table 6).[76]. For the purposes of this analysis, the values were recalculated and expressed in percentages, in order to express the structure, that is, the share.

Table 6 Share of used areas in the production of the main field crops (%), by region, 2018 census

[76] Survey on the structure of agricultural holdings, 2018 - Land. Republic Statistical Office, Belgrade, 2019

Type of crop	UAL by region (%)			
	Belgrade region	Vojvodina Region	Šumadija Region and Western Serbia	South and Eastern Serbia
Wheat and spelt	25,76	22,05	26,21	31,80
Rye	0,47	0,08	0,35	0,16
Barley	7,53	3,14	5,15	4,24
Oat	2,39	0,14	2,92	1,30
Corn for grain	32,75	34,98	36,05	34,32
Other grains for grain	1,67	0,97	1,74	0,84
Total grains	70,56	61,36	72,43	72,66
Potato	0,33	0,27	3,07	1,32
Sugar beet	0,99	3,05	0,00	0,00
Rapeseed	1,41	2,84	0,23	0,42
Sunflower	5,13	13,82	1,86	5,54
Soybean	5,41	12,42	2,05	0,26
Total used area Arable land and garden (ha)	112787	1433130	565616	460046

The production of corn for grain occupies the largest areas of arable land in the Republic of Serbia, and in the region of Vojvodina, the largest areas are under this crop (501,315 ha). Also, the region of Vojvodina has the largest production of wheat and spelt (315,942 ha), barley (45,032 ha), other grains for grain (13,894 ha), sugar beet (43,711 ha), oilseed rape (40,758 ha), sunflower (198,000 ha) and soybeans (177,975 ha). The largest areas under the production of rye (2,003 ha), oats (165,517 ha) and potatoes (173,389 ha) are located in the region of Šumadija and Western Serbia.

Table 7. Areas used in the production of the main crops, by region, 2018

Type of crop	UAL by region (ha)			
	Belgraderegion	Vojvodina Region	Šumadija region and Western Serbia	South and Eastern Serbia
Wheat and spelt	29053	315942	148256	146315
Rye	529	1146	2003	730

Barley	8494	45032	29116	19483
Oat	2697	1983	16517	5978
Corn for grain	36934	501315	203906	157893
Other grains for grain	1881	13894	9854	3879
Total grains	79588	879312	409651	334278
Potato	368	3881	17389	6062
Sugar beet	1118	43711	21	19
Rapeseed	1593	40758	1303	1921
Sunflower	5789	198000	10498	25507
Soybean	6098	177975	11618	1212

6.2. Soil Quality in Different Production Systems

Conventional agricultural production has a negative impact on our environment, impairing the quality of water, soil and air. In addition, it contributes to the reduction of arable land, the loss of biodiversity, the destabilization of ecosystems and the emission of greenhouse gases, which cause global warming. As we face the challenges of climate change, it is becoming clear that we need more sustainable agricultural practices. Therefore, in conditions of environmental threats caused by human activity, preference is given to agroecological and agricultural practices that have a lower risk of harmful effects on soil, water and air.[77] Systems of conservation agricultural production are of particular importance, because they influence the improvement of soil health and biodiversity, stimulating regenerative biological processes both below and above the ground.[78]

During the analysis conducted for the period from 1960 to 2000 [79], the research showed that the technique known as "no till" or the system without cultivating the soil was tested on all continents by researchers and farmers. However, the introduction of this technique was limited and only started in the 1980s and 1990s, mainly in countries such as the USA, Canada, Brazil, Argentina, Paraguay, Uruguay, Bolivia, Venezuela, Great Britain,

[77] Wezel et al., 2014, Villalobos i Ferens, 2016

[78] Shrestha et al., 2020, Dey et al., 2022, Carnevale Zampaolo et al., 2023

[79] Kassam et al. (2022),

Australia, New Zealand, Spain, Germany, Kazakhstan, Zambia and South Africa. Until the year 2000, the no-tillage system was carried out in the mentioned countries on a total of about 65 million hectares of land. Previously, US soil and water conservation programs played a key role in the development of various land management practices, including the no-till system. During the period from 1970 to 1997, farmers, agronomists and researchers who pioneered the application of no-till systems gained enough experience and knowledge to define the key components of a sustainable soil system, which is known as conservation agriculture. The term was first proposed in Spanish in 1997 at the IV RELACO meeting in Morelia.[80] The term was also adopted in 1997 by the Food and Agriculture Organization of the United Nations (FAO) to describe sustainable production systems.

By 2019, conservation agriculture systems were operating on 205 million hectares in more than 100 countries around the world. Since 2008, conservation systems have been expanding at an annual rate of about 10 million hectares. Globally, the ten leading countries in the application of conservation agriculture are: USA, Brazil, Argentina, Australia, Canada, China, Russia, India, Paraguay and Kazakhstan. In South and Central America, the five leading countries are: Brazil, Argentina, Paraguay, Bolivia and Uruguay; in Europe, Spain, France, Romania, Great Britain and Italy; in Africa, South Africa, Zambia, Mozambique, Ghana and Malawi; and in Asia, China, India, Kazakhstan, Pakistan and Iran. [81]

In order to examine the quality of the soil in different production systems, soil analysis was carried out on samples taken from four tillage systems: (i) mulch tillage,

(II) zonal processing, (III) no processing and (IV) classic processing, carried out at the Experimental Site of the Tamiš Research and Development Institute in Pančevo.

Protective treatment or mulch treatment includes the treatment of the entire arable area, with the fact that it is surface coverage with plant residues greater than 30%.

