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# Sustainable transition of the Republic of Serbia: measuring capacity for circularity in agriculture and rural areas

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## Abstract

**Background** The Republic of Serbia (RS) is strategically oriented towards sustainable development, but the implementation thereof faces different limitations and problems. RS emits substantial pollution caused by fossil fuels, and pollution from agricultural sector characterized by inefficient use of energy and intensive use of fertilizers. Bearing in mind the significant agricultural capacities and the orientation towards rural development, a special green transformation must be implemented in this domain. Taking into account the specificities and tradition, the introduction of the circularity concept can be considered the most acceptable. Research on readiness for transition to circularity in RS rural areas has not been conducted; therefore, the goal of the paper is to develop a concept for assessing the capacity of rural areas for circularity. This study is the first scientific proposal that aims to provide input for policymakers, thus contributing to the creation of a new identity of RS, whose development is based on the principles of sustainability.

**Methods** The study was conducted as conceptual research, with the objective of examining an undiscovered phenomenon without empirical evidence and incorporating the targeted phenomenon into a conceptual framework, while providing a proposal for a solution model based on an interdisciplinary approach—the application of qualitative and quantitative methods (aggregation of composite indicators and Delphi method).

**Results** Paper results can be summarized as follows: (a) qualitative analysis of policy framework related to RS transition towards circularity (which shows that regulation is insufficient or non-existent, so conceptual research at this stage is necessary and only possible); (b) research questionnaire; (c) original set of indicators for measuring capacity for circularity (derived from the questionnaire); (d) concept of index of capacity of agriculture and rural areas for circularity (based on a set of indicators); and (e) concept of the monitoring of circularity implementation.

**Conclusions** The main research findings presented in this paper could be beneficial for countries at early stages of introducing circularity, having both low and high agricultural potential. With slight modifications, they can also be applied to other economic activities.

**Keywords** Sustainable development, Climate change, Agriculture, Rural development, RS, Measuring capacity for circularity

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## Background

The agricultural sector is of particular importance for the development and stability of each individual country, as well as for the well-being of humanity [1], especially in developed and poor countries [2]. RS is mainly an agricultural country, where rural areas cover most of its territory, as shown in Fig. 1 [3]. Rural areas are exposed to severe pollution of soil, air, and water due to burning agricultural waste. Despite a significant percentage of arable land and a wide range of different soil types that still exist in these areas, RS is faced with pollution that leads to soil degradation by 33%. Soil quality in RS is systematically monitored according to a Soil Framework Directive recommendation [4]. Inadequate waste management, together with inappropriate use of chemicals, are the main pollutants of agricultural land in RS. Lack of institutional capacities, insufficient funding, insufficient integration of systemic monitoring, and the existence of legal gaps, are some of the main causes of pollution problems that RS faces.

The agricultural sector of RS is in a similar position as in a large number of developing countries, where the main goal is to feed the population and earn income through exports. Intensive agriculture, enabling high

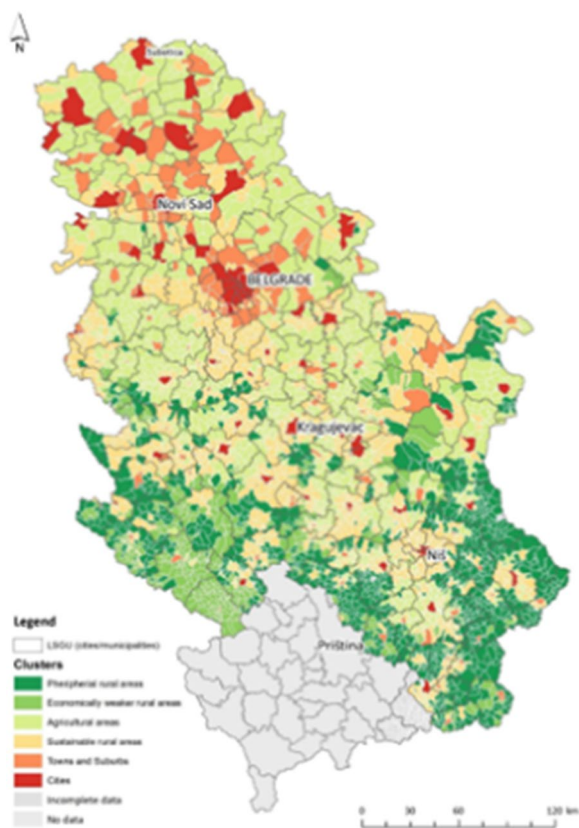
yield, is possible only with the use of several means to promote growth, to control weeds, disease, and pests. However, the use of said means leads to contamination of soil, water, and food, as the end products, which all have and will have a negative impact on sustainability in the coming decades [5].

As the world population is expected to increase by one-third by 2050, the best estimates indicate the need to increase agricultural and food production by two-thirds by 2050 to provide enough food for the increased population [6]. An increased impact of climate change on agricultural systems is expected; rising temperatures and changing precipitation patterns increase the likelihood of a decrease in crop yields, along with an increase in the occurrence of weeds and pests on agricultural land [7].

Conventional agriculture is one of the key drivers of greenhouse gas (GHG) generation due to the use of synthetic fertilizers, pesticides, heavy machinery, monocultures, land conversion, deforestation, waste, and transport. It significantly contributes to global climate change [8] especially in countries at a lower level of development, like RS [9]. Conventional farming practices, from industrial animal feeding operations to corn and soybean monocultures fertilized with synthetic fertilizers and formation of genetically modified crops to tolerate large amounts of herbicides, not only contribute to generation of GHGs, but may also contribute to creating an unequal and unhealthy global food system [10].

Contemporary conventional agriculture is an energy-intensive fossil-fuel-based industry that greatly contributes to climate change [11]. On the other hand, the farmers themselves have been negatively impacted by climate change for decades, and these impacts have worsened significantly in recent years. Even a relatively small increase in temperature has significant impacts on agriculture, including accelerated degradation and salinization of arable land, increased presence of pests, crop losses due to high temperatures and floods and increased scarcity of clean water [12].