Zone processing includes strip processing, where up to 1/3 of the surface is processed. When it comes to this soil tillage system, the most prevalent in our country is tillage in the sowing zone (Figure 11).

[80] Latin American Conservation Processing Network Meeting in Morelia, Mexico 1997 by Rolf Derpsch and Theodore Friedrich.

[81] Kassam et al., 2022; Information on the global application of conservation agriculture practices is periodically updated and publicly available on the CA-Global website (https://www.ca-global.net/ca-stat)

Figure 11. Zonal tillage (Photo: B. Garalejić)

System **without tillage (direct sowing)** - the sowing zone is tilled during sowing with a width of up to 5 cm (Figure 12 and 13).

Figure 12. Sowing wheat without cultivation (Photo: B. Garalejić)

Figure 13. Sowing corn without cultivation (Photo: B. Garalejić)

Conventional cultivation is usually ploughing and is done with field ploughs. It is carried out in a period critical for erosion and the mass of plant remains is less than 560 kg ha-1 (Figure 14).

Figure 14 Conventional ploughing (Photo: B. Garalejić)

The chemical analysis covers the basic chemical properties of the soil, on the basis of which the fertility of the soil is estimated: humus content, phosphorus content and potassium content. The soil was sampled at three depths: 0 to 10 cm, 10 to 20 cm, and 20 to 30 cm. In addition to these analyses, the content of total carbon in the soil was also analysed (samples taken from a depth of 0 to 30 cm).

The content of humus (organic matter) in the soil determines its fertility. Hummus represents a source of nutrients, participates in the processes of soil education, affects the physical and chemical properties of the soil, participates in plant nutrition, i.e. is an indicator of soil fertility.[82] Soils containing less than 1% humus are considered very low humus, from 1.01 to 3% low humus, then from 3.01 to 5% humus, and from 5.01 to 10% high humus.[83]

The analysis of the humus content of four tillage systems found that the humus content varies according to the depth of the soil in conservation tillage systems, **while in the conventional tillage system humus content is unchanged in depths from 0 to 30 cm and amounts to 3,5%**. The reason for this may be soil mixing at a particular depth during ploughing (overturning the layers). In conservation tillage systems (mulch tillage, zone tillage and no tillage), the highest content of humus is present at a depth of 0 to 10 cm, and the lowest at a depth of 20 to 30 cm. According to the statements from

[82]Vasin, (2008)

[83] Manojlović, (1986)

2015 analysis[84], organic matter accumulates mainly in the upper layer, which increases not only soil productivity, but also its resistance to degradation under the influence of agricultural treatments and environmental factors.

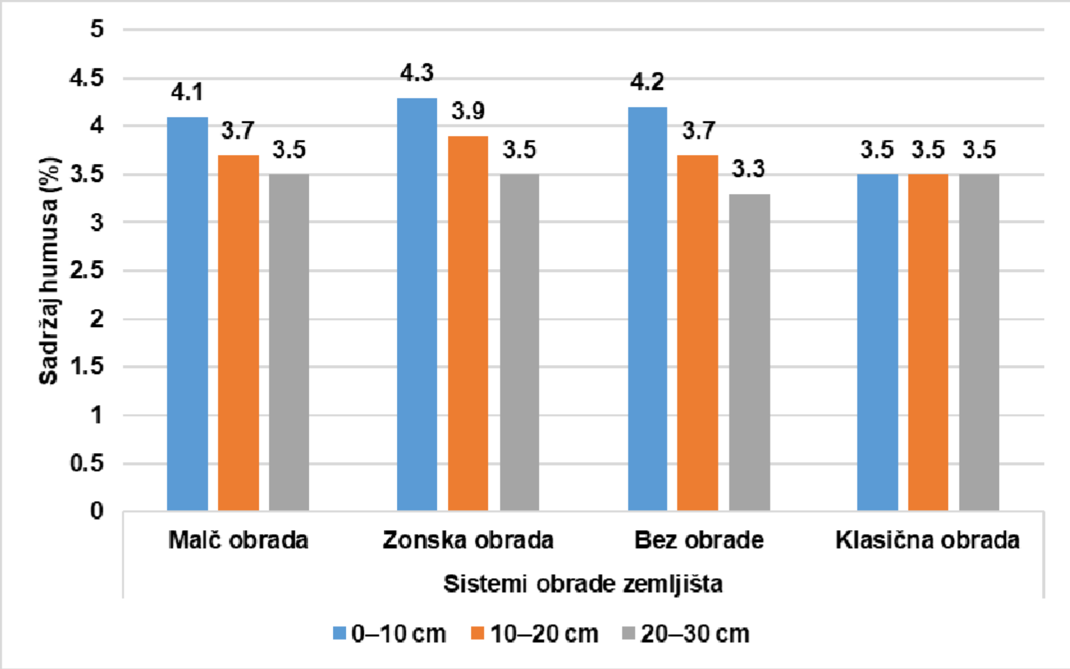
The highest content of humus at a depth of 0 to 10 cm was measured in the zone tillage system (4.3%), followed by the no tillage system (4.2%), and the lowest in the mulch tillage system (4.1%). At a soil depth of 10 to 20 cm, the highest humus content was found in the zonal tillage system (3.2%), while the humus content in the mulch tillage system and the no tillage system is equal and amounts to 3.7%. At a soil depth of 20 to 30 cm, the humus content is 3.5% in the system of mulch treatment and zonal treatment, while in the system without treatment, the humus content is the lowest and was 3.3% (Figure 15). In a study conducted in Illinois, USA[85] soil properties were compared after five years of no-till and zone tillage systems. Their results indicate that the content of organic matter is higher in the soil cultivated according to the zone tillage system compared to the soil without cultivation. This phenomenon can be explained by better soil aeration in the zone tillage system. Based on the analysis of humus content in the soil in different tillage systems, it can be concluded that conservation tillage systems affect the improvement and preservation of organic matter in the soil. According to a 2015 study in [86] organic matter accumulates mainly in the upper layer, which increases not only soil productivity, but also its resistance to degradation under the influence of agricultural treatments and environmental factors.

Figure 15. Humus content in the soil in different tillage systems

[84] Fernàndez et al. (2015)

[85] USA, Fernàndez et al. (2015)

[86] Madejón et al. (2009)



A degree of assurance for phosphorus and potassium (according to the AL method) for the content of readily available phosphorus and readily available potassium is 15 to 25 mg/100g.[87]

Phosphorus is included in the group of necessary macroelements. It affects blooming and fertilization of plants, as well as physiological processes in plants. Phosphorus, as a very important macroelement in plant nutrition, is almost immobile in the soil due to its characteristics. Practically, where you leave it, it stays there. By mixing the layers in turning over the layers several times, during ploughing, it is distributed by depth and the results show its uniform content in the form of easily accessible phosphorus in the form of P_2O_5, which is almost uniform for all three depths. As the processing intensity decreases, the content of this element changes in depth. In the 0 to 10 cm layer, it is higher in all conservation tillage systems compared to the classic one (ploughing). The highest content is in the no-till system because it is absent, and the mineral fertilizer is either scattered on the surface or introduced by depositors during sowing. This is also typical for a layer of 10-20 cm, with the fact that in zonal cultivation, the depositing of fertilizers is linked to the working body that places the mineral fertilizer, during processing, 5 cm shallower than the specified depth of processing. In this way, the 10-20 cm layer turns into a "reservoir" of this element. In the 20-30 cm layer, the content of this element is slightly higher with zone tillage and without tillage if we compare it with ploughing. The lowest content, in the 20-30 cm layer, is in the system without processing. This is also an indicator that the plant at this depth, of all three layers, uses phosphorus the most (Figure 16).

[87] Manojlović, (1986)

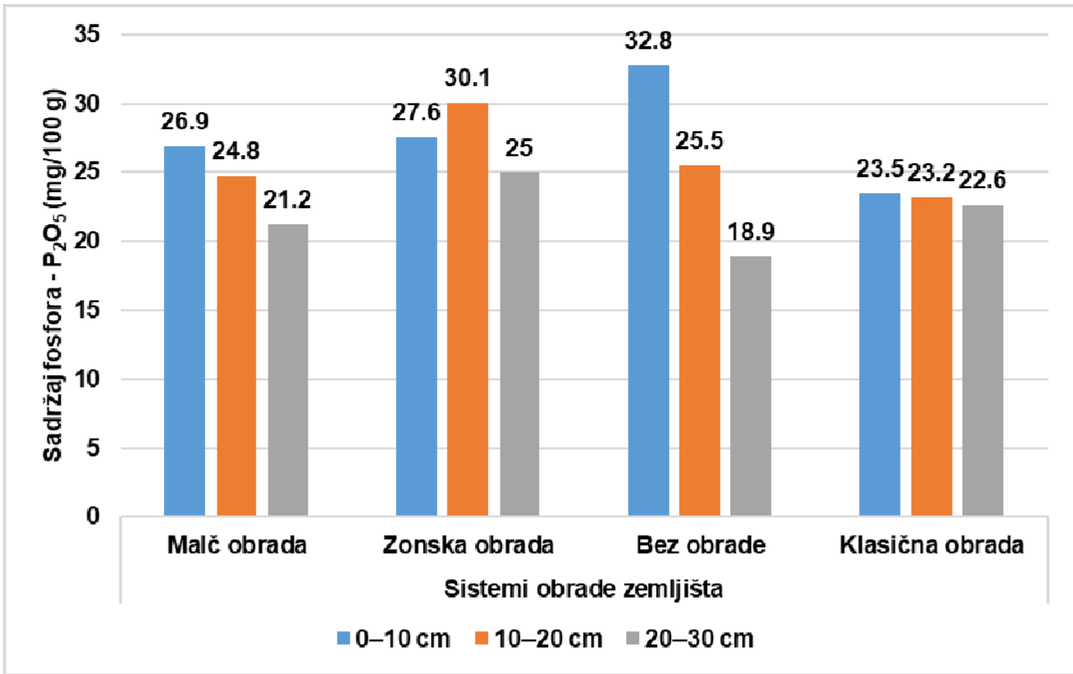


Figure 16. Content of easily accessible phosphorus in the soil in different tillage systems

Potassium plays a key role in plant health and growth, where it participates in metabolism, nutrient transport and carbohydrate storage. Potassium regulates water use in plants, helping them stay hydrated in stressful drought conditions.

Based on the results, it was determined that the potassium content is significantly higher in soil conservation tillage systems compared to conventional tillage, especially in the 0-10 cm sowing layer due to the large amount of crop residues on the surface that are exposed to more intense decomposition compared to the crop residues moved into depth. Mixing of harvest residues, in a layer of 0-10 cm, in addition to minimal processing or without processing, is also done under the activity of macro and micro organisms. The consequence of the high content of this element in classic processing in a layer of 10 - 20 cm is the very method of overturning the plastic during ploughing, the angle of which is 132 - 135^0, where during processing at a depth of 30 cm, the harvest residues, from the surface, are distributed in the layer 15 - 22 cm (more than 70% of body weight) (Figure 17).