According to FAO reports, the agricultural sector, in the context of direct and indirect emissions, is responsible for about 30% of global warming [13]. Direct emissions from agriculture, according to the data from the Intergovernmental Panel on Climate Change (IPCC), currently account for 10–12% of global gas emissions with greenhouse effect (GHG), and that amount is expected to increase. GHGs attributed to agriculture include emissions from soil, enteric fermentation (from the digestive process of ruminant animals), rice production, biomass burning and inadequate manure management. Indirect sources of greenhouse emissions that are not calculated by the IPCC in agriculture are those caused by changes in land use, the use of fossil fuels for mechanization,



**Fig. 1** Rural and urban areas of Serbia

transport, fertilizers, and other agrochemicals [14]. The most significant indirect emissions are changes in natural vegetation and traditional land use, including deforestation, biomass burning and land degradation [15].

In the current context of resource scarcity, global climate change, environmental degradation and increasing demand for food, the circular economy represents a promising strategy to support sustainable, restorative, and regenerative agriculture [16] with increased energy efficiency and reduced impact on climate change [17]. The circular economy is designed as a model to comprise circular flows that include reuse, repair, renewal and recycling of existing materials and products as long as possible, in order to achieve a product life span [18].

There is no single definition of circular economy, but circular economy can be regarded as a departure from the traditional, linear economic model, which is based on the principle of take–make–consume–throw. This model relies on large amounts of cheap, readily available materials and energy [19]. Part of this model is planned obsolescence, that is, a departure from the practice of designing a product to have a limited life span so that consumers must buy it again.

The world population is growing, and so is the demand for raw materials. However, the supply of key raw materials is limited [20]. In addition, the extraction and use of raw materials has a negative impact on the environment. The transition to a circular economy implies smarter use of raw materials, which can reduce CO<sub>2</sub> emissions, but the implementation of which requires, primarily, recognition and acceptance by all stakeholders [21]. Thus, this transition would have multipurpose benefits, such as reduced environmental impact, raw material supply security, increased competitiveness, stimulation of innovation and economic growth, as well as the opening of opportunities for new jobs. Consumers will also benefit from more durable and innovative products that will increase quality of life and save money in the long run [22].

The action plan for the circular economy, presented by the European Commission in March 2020, was based on the promotion of sustainable product design, reduction of waste generation, and strengthening of consumer rights. The focus is not only on strengthening the sectors in the field of electronics, information technology, plastics, textiles and construction in order to achieve a reduced carbon footprint, but also on ecologically sustainable circular economy by 2050 as well as on stricter rules related to recycling and the use of binding materials and consumption by 2030 [23]. In March 2022, the European Commission announced the first package of measures to accelerate the transition from the linear to the circular economy [24]. The proposals include the creation of sustainable products, strengthening and raising awareness of the population

towards the green transition, revising product regulations and designing a strategy for textiles. After that, in November 2022, the Circular Economy Package II was adopted. It sets new rules for product packaging in the EU, with the aim of reducing the occurrence of packaging waste and improving product design with reuse and recycling clearly stated and promoted, as well as raising awareness about the use of biodegradable plastics [25].

## Methods

The research methods were chosen in accordance with the research goal, i.e., a proposal for a novel research concept for determining the capacity for circularity, which has never been implemented in RS. The methodology itself is unknown and has therefore been designed as conceptual research.

The research is based on the application of qualitative and quantitative approaches. Qualitative research was conducted by looking at the available, very limited literary sources and official documents of RS related to circularity, agricultural development, rural development, and sustainable development as a whole.

Based on that, a research questionnaire was defined and adapted to the specificities of RS and its rural areas, while respecting the state's strategic determination for sustainable development, which is also reflected through scientific work, in this case through the priorities of the Science Fund of the Republic of Serbia.

The conceptual research on which this work is based does not contain empirical data (which do not exist for RS), but provides key phenomena that should be defined through the presentation of the following:

- a) Existing knowledge on the given issue (policy framework and initiatives on the circular economy);
- b) Definition of the problem (absence of a research concept or a methodology for measuring the capacity for circularity in RS);
- c) Proposal for solving the problem (modeling of the research and the capacity for measuring the capacity for circularity in selected parts (agriculture and rural areas): defining research methods, research questionnaire, and measurement tools), as input for policy-makers.

It is necessary to emphasize that the research is carried out and the proposals are given for RS. However, they can certainly be considered acceptable for the countries of the Western Balkans, as well as for other countries that have decided to implement circularity in rural development, but do not have enough knowledge or data input to define related policies.

## Results

### Circular economy in the Western Balkans—policy analysis

*The Sofia Declaration on the Green Agenda for the Western Balkans* is a document adopted by the leaders of the European Union and the Western Balkan countries on 10 November 2020. The Declaration aims to support the Western Balkan countries in their transition towards a more sustainable and greener future, while also promoting regional cooperation and EU integration [26].

The Declaration recognizes the urgent need to address the environmental challenges facing the Western Balkan region, including air pollution, water scarcity, deforestation, and climate change. It emphasizes the importance of promoting sustainable economic growth, improving the quality of life of citizens, and protecting the natural resources of the region.

The Sofia Declaration outlines several key areas of action to achieve these goals, including: promoting sustainable energy, improving air quality, protecting biodiversity, strengthening regional cooperation and supporting EU integration. In terms of promoting sustainable energy, the Declaration calls for increased investment in renewable energy sources and the promotion of energy efficiency to reduce greenhouse gas emissions and promote sustainable economic growth. Declaration recognizes the serious health risks associated with air pollution in the region and calls for measures to improve air quality, such as the adoption of stricter emission standards and the promotion of public transportation. Moreover, the Declaration highlights the need to protect and restore the rich biodiversity of the Western Balkans, including the region's forests, rivers, and wetlands. The importance of regional cooperation in achieving these goals and calls for increased collaboration between the Western Balkan countries and the EU is emphasized as well. Furthermore, the Declaration reaffirms the EU's commitment to supporting the Western Balkan countries on their path towards EU integration, including through financial assistance and technical support.

Overall, the Sofia Declaration on the Green Agenda for the Western Balkans represents an important step towards a more sustainable and greener future for the region. By promoting sustainable economic growth, protecting natural resources, and strengthening regional cooperation, the Declaration has the potential to improve the quality of life for citizens in the Western Balkans and support the region's long-term development.