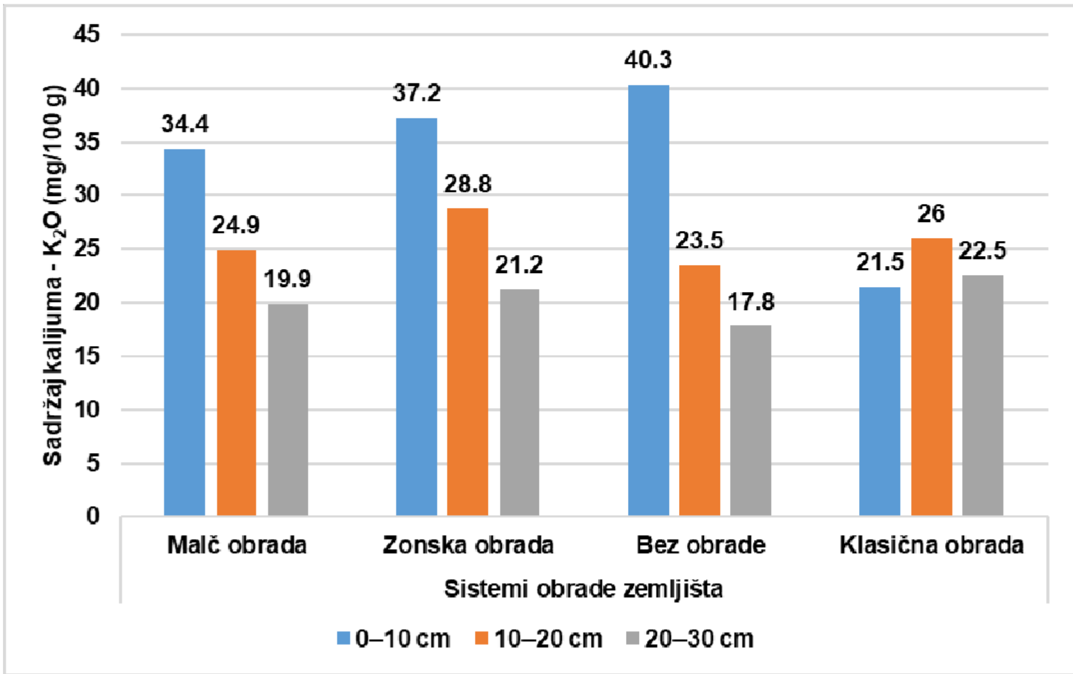
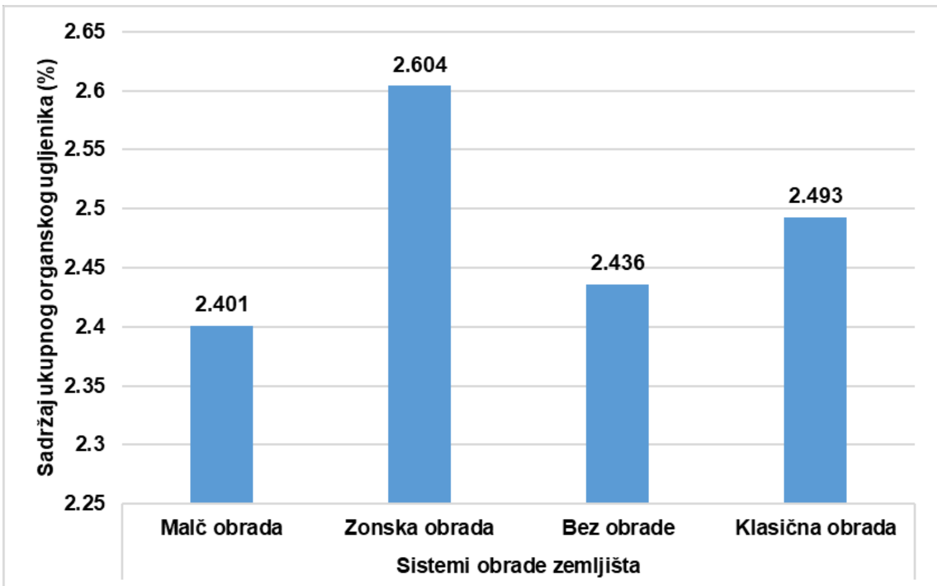


Figure 17. Potassium content in soil in different tillage systems

Organic carbon has a positive effect on the physical, chemical and biological properties of the soil, and it is introduced into the soil through the application of organic fertilizers.[88] Increasing the stock of organic carbon in the soil mitigates the impact of agriculture on CO_2 emissions.[89] **Total organic matter content of carbon is the highest in the zonal tillage system (2.604%),** while the content is in the others systems, including the classic tillage system, was significantly lower and ranged from 2.401% in the mulch tillage system to 2.493% in the classic tillage system (Fig. 18).



[88] Manojlović, (2008)

[89] Smith et al. (2008)

Figure 18. Content of total organic carbon in the soil in different tillage systems

6.2.1. Yield of major crops on conservation tillage plots compared to conventional crop cultivation practices

A comparative analysis of different processing systems in terms of the grain yield of the main crops (winter wheat, oilseed rape, corn and sunflower with respect to the crop rotation of oilseeds) was carried out on an experiment carried out at the Research and Development Institute Tamiš in Pančevo. The yield of field crops is ranked from 1 to 4, where rank 1 represents the highest yield, and rank 4 the lowest yield in the seven-year period of the experiment (2017 do 2023).

By comparing data on the amount of yield obtained in the period 2017-2023 in the system without tillage and classic ploughing with a field plough, it is noted that in the seven-year period the rank of classic tillage is better compared to the system without tillage. In this particular case, the reason lies in the fact that suitable seed drills were not always used for sowing in the no-till system, especially when it comes to sowing hoe-maize and sunflower and sowing oilseed rape, which was at a distance of 50 cm from row to row. The seed drills could not achieve a uniform arrangement in the row and a uniform sowing depth with the problem of cutting a large amount of harvest residues if the pre-crop is winter wheat. The seeders used for short-term sowing, for winter wheat, were seeders for the no-tillage system, which also sow classic tillage. The opposite is not possible. Having this in mind, it can be said that the availability of adequate mechanization is a key limiting factor for the wider use of conservation crop cultivation systems in Serbia, but it is also an important factor that affects the yield. A study[90] showed that under semi-arid conditions a no-tillage system produced a higher yield of durum wheat compared to the yield obtained in a conventional tillage system. Another analysis[91] reached a similar conclusion for the Foggia region of Italy, where low rainfall was recorded, stating that the no-till system was more suitable for achieving higher wheat yields compared to conventional tillage. The mentioned authors stated that the reason for the higher yields in the no-till system is that the no-till system reduces the evaporation of water from the soil (evapotranspiration) and improves the availability of water in the soil compared to the conventional tillage system. Therefore, in conditions of drought, or lack of precipitation, conservation tillage systems are more suitable for achieving higher yields compared to conventional tillage systems.

Table 8. Number of years of yield rank (sum of yield ranks) of crops in different processing systems in a seven-year period (2017–2023) during a trial conducted at the Tamiš Research and Development Institute in Pančevo.

[90] Baiamonte et al. (2019)

[91] De Vita et al. (2007)

Processing System/Rank *	1	2	3	4
Mulch treatment	3	2	1	1
Zone processing	3	3		1
Without processing	1		3	3
Conventional treatment	1	2	2	2

***1 – the highest yield in the observed year, 4 – the lowest yield in the observed year for the cultivated crop**

6.2.2. Identifying differences in the number of operations and energy consumption in production based on the principles of conservation and conventional tillage

In recent decades, the concentration of greenhouse gases such as methane, carbon dioxide and nitrogen oxides in the atmosphere has been increasing. Current climate changes bring ever-increasing temperatures, more frequent periods of drought or excess precipitation, and weather events, which represent a major challenge for new approaches and technologies in agriculture. The Intergovernmental Panel on Climate Change (IPCC) predicts an increase in global temperatures of at least 1.5 °C by the end of the 21st century. Agriculture is the source of over 10% of global greenhouse gas emissions and about half of non-CO_2 greenhouse gas emissions.[92] Intensive tillage, together with higher temperatures and other events, contribute to the loss of soil organic matter, increase CO_2 emissions into the atmosphere and, as a consequence, result in loss of soil fertility, disruption of soil aggregates and soil losses due to increased erosion.[93] Therefore, it is necessary to find solutions to reduce greenhouse gas emissions in agriculture, while maintaining productivity and economic profitability.

The intensity of soil cultivation can have different effects on the loss of carbon and nitrogen gases into the atmosphere (Figure 19). Moreover, during another analysis [94] research was conducted to determine how tillage intensity affects greenhouse gas emissions by comparing experimental data from different types of ploughing and no-till systems after 40 years of growing corn and soybean crops. Based on the data of a long-term experiment, the aforementioned authors determined that the system without processing proved to be the most effective for reducing CO_2 losses in the atmosphere. According to further research conducted in[95] in the Czech Republic,

[92] Jaskulski et al. (2023)

[93] Melero et al. (2009) ; Chi et al. (2017).

[94] Ruiz et al. (2022)

[95] Mühlbachová et al. (2023)

where investigated CO_2 emissions in different tillage systems, found that reduced tillage practices and no-tillage practices reduced CO_2 emissions compared to conventional tillage by an average of 45 and 51%, respectively. In general, ploughed soils have better aeration (better access to oxygen), which accelerates the mineralization (decomposition) of organic matter in the soil and consequently leads to higher CO_2 emissions.