Additional details on the Sofia Declaration on the Green Agenda for the Western Balkans are as follows:

1. Strengthening climate action: The Declaration recognizes the urgent need to address climate change and calls for increased climate action, including the adoption of more ambitious emission reduction targets and the development of adaptation strategies.
2. Improving waste management: The Declaration highlights the need to improve waste management practices in the region, including reducing waste generation, and promoting recycling and circular economy principles.
3. Supporting green investments: The Declaration calls for increased investment in green infrastructure, including renewable energy projects, sustainable transport systems, and nature-based solutions.
4. Promoting sustainable agriculture: The Declaration recognizes the importance of sustainable agriculture in promoting rural development and reducing environmental impacts and calls for measures to support the development of sustainable agriculture practices in the region.
5. Strengthening environmental governance: The Declaration emphasizes the need for effective environmental governance systems in the Western Balkans, including strengthening environmental institutions and improving regulatory frameworks.

The Sofia Declaration on the Green Agenda for the Western Balkans also recognizes the important role of civil society, the private sector, and other stakeholders in achieving these goals. It calls for increased engagement and participation of these actors in the development and implementation of green policies and initiatives.

In addition, the Declaration highlights the importance of alignment with EU policies and standards in promoting sustainable development in the Western Balkans. It calls for increased cooperation and dialogue between the Western Balkan countries and the EU to promote a harmonized approach to environmental and climate policies.

*The Action Plan of the Sofia Declaration on the Green Agenda for the Western Balkans* is a detailed document that outlines specific steps and measures to be taken by the Western Balkan countries and the European Union to implement the Declaration's vision for a more sustainable and greener future for the region. It also calls for the implementation of measures to reduce greenhouse gas emissions, including through the promotion of renewable energy sources, energy efficiency, and sustainable transport. The Action Plan is organized around six key thematic areas [27]:

1. Environment and health: The Action Plan prioritizes measures to improve air and water quality, reduce exposure to hazardous chemicals, and promote sustainable waste management practices. It also calls for the strengthening of environmental governance



systems and the promotion of public participation in environmental decision-making processes.

2. **Circular economy:** The Action Plan promotes the development of circular economy practices in the region, including the reduction of waste generation, the promotion of recycling and reuse, and the development of sustainable production and consumption patterns.
3. **Biodiversity:** The Action Plan emphasizes the importance of protecting and restoring the biodiversity of the Western Balkans, including through the implementation of measures to preserve forests, rivers, and wetlands. It also calls for the promotion of sustainable agriculture and the conservation of endangered species.
4. **Sustainable connectivity:** The Action Plan highlights the importance of sustainable transport infrastructure in promoting regional integration and reducing carbon emissions. It calls for the development of sustainable transport systems, including the promotion of electric and hybrid vehicles, the expansion of public transport networks, and the development of cycling and walking infrastructure.
5. **Governance:** The Action Plan prioritizes the strengthening of environmental governance systems in the region, including the development of regulatory frameworks, the strengthening of institutional capacity, and the promotion of transparency and accountability in environmental decision-making.

The Circular Economy is a significant focus area in the Sofia Declaration on the Green Agenda for the Western Balkans. It is one of the six thematic areas of the Action Plan and has its own dedicated roadmap for implementation. The Declaration recognizes that the transition to a circular economy is a promising direction that can significantly contribute to achieving sustainable development in the Western Balkans and for supporting the global efforts for climate change and environmental degradation.

The Circular Economy roadmap sets out a range of specific measures to promote the transition to a circular economy in the Western Balkans. These measures include reducing waste generation, promoting recycling and reuse, and developing sustainable production and consumption patterns. The roadmap also emphasizes the importance of cross-sectoral collaboration, stakeholder engagement, and capacity building to support the implementation of circular economy measures. The Sofia Declaration recognizes the potential benefits of a circular economy for the Western Balkans, including job creation, resource efficiency, and reduced environmental impact. It also recognizes the role of the EU in supporting the

transition to a circular economy in the region, including through financial support, technical assistance, and capacity building.

Overall, the Sofia Declaration recognizes the importance of the circular economy as a key component of the Green Agenda for the Western Balkans. The Circular Economy roadmap provides a detailed plan for implementing specific measures to promote the transition to a circular economy in the region. The successful implementation of these measures will depend on the commitment and cooperation of all stakeholders, including the Western Balkan countries, the EU, civil society, and the private sector.

Overall, the Action Plan of the Sofia Declaration on the Green Agenda for the Western Balkans provides a detailed roadmap for action in key areas of environmental and climate policy. Its focus on regional cooperation, stakeholder engagement, and EU integration is likely to support the region's long-term sustainable development goals. However, the successful implementation of the Action Plan will depend on political commitment, adequate financial resources, and effective coordination and collaboration between the Western Balkan countries and the EU.

*Part 2 of the Sofia Declaration on the Green Agenda for the Western Balkans* outlines the roadmaps for the implementation of the Declaration's Action Plan. The roadmaps provide a detailed plan for the Western Balkan countries and the European Union to achieve the goals set out in the Action Plan. The roadmaps are organized according to the six thematic areas of the Action Plan:

1. **Climate action:** The Climate Action Roadmap sets out specific measures to reduce greenhouse gas emissions in the region, increase the share of renewable energy, improve energy efficiency, and develop adaptation strategies to address the impacts of climate change.
2. **Environment and health:** The Environment and Health Roadmap prioritizes measures to improve air and water quality, reduce exposure to hazardous chemicals, promote sustainable waste management practices, and strengthen environmental governance systems.
3. **Circular economy:** The Circular Economy Roadmap sets out specific measures to promote the transition to a circular economy in the region, including the reduction of waste generation, the promotion of recycling and reuse, and the development of sustainable production and consumption patterns.
4. **Biodiversity:** The Biodiversity Roadmap emphasizes the importance of protecting and restoring the biodiversity of the Western Balkans, including through the

implementation of measures to preserve forests, rivers, and wetlands, promote sustainable agriculture, and conserve endangered species.

5. Sustainable connectivity: The Sustainable Connectivity Roadmap focuses on the development of sustainable transport infrastructure in the region, including the promotion of electric and hybrid vehicles, the expansion of public transport networks, and the development of cycling and walking infrastructure.
6. Governance: The Governance Roadmap sets out measures to strengthen environmental governance systems in the region, including the development of regulatory frameworks, the strengthening of institutional capacity, and the promotion of transparency and accountability in environmental decision-making.

The roadmaps provide a detailed plan for the Western Balkan countries and the EU to achieve the goals of the Action Plan. They include specific actions, timelines, and responsible institutions for each measure. The roadmaps also emphasize the importance of regional cooperation, stakeholder engagement, and EU integration in achieving the goals of the Action Plan.

Overall, the roadmaps provide a clear and comprehensive plan for the implementation of the Sofia Declaration on the Green Agenda for the Western Balkans. However, the successful implementation of the roadmaps will depend on the political will and commitment of the Western Balkan countries and the EU, as well as adequate financial resources and effective coordination and collaboration between all stakeholders.

*Part 3 of the Sofia Declaration on the Green Agenda for the Western Balkans* outlines the governance, monitoring, reporting, and other mechanisms that will support the implementation of the Declaration's Action Plan and roadmaps. This section highlights the importance of institutional coordination and stakeholder engagement to ensure the success of the Green Agenda.

The Governance section emphasizes the importance of effective governance structures to support the implementation of the Action Plan. It calls for the establishment of National Coordinators in each Western Balkan country to oversee the implementation of the Action Plan and roadmaps. It also calls for the creation of a Regional Coordination Body to facilitate regional cooperation and coordination between the Western Balkan countries and the EU.

The Monitoring and Reporting section outlines the importance of monitoring and reporting mechanisms to track the progress of the implementation of the Green Agenda. It calls for the establishment of a Regional Monitoring and Reporting Mechanism to monitor and

report on progress at the regional level. It also calls for the establishment of National Monitoring and Reporting Mechanisms in each Western Balkan country to monitor and report on progress at the national level.

The section on Stakeholder Engagement highlights the importance of engaging with stakeholders in the implementation of the Green Agenda. It calls for the establishment of a Regional Stakeholder Platform to facilitate engagement and dialogue between stakeholders and decision-makers. It also calls for the establishment of National Stakeholder Platforms in each Western Balkan country to ensure that the views and concerns of local stakeholders are taken into account.

Overall, Part 3 of the Sofia Declaration emphasizes the importance of institutional coordination, monitoring, and stakeholder engagement to support the successful implementation of the Green Agenda. The establishment of National Coordinators, a Regional Coordination Body, Regional and National Monitoring and Reporting Mechanisms, and Stakeholder Platforms will provide the necessary governance structures and mechanisms to support the implementation of the Green Agenda. The success of these mechanisms will depend on the commitment and cooperation of all stakeholders, including the Western Balkan countries and the EU, civil society, and private sector actors.

### **Circular agriculture in the Republic of Serbia—policy analysis and initiatives**

Republic of Serbia is part of the Western Balkans region where agriculture is an important sector with gross domestic product (GDP) in 2020 amounted to RSD 5,502,216 million at current prices, and it accounts for 6.3% of GDP [28].

*Energy sector development strategy of the Republic of Serbia up to 2025 with the projections up to 2030* aims to increase the share of renewable energy sources in the total energy production and to reduce the emission of greenhouse gases. The Strategy also aims to increase energy efficiency, enhance energy security, and promote regional cooperation in the energy sector [29]. The Strategy plans to increase the share of renewable energy sources in the total energy production to 27% by 2025 and to 40% by 2030. To achieve these goals, the Strategy envisages the construction of new renewable energy facilities, such as wind and solar power plants, and the modernization of existing hydropower plants.

To reduce emissions of greenhouse gases, the Strategy envisions the adoption of modern technologies and improvement of energy efficiency in the energy sector. Additionally, it aims to reduce air pollution by implementing new technologies for reducing harmful

emissions from thermal power plants and other sources of pollution.

The total investment value of planned projects until 2030 is estimated at around 12.5 billion euros. A considerable amount of these funds will be invested in the modernization and construction of new energy facilities, while some portion of funds will be invested in the development of infrastructure for renewable energy sources.

Despite ambitious goals and plans, the Strategy faces numerous challenges, such as the lack of financial resources, the shortage of personnel and complex procedures for obtaining permits for the construction of new energy facilities. However, with the right approach and investment in education, technology and infrastructure, Serbia has the potential to achieve its energy goals and become a regional leader in the field of renewable energy sources.

Moreover, the implementation of this Strategy could have a positive impact on the economy and society in Serbia, as it would increase energy security, reduce dependence on energy imports, enhance the competitiveness of the economy and create new jobs in the energy sector, as well as in other sectors.

*The roadmap for circular economy in Serbia* provides a detailed analysis, as a strategic document created by the Government of the Republic of Serbia in order to guide the country's transition towards a circular economy [30]. This Roadmap is a comprehensive document, outlining the country's vision, goals and actions for the transition to a circular economy. The Roadmap was prepared by the Ministry of Environmental Protection of the Republic of Serbia in cooperation with the United Nations Development Program (UNDP) and the European Union (EU). The Roadmap is organized into several chapters, each of which deals with a specific aspect of the circular economy.

The concepts contained in the document are explained at the very beginning, with special emphasis on the circular economy. The document states that the circular economy is a model that aims to promote sustainable patterns of production and consumption, reduce waste generation and optimize the use of resources. It is based on the principle of efficient use of resources, keeping products and materials in use as long as possible and renewing and regenerating materials at the end of their useful life. The circular economy is gaining increasing attention around the world as a means of solving environmental challenges, creating economic opportunities and improving social well-being.

The introductory chapter provides an overview of the concept of circular economy and its potential benefits for Serbia. The chapter highlights the challenges that Serbia is facing, such as limited availability of resources,

inefficient use of resources and high level of waste generation. This part also presents the document's visions and goals, including reducing waste generation, increasing resource efficiency, and creating new economic opportunities through the circular economy. Furthermore, the document deals with the analysis of the current situation, where an overview of the current situation in Serbia is given in terms of resource use, waste generation and the circular economy practices. This section identifies the main sectors that have significant potential for circularity, such as construction, agriculture, and manufacturing. This chapter also highlights the obstacles and challenges that Serbia faces in the circular economy transition, such as lack of awareness, inadequate regulations, and limited investment in circular economy practices.

The document also deals with priority areas for the development of the circular economy. This part provides an overview of the priority areas for the development of the circular economy in Serbia. The chapter identifies six key areas, specifically waste management, resource efficiency, product design, green public procurement, sustainable tourism, and circular business models. For each of these areas, the document provides a detailed analysis of the current situation, challenges and opportunities, as well as a set of recommended actions.

In addition, the document deals with implementation mechanisms for carrying out activities, including governance and institutional arrangements, financing mechanisms, and monitoring and evaluation. The chapter highlights the importance of stakeholder engagement and collaboration, as well as the need for effective communication and awareness raising.