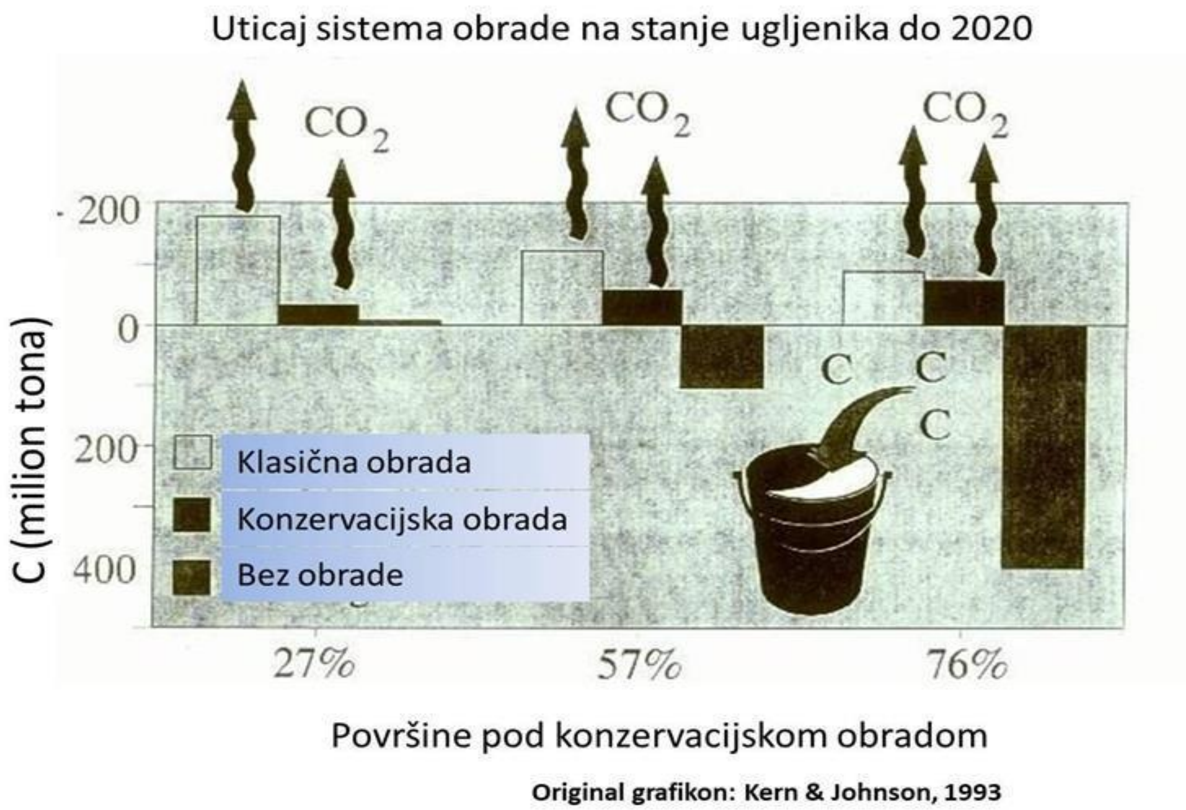


Figure 19. The impact of processing systems on the carbon situation by 2020 (http://www.rolf-derpsch.com/en/no-till/sustainability/#c545)

Table 8. Soil conditions in conventional and conservation tillage in rainy and dry seasons conditions

Depth (cm)	Conventional processing (classic)		Conservation treatment	
	Rainy season	Dry season		Rainy season
0–25	Water retention to a compacted layer	Drying of the layer, formation of lumps/dust, additional compaction and impermeability	Preservation of structure layer, permeability layer, moisture preservation	Minor damage during operations and transport, ability bandwidth redundancy humidity

25–30	Appearance and expansion compacted layer	Limited infiltration of water	Normal transport of water in the loose form layer	There is no compaction or additional compaction layer
Over 35	Lack of water and air	Unused layer, not able to supply plants with water	Used layer, able to supply plants with water	Water storage necessary for cultivation Plants

Table 9. Advantages and disadvantages of conventional (classical) and conservation tillage

CONVENTIONAL (CLASSIC) PROCESSING	
Advantages	**Disadvantages**
Suitable for heavy draining soils. Without herbal residues on the surface. Excellently processed surface for sowing.	The moment of ploughing is important. High fuel consumption and labour intensive.
CONSERVATION TREATMENT	
Advantages	**Disadvantages**
Less erosion, more residue. Well adapted for hard to drain soils. Good intake of the greater part of plant residue. Conservation of moisture in the soil. Reduced operation and labour costs. Improves soil structure and its basic properties (soil health).	Plant residue on the surface. Increases dependence on herbicides. Slower soil heating on hard draining soils. Higher compressibility of wet land. For better quality of operations and sowing plant residue needs shredding.

Table 10. Agro-technical operations in different tillage systems

Agro-technical operation	Classic	Reduced	Conservation	Without processing and regenerative
Basic and pre-seeding Fertilization	YES	YES	YES	WITHOUT
Basic processing	Plough	Disc harrow /2×	Ripper/protective treatment	WITHOUT
Pre-sowing preparation	YES	WITHOUT	WITHOUT	WITHOUT
Sowing	YES	YES	YES	YES/option with fertilizers
Rolling (for stubble)	YES	YES	YES/NO	WITHOUT
Supplementation *	YES	YES	YES	YES*

Plant protection **	YES	YES	YES	YES
Harvest	YES	YES	YES	YES
Stubble cultivation	YES	YES	YES	WITHOUT
Sowing of the cover crops***	NO	NO	YES	YES

* means that it can be done once or twice, or it is not done at all - it refers to regenerative if the application of fertilizers is stopped and cover and intercrops are introduced

** protection can be done multiple times in all systems. Over time, the number of treatments in the no-till/no-till system is reduced

*** with regenerative, it is important to sow cover crops, without cultivation/direct sowing, in the stubble after harvesting wheat or other crops that leave the plot in the 7th month

If you look at the previous table, you can see that in the system of direct sowing, which is the basis of Regenerative Agriculture, soil cultivation is absent and only sowing is done (tab. 10). At the basis of conservation agriculture is also the attitude of minimal or omitted processing in the production of crops.

In order to do the sowing, it is necessary to have a seeder that can open the soil to the planned depth, place the seeds and close the furrow. It is also important, since our surface is covered with plant residue from the previous crop, that it is cut, moved to the left or right or the sowing is done by moving under the residue. This tells us that the seeder is the most important factor for the sowing itself. Other necessary pieces of machinery are the spreader and sprinkler, and they have been already acquired for the "old" production.