The document contains the conclusion, and states the next steps for implementing the activities defined therein. It emphasizes the need for continued commitment and cooperation among all stakeholders, including government, the private sector, civil society and citizens. The chapter also highlights the importance of aligning this document with other relevant policies and strategies, such as the National Strategy for Sustainable Development and the EU's Circular Economy Action Plan.

The roadmap for circular economy in Serbia represents a significant step towards promoting sustainable development and solving environmental challenges in the country. The Roadmap provides a comprehensive and integrated approach to the transition to a circular economy, with clear goals, priorities and actions. Some of the advantages highlighted in this document can be summarized in the following activities:

The Roadmap provides a comprehensive approach for the transition towards a circular economy, addressing various aspects such as waste management, resource efficiency, product design, green public procurement,

sustainable tourism and circular business models. This approach ensures that the circular economy is involved in different sectors and is not limited to a specific area.

In addition, the Roadmap emphasizes the importance of cooperation and engagement of stakeholders in the implementation of the circular economy. It recognizes that a successful transition to a circular economy requires the involvement of various stakeholders, including government, the private sector, civil society and citizens. The Roadmap provides a platform for dialogue and collaboration between stakeholders, which can help build a shared understanding of the circular economy and promote collective action. The Roadmap identifies six key priority areas for the development of the circular economy, which are based on the current situation in Serbia and the potential for circularity. Moreover, the Roadmap describes various implementation mechanisms, such as governance and institutional arrangements, financing mechanisms and monitoring, as well as evaluation. These mechanisms provide a framework for translating the Roadmap goals and actions into concrete actions and results. The Roadmap also highlights the importance of effective communication and awareness raising, which can help build support for the circular economy among various stakeholders.

On the other hand, the document also recognizes certain weaknesses related to the following:

Although the Roadmap outlines clear goals and actions, concrete goals and indicators to measure progress toward these goals are lacking. This can make it difficult to monitor and evaluate the impact of the Roadmap over time and ensure accountability and transparency. In addition, the Roadmap fails to place a strong emphasis on innovation and the development of new technologies and business models. Although the document recognizes the importance of circular business models, it does not provide sufficient guidance on how to foster innovation and entrepreneurship in the circular economy. Moreover, the Roadmap fails to fully integrate other relevant policies and strategies, such as the National Sustainable Development Strategy and the EU Circular Economy Action Plan. This may limit the effectiveness of this document and create potential inconsistencies with other policies and strategies. Moreover, the Roadmap places relatively limited emphasis on the social aspects of the circular economy, such as job creation, social inclusion and poverty reduction. Although the Roadmap recognizes the importance of social aspects, it does not provide sufficient guidance on how to ensure that the benefits of the circular economy are shared equally among different groups and communities.

Finally, the Roadmap for Circular Economy in Serbia represents a significant step towards promoting

sustainable development and solving environmental challenges in the country. This document provides a comprehensive and integrated approach for the transition to a circular economy, with clear goals, priorities, and actions. Overall, the document provides a useful framework for guiding Serbia's transition to a circular economy, but further efforts will be needed to ensure its effective implementation and monitoring.

*Serbia's circular economy efforts towards food and waste management* provide an overview of Serbia's circular economy activities in the food and waste management sectors [31]. The article highlights some of the key initiatives and projects underway in Serbia, as well as the challenges the country faces in the transition to a more circular economy. The document opens by considering the importance of the circular economy in the context of Serbia's economic and environmental challenges. It states that Serbia faces significant environmental problems related to waste management and air pollution, as well as economic challenges related to job creation and sustainable economic growth. The circular economy is presented as a potential solution to these challenges, offering opportunities for resource efficiency, job creation and economic growth.

The document subsequently provides an overview of some of the key initiatives and projects currently underway in Serbia's circular economy transition. As for the food sector, the article highlights efforts by local farmers to implement organic farming practices and develop more sustainable supply chains. Moreover, the document highlights the role of innovative technologies such as vertical farming in reducing food waste and increasing the efficiency of food production. As for the waste management sector, the article emphasizes the importance of developing infrastructure for waste collection, sorting and recycling. It is noted that Serbia has made significant progress in this area, by developing a national waste management strategy and establishing recycling centers in many municipalities.

However, the document also recognizes significant challenges yet to be addressed, such as the need to improve waste collection and sorting practices and to develop more efficient recycling technologies. The document ends by emphasizing certain challenges that Serbia faces in the circular economy transition, such as the need for greater cooperation between stakeholders, as well as the need for the development of more effective policies and regulations. In addition, the importance of continuous investment in circular economy initiatives and projects is emphasized. It is concluded that the document provides a useful overview of Serbia's circular economy efforts in the food and waste management sectors as it highlights some of the key initiatives and projects



underway, as well as the challenges the country faces in its transition to a more circular economy. The document could be useful for policymakers, investors, and other stakeholders to support the transition of the circular economy in Serbia.

### **1st national policy dialogue on the circular economy in the agri-food sector**

In spring 2021, at the 69 Session of the United Nations Economic Commission for Europe (UNECE), the 56 Member States of UNECE took important decisions regarding the circular economy and the sustainable use of natural resources. In relation to these decisions, the project “Accelerating the transition towards a Circular Economy and the Sustainable Use of Natural Resources in the UNECE region” was launched in October 2021 to chart the way forward through in-depth discussions on the potentials and members’ experiences. Serbia is one of the beneficiary countries of this project [32]. The project aims to support the implementation of national policies, programs and strategies to promote the circular economy. It is financed from the United Nations Development Account (UNDA) and is to be implemented over the period 2021–2024.

Objectives of the 1st National Policy Dialogue in Serbia were related to expanding the knowledge of government officials and other stakeholders about the concept of circular economy and its basic principles.

In their speeches, the participants presented the current state of circular economy practice in the region of the United Nations Economic Commission for Europe (UNECE). The presentation entitled “Accelerating the transition towards a Circular Economy and the Sustainable Use of Natural Resources in the UNECE region” highlighted the potential benefits of adopting a circular economy approach, such as waste reduction and increased resource efficiency, as well as the challenges that must be met to accelerate the transition towards circular economy. In addition, the participants emphasized the efforts of the United Nations Development Program (UNDP) to promote the circular economy in Southeastern and Eastern Europe. The document entitled “EU for Green Agenda in Serbia 2022–2024” presents case studies from different countries in the region, highlighting successful circular economy initiatives in areas such as waste management, sustainable production, and resource efficiency.

Moreover, this presentation indicates the challenges the region faces in promoting the circular economy, such as limited funding and weak political frameworks. In this presentation, the author offers recommendations to policymakers and stakeholders to overcome these challenges. Overall, the document serves as a useful

resource for those interested in promoting the circular economy in the region of Southeastern and Eastern Europe. Likewise, the conference discussed the potential benefits of adopting a circular economy approach, such as waste reduction, increased resource efficiency and job creation. Participants were engaged in identifying the main challenges the region faces in the transition to a circular economy, including limited infrastructure, insufficient financing, and weak policy frameworks. Food loss and waste reduction were also discussed at the conference. Specifically, the presentation entitled “Food Loss and Waste Reduction in Europe and Central Asia” dealt with the circular economy approach and with the support to the transition to more sustainable food systems.

The presentation examined the principles of the circular economy and their application in the context of the food system, highlighting the opportunities to reduce waste, increase resource efficiency and promote renewable agriculture. There was also talk about successful circular economy initiatives in the food system, including reducing food waste and recycling usable nutrients. There was much talk about the circular economy in agri-food sector, with an emphasis on an overview of the innovative solutions for the circular economy in the agri-food sector. This presentation focused on case studies of the successful circular economy initiatives in areas such as sustainable packaging, waste reduction and nutrient recovery. Moreover, this document offers recommendations for policymakers and businesses to promote circularity in the agri-food sector and support a more sustainable and resilient food system.

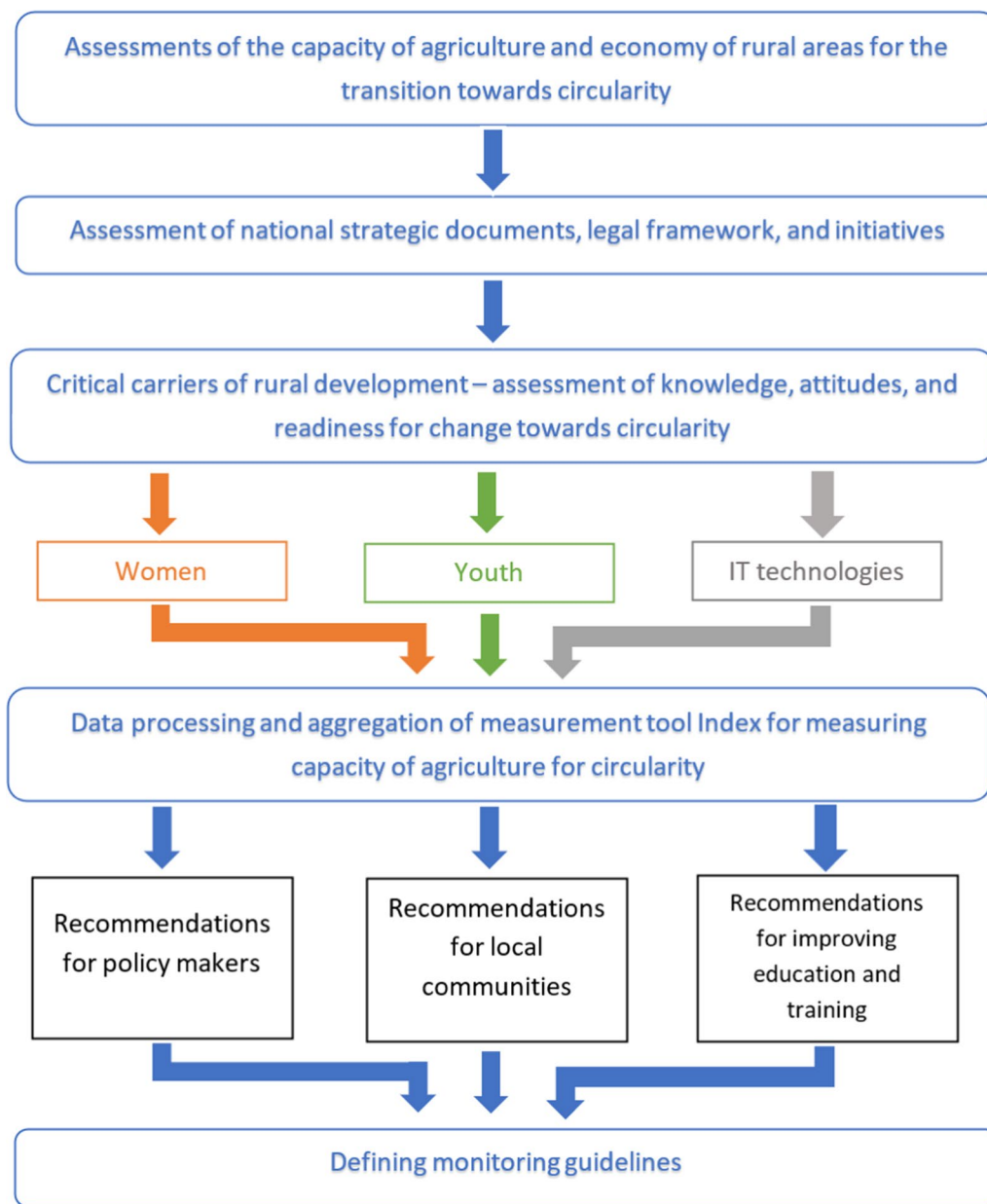
In the part of the conference dealing with international experience in the transition of the circular economy and food waste management and its relevance in Serbia, a paper entitled “Circular Economy in Turkey: current state and future possibilities” was also presented. This presentation provides an overview of the current state of circular economy practices in Turkey and presents the challenges the country faces in transitioning to a circular economy, including limited awareness, lack of regulation, and insufficient funding.

The paper entitled “Circular Economy in Finland: success factors and challenges” was presented in the same session. This paper provides insight into Finland’s success in promoting and implementing circular economy practices. The document considers the country’s strong political framework, stakeholder cooperation and innovative business models as key success factors. This paper presents case studies of successful circular economy initiatives in Finland, including waste reduction, material recycling and sustainable transport.

Finally, the paper entitled “Circular Economy in Dublin: Challenges and Opportunities” was presented. This document also focuses on the current state of circular economy practices in Dublin, Ireland. The document discusses the potential benefits of adopting a circular economy approach, such as reduced waste and increased resource efficiency. It also highlights the challenges the city faces in transitioning to a circular economy, including limited infrastructure, insufficient funding, and weak policy frameworks.