In order for the above to happen, it is necessary that, during the harvesting process, the stems and leaves of the forage are well chopped and evenly distributed over the surface, creating mulch. In some cases, when the sowing of wheat is done after the corn, the harvest residue can be used for the needs of livestock, which facilitates the sowing of the crop. Here, we do not have a problem with leaving the surface bare in the fall, during the winter, and until spring, as in the case of the sowing of tillage (corn, sunflower, soybeans). High quality preparation of harvest residue can be obtained by paying for the harvesting service, if such a combine harvester is not owned. On the other hand, you can use a shredder of harvest residue or a mulcher, which would take care of it.

The transition to a production system in which there is no processing, for smaller producers, must be gradual. It cannot take place on all plots at once. The plots should be selected, the sowing structure should be determined, i.e. put in the third or fourth crop, do a fertility analysis and, if necessary, add what is missing from the nutrients and only then start the transfer. If the producer already has analyses, applied nutrients or some other fertility repair operation, all he has to do is to start the change.

It is difficult to determine whether to start in the production of stubble or wide-row crops. From our side, starting with stubble is simpler, especially if we are related to animal husbandry (dairy and cattle breeding), where in addition to stubble, we can sow mixtures for green mass or hay, which are sown with the same seeder. If we are talking about smaller producers, seed drills for sowing without tillage can have a working reach of 1.5-3 m, carried or pulled by tractors up to 75 KW (100 HP).

Once one starts with the omission of tillage, a return to classical tillage, ploughing, would be the destruction of everything that was done with the aim of preserving and improving the quality of the soil, reducing the emission of gases and stored carbon.

6.3. The Level of CO_2 Emissions Due to Agro-Technical Measures in the Primary Crop Production Process

For the purposes of the implementation of the Project, a survey was conducted in the territory of the Republic of Serbia, which included 170 agricultural farms in the territory of the following cities and municipalities: Loznica, Kragujevac, Požarevac, Čačak, Sombor, Zrenjanin, Negotin, Sremska Mitrovica, Vrbas, Subotica and Pančevo.

The results of the survey showed that in the production structure of agricultural holdings, the cultivation of corn is dominant, followed by sunflowers, wheat, then soybeans, barley and rapeseed.

Based on the results of the survey, the calculation of the carbon footprint was performed on the production plots of the farms included in the survey, in accordance with the implemented operations in the technology of growing different crops. Identified operations that contribute to the emission of carbon dioxide during the cultivation of arable crops at the investigated farms are: management of harvest residue, production of fertilizers, applied fertilizer, protection of crops, and energy used in the production process. The obtained results showed that the CO_2 emissions of all analysed crops, except soybeans, are contributed the most by fertilizer (from 167.13 kg CO_2/ha for sunflower to 451.57 kg CO_2/ha for corn), that is, CO_2 emissions that occur in the production of fertilizers. In the case of soybeans, CO_2 emission is contributed more by the energy consumed during the implementation of agro-technical operations in the field (200.96 kg CO_2/ha) than by the emissions produced in the production of fertilizers (156.55 kg CO_2/ha). Soy is a crop from the leguminous group (legume) and has the ability to fix nitrogen, so it has less nitrogen requirements. For this reason, significantly smaller amounts of mineral fertilizers are used in the production of soybeans compared to other crops.

The CO_2 emission that occurs during the management of plant residue, i.e. during the shredding of crop residue or ploughing, ranges from 23.02 kg CO_2/ha in the production of rapeseed to 165.89 kg CO_2/ha in the production of corn. The implementation of crop protection measures contributes the least to CO_2 emissions. CO_2 emission resulting from the implementation of crop protection measures ranges from 3.73 kg CO_2/ha in corn production to 6.35 kg CO_2/ha in soybean production (Table 11).

Table 11 - Emission of carbon dioxide per hectare (kg CO_2/ha) in the production of the main arable crops, expressed by operation

Operation	Crop					
	Corn	Wheat	Soybean	Barley	Rapeseed	Sunflower
Residue management	165,89	105,54	24,48	151,95	23,02	37,61
Fertilizer production	476,73	703,17	218,12	404,89	500,9	279,92
Fertilizer	451,57	340,95	156,55	363,82	339,11	167,13
Crop protection	3,73	4,25	6,35	3,53	5,6	6,18
Energy consum. (field)	279,68	160,8	200,96	367,93	14,66	166,55

The total CO_2 emission per hectare, expressed as kg CO_2/ha, represents the CO_2 emission value which have all operations carried out in the production of a given field crop. The largest total emission of CO_2 is represented in the production of corn and amounts to 1428.48 kg CO_2/ha. The total emission of CO_2 during the production of wheat amounts to 1314.46 kg CO_2/ha, then during the production of barley 1290.45 kg CO_2/ha. The total emission of CO_2 during the production of rapeseed, sunflower and soybeans is significantly lower and amounted to 883.31, then 657.24, and 606.5 kg CO_2/ha, respectively (graph 11).

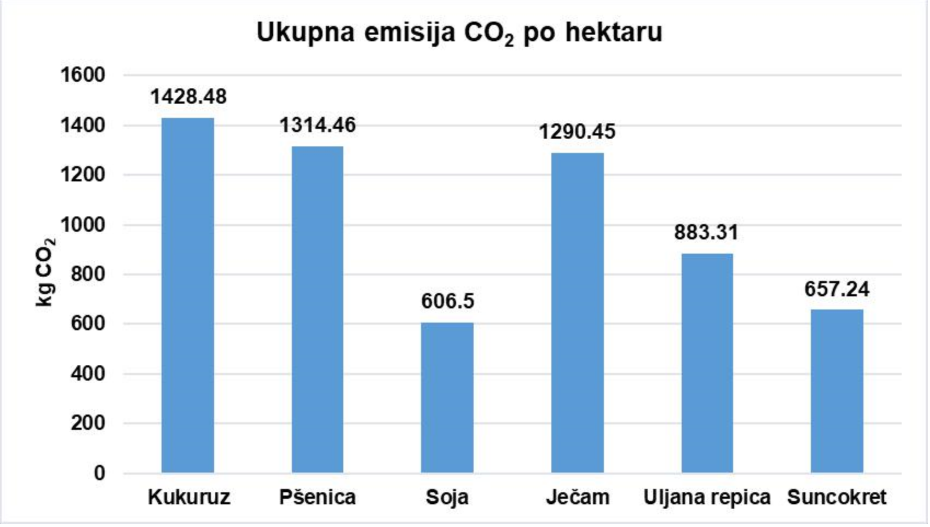


Figure 20. Total carbon dioxide emissions per hectare in the production of the main crops

6.3.1. Emission of carbon dioxide per hectare by production systems and crops

Based on the conducted questionnaire, it can be concluded that the conservation and conventional tillage systems are applied to corn, wheat and barley crops; that in the cultivation of rapeseed, the conservation cultivation system is dominantly applied; and that with soybeans and sunflowers, only the conventional variant of processing is practiced. For this reason, for further analysis of the differences in carbon dioxide emissions between processing systems, only the data for corn, wheat and barley are comparative (table 12).

The obtained results of the research indicated that when growing corn, wheat and barley in the conventional and conservation system of processing, there are the following differences in CO_2 emissions:

- In corn production, the following emission values were established: 1429 kg CO_2/ha in conventional cultivation, and 1410 kg CO_2/ha in conservation.
- In the case of wheat, it was determined that the average carbon dioxide emission in the conventional system is 1340.7 kg CO_2/ha, and in the conservation system is 1289.7 kg CO_2/ha.
- The average carbon dioxide emission in conventional processing, in the production of barley, is 1450 kg CO_2/ha, and in conservation processing it is 811.8 kg CO_2/ha.

In general, it can be concluded that conservation treatment contributes to lower carbon dioxide emissions compared to conventional treatment.

The test results showed that some producers applied mineral fertilizers, formulations, types and amounts, as well as pesticide protection uniformly on all plots under the same crops, regardless of soil type, pre-crop, cultivation or fertility of the plot, which is a consequence of insufficient knowledge about cultivation systems.

That being said, the priority of future research should be improving the knowledge of agricultural producers in the field of sustainable agriculture, with an emphasis on regenerative or conservation systems of agricultural practice.

Table 12. Emission of carbon dioxide per hectare (kg CO_2/ha) in the production of the main arable crops by cultivation systems

Processing	CO₂ emission (kg/ha)		
	Corn	Wheat	Barley
Conventional	1429	1340,7	1450
Conservation	1410	1289,7	811,8

6.3.2. Differences in carbon dioxide emissions between processing systems

For the purposes of this research, the data of the Tamiš Research and Development Institute in Pančevo, obtained at the Institute's Experimental Field in the production year 2021/2022, were used. The data refer to the production of winter wheat, which was grown in a no-till system, i.e. direct sowing, on an area of 45 ha.

Winter wheat has been grown in the system of reduced tillage, with the use of disc harrows, on the Institute's Experimental Field since the mid-80s of the 20th century, which is a relevant fact for comparing emissions in relation to direct sowing of this crop. The results showed that the no-tillage system had lower CSO_2 emissions compared to reduced tillage by 155 kg/ha CO_2 (Table 13).

Table 13. Emission of carbon dioxide per hectare on different cultivation systems and in different crops on the Experimental Field of the Tamiš Research and Development Institute in Pančevo 2021/22

Processing system	Crop	CO_2 emission (kg CO_2/ha)
Conservation without processing	Wheat	1415,0
Conservation Reduced-disking	Wheat	1570,0
Conservation Reduced-disking	Rapeseed	886,05
Conventional	Corn	1247,5
Conventional	Sunflower	668,14
Conventional	Soybean	524,61

If the differences in carbon dioxide emissions between operations in reduced tillage systems are analysed, it can be noted that except for the use of mineral fertilizers and pesticides, CO_2 emissions are lower in the system without tillage compared to reduced tillage. Smaller amount of energy in the direct seeding system is consumed due to the smaller number of passes, considering that in this system only sowing is done without basic processing and pre-sowing preparation (Table 14).

Table 14. Emission of carbon dioxide per hectare (kg CO_2/ha) in the production of winter wheat in two processing system, expressed by operation

Operation	Winter Wheat	
	Conservation without processing	Conservation reduced-disking
Residue management	121,17	124,63
Fertilizer production	936,52	1090,0
Fertilizer	335,25	335,25
Crop protection	7,26	7,26
Energy consumption (field)	6,75	10,92

Sources

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Used for the weight-based emission factors for the production and processing of the following agricultural products:
Sour-cherries (Cherries used as a proxy), Tomatoes, Cabbage, Pears, Plums, Maize to canned corn, Rapeseed to rapeseed oil, Potatoes to chips, Sour-cherries – frozen (Raspberries – frozen used as a proxy), Raspberries - to marmalade

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