**Novel policy concept for introducing circular agriculture in Republic of Serbia**

Based on the previous qualitative analysis of the EU regulatory framework, existing initiatives in RS as well as main findings presented above, the authors of the paper propose a novel concept for introducing circularity in agriculture and rural development in RS, which is summarized in Fig. 2. The agricultural sector and rural development have been selected as the subject of assessment because they represent an integral element of the circular



**Fig. 2** Novel concept for introducing circular agriculture in RS

economy in RS, which is based on tradition, climate, and favorable natural resources. Specifically, RS has significant agricultural capacities that enable self-sufficiency in terms of feeding the population and a significant export product. In addition, RS is a predominantly rural country, whose development and survival are administratively based on the performance of agricultural activities, and therefore must be viewed as an indivisible whole.

#### **Assessing the capacity for circularity of agriculture and rural areas in RS**

The first step necessary to be taken to be able to define expedient and feasible state policies in this area is the assessment of the capacity of agriculture and rural areas of RS for the implementation of the circular economy concept. The focus of the research is on women and young people in rural areas, who are a critical factor in the rural development of RS and, as such should be the main bearers of the transition towards circularity. The result of the first step would be a starting point for looking at the real situation in rural areas, with information about the familiarity of the key agents of change and their readiness for the transition towards circularity. All of the above provides valuable, but currently missing data for policymakers.

#### **Critical carriers of rural development—assessment of knowledge, attitudes, and readiness for change towards circularity**

Bearing in mind the adverse demographic trends in RS (population aging, reduced birth rate, and migration), it can be firmly stated that, in rural areas of RS [33] under present circumstances, women, young people and the application of adequate IT technologies have the key influence on the potential introduction of the circular economy postulate in rural areas of RS. In order to obtain the necessary data and make an overview of the existing situation, a research instrument, i.e., the Questionnaire with five basic segments, was created:

- a) Determining the socio-demographic characteristics of the research sample;
- b) Assessing the degree of familiarity of respondents with sustainable development and circular economy (which was completely unknown before conducting the research);
- c) Assessing the social position of women in rural areas, while defining the basic motivators that would initiate the transition towards circularity (completely unknown);
- d) Determining the social position of the young population in rural areas, while defining the basic motiva-

tors that would initiate the transition towards circularity (completely unknown);

- e) Defining the degree of familiarity and the application of modern IT technologies in rural areas (which RS defined as mandatory, but whose degree of acceptance is completely unknown).

The questionnaire is attached as Additional file 1.

#### **Data processing and aggregation of a measurement tool—index for measuring capacity of agriculture for circularity**

In addition to an appropriate statistical tool (SPSS), the analytical software package (Analytica—<https://analytica.com/>) should and will be used for the processing of empirical research data in the future, as it enables the creation of a precise sample from the variables, as well as the quantification of qualitative data and their visualization and simulation with respect to multiple scenarios. This was concluded based on the training and testing of software capabilities that were conducted by the authors.

#### **Defining the index for measuring capacity of agriculture and rural development for circularity**

The determination of the composite index was carried out by applying the recommendations for the aggregation of indicators, first by selecting the indicators, then weighting their values, assigning weight coefficients, and finally aggregating the final value [34].

#### **Selection of indicators**

All the five previously defined parts of the research questionnaire will provide the information necessary to identify the original set of indicators related to the segment observed by that part of the research. Bearing in mind the basic assumptions of circularity, it was determined to observe capacity for circularity through the following indicators:

- Knowledge on basic principles of circularity;
- Attitude for changes in agriculture and rural areas;
- Waste management in rural areas;
- Energy efficiency in rural areas;
- Social position of women in rural areas and key motivators for change;
- Social position of youth in rural areas and key motivators for change; and
- Acceptance of IT technologies in rural areas.

The above indicators are based on the results obtained from the research questionnaire, as shown in Table 1.

**Table 1** Research questions from the questionnaire, based on which the indicator values are derived for assessing the capacity of agriculture and rural areas of RS for the transition to circularity

Indicator	Inquiries that determine the indicator
Knowledge on basic principles of circularity	Degree of education You are familiar with the term “circular economy” You are familiar with basic information about sustainable development Do you think that organic and circular agriculture are the same? E-agrar, to be introduced by the state, is good news for farmers
Attitude for changes in agriculture and rural areas	Does your household independently produce more than 50% of the food needed for the household members? Are you actively involved in the work of the local community, group of citizens or associations that deal with the development of rural areas? I am willing to invest in organic farming, even if it involves higher costs in the short term
Waste management in rural areas	You are familiar with basic information about sustainable development Are you satisfied with the way in which waste is removed from the environment in which you live? You are familiar with basic information about sustainable development Is there waste recycling in the area where you live? Do you recycle waste from your household?
Energy efficiency in rural areas	You are familiar with basic information about sustainable development Does your household independently produce more than 50% of the energy it needs for heating (residues from agriculture, waste)? Do you have a stable electricity supply?
Social position of woman in rural areas and key motivators for change	Gender Age In your opinion, what are the biggest problems that women in rural areas face? What are the most important factors that make life difficult for women in rural areas? Rural women participate equally in decision-making and financial distribution in the household
Social position of youth in rural areas and key motivators for change	Age You believe that in rural areas life is healthier and better for families with children The existing policies and programs of the state, which promote the stay of young people in rural areas, are effective Young people in rural areas participate equally in decision-making in the households where they live I believe that agriculture can be a profitable activity for youth in rural areas in the future
Acceptance of IT technologies in rural areas	You often use the Internet to obtain information that is important for your business and life in a rural environment The use of the Internet or modern digital technologies can contribute to reducing the movement of people from rural areas You have the possibility to sell your products online Do you use the Internet and IT tools or technologies, and which ones? What, in your opinion, are the main advantages of using the Internet and IT tools or technologies in agriculture in rural areas?

**Weighting**

Following the selection of indicators, each indicator was assigned a weighting coefficient. The weighting was carried out using the Delphi method by subject matter

experts, who took into account the importance of each indicator in measuring the capacity of agriculture and rural areas for circularity in RS. Table 2 shows the selection of a weighting coefficient for each indicator.



**Table 2** Weighting coefficients for indicators of the capacity of agriculture and rural areas of RS for the transition to circularity

Indicator	Indicator weight
Knowledge on basic principles of circularity	0.17
Attitude about changes in agriculture and rural areas	0.17
Waste management in rural areas	0.10
Energy efficiency in rural areas	0.15
Social position of women in rural areas and key motivators for change	0.15
Social position of youth in rural areas and key motivators for change	0.15
Acceptance of IT technologies in rural areas	0.10

### Aggregation

After defining set of indicators and the associated weights, aggregation is performed to obtain a summary index of capacity of agriculture and rural areas for circularity, as calculated by the following formula:

$$ICARC = \sum_{i=1}^7 x_i \cdot w_i. \quad (1)$$

*ICARC*—index of capacity of agriculture and rural areas for circularity.  $x_i$ —value of indicators.  $w_i$ —the corresponding weight of the individual indicator.

### Defining the monitoring guidelines

After assessing the capacity for circularity, and in accordance with the obtained results, the state and local self-government units will be able to define adequate policies. Bearing in mind the lack of knowledge of the issue and the limited presence of the principle of circularity in RS, this study also provides a proposal for the monitoring indicators that will enable a timely response in the event that the indicators are not within the defined range and send proposals to key decision-makers in a timely manner. Taking into consideration the competences of the ministries in RS, which sometimes overlap, the initiative must be aimed at several of them. Therefore, the proposal is given in Table 3.

It is evident that RS does not have a unified institutional approach to both the implementation of sustainable development and the introduction of the principle of circularity. Therefore, it is proposed to establish a single intersectoral body that will be responsible exclusively for the green transition issues. The results of this (and similar research studies in progress) can serve as a starting point for considering the current possibilities of RS to approach the transition to a circular economy, and for the adoption of appropriate policies in the form

of strategies, programs, goals and tasks, both at the national and local level.

### Discussion

The agricultural sector is one of the most important foundations of the Serbian economy. The market of agricultural and food products is one of the most competitive, where producers, especially those who export food to the market of EU member states, are often faced with additional requirements for the application of certain standards, initiated primarily by large retail chains, but also and by consumers. Agricultural and food products play a significant role in the foreign trade exchange of RS, especially in exports. The share of agricultural and food products in total imports somewhat over the years, and in recent years it has stood at between 6 and 8% [35].

Agricultural activity has a significant impact on soil and water quality, as well as on biodiversity and climate. Serbian agriculture had a significant impact on the emission of greenhouse gases, therefore RS, in its Nationally Determined Contribution (NDC) within the United Nations Framework Convention on Climate Change (UNFCCC), committed to reduce its national greenhouse gas emissions by 33.3% until 2030, compared to 1990.

The circular economy model has been established in recent years as a vision in meeting the needs of global society within the safe boundaries of key ecological systems and processes. The transition to circular agriculture in rural areas of RS is a multidimensional and complex challenge that requires systemic changes including innovations in practice, technology, production, business and in social and cultural areas.

The main goals of setting up a strategy for transition towards circularity of RS are the review of production and consumption practices: the use of sustainable resources; optimization process; prevention of waste generation and provision of sufficient amounts of food; reduced and alternative use of materials; and sustainable consumption. Intensifying the use of products by increasing the shelf life of foods, redistributing food production for humans, as well as extending the shelf life of products through the creation of new food, livestock, industrial and bio-economic products while reducing waste from the food sector.

Moreover, the following steps are necessary: rethinking the production and consumption of resources for sustainable production inputs; process optimization; food loss and waste reduction; rethinking and reducing material waste; rethinking the consumption; intensifying the use of products; increasing the lifespan of food; redistributing the food for human consumption; equipment sharing; smart prosperity institute; extending the life of

**Table 3** Competent ministries of RS and areas of monitoring the implementation of the principle of circularity in agriculture and rural development of RS

Competent ministry	Indicator for monitoring
Ministry of Agriculture, Forestry and Water Management	Cultivable areas, areas under forests Number and size of illegal landfills in rural areas Migration of young people and women from rural areas Scholarships for the education and upskilling of young people from rural areas Subsidies and incentives for rural areas Number of registered farms and entrepreneurial organizations in rural areas Number of newly employed individuals in rural areas
Ministry of Environmental Protection	Cultivable areas, areas under forests Energy consumption in rural areas Number and size of illegal landfills in rural areas Number and capacity of recycling in rural areas
Ministry of Construction, Transport and Infrastructure	Infrastructure projects in rural areas
Ministry of Mining and Energy	Energy consumption in rural areas (by types of energy sources) Energy efficiency of agriculture Energy efficiency in rural areas
Ministry of Internal and Foreign Trade	Unmarked surplus products in rural areas
Ministry of State Administration and Local Self-Government	Scholarships for the education and upskilling of young people from rural areas State investment in rural areas Local self-government investment in the development of rural areas GDP in rural areas Migration of young people and women from rural areas Subsidies and incentives for rural areas Number of registered farms and entrepreneurial organizations in rural areas Number of newly employed individuals in rural areas
Ministry of Education	Scholarships for the education and upskilling of young people from rural areas Migration of young people and women from rural areas Number and type of trainings for the population in rural areas Number of primary school students in rural areas Transfer of knowledge and innovation to rural areas Number and scope of digitization trainings in rural areas
Ministry of Health	Costs of treatment of the population in rural areas Number of doctors per inhabitant in rural areas
Ministry of Labour, Employment, Veterans and Social Affairs	Investment in rural areas GDP in rural areas Migration of young people and women from rural areas Subsidies and incentives for rural areas Number of trainings for the population in rural areas Number of primary school students in rural areas Transfer of knowledge and innovation to rural areas Number and scope of digitization trainings in rural areas Number of registered farms and entrepreneurial organizations in rural areas Number of newly employed individuals in rural areas
Ministry of Family Welfare and Demography	Investment in rural areas GDP in rural areas Migration of young people and women from rural areas Subsidies and incentives for rural areas Number of primary school students in rural areas
Ministry of Rural Welfare	Number of illegal landfills in rural areas Scholarships for the education and upskilling of young people from rural areas Migration of young people and women from rural areas Subsidies and incentives for rural areas Number of trainings for the population in rural areas Number of primary school students in rural areas Transfer of knowledge and innovation to rural areas Number and scope of digitization trainings in rural areas Number of registered farms and entrepreneurial organizations in rural areas Number of newly employed individuals in rural areas
Ministry of Science, Technological Development and Innovation	Number and scope of trainings for the population in rural areas Number of primary school students in rural areas Transfer of knowledge and innovation to rural areas Number and scope of digitization trainings in rural areas The degree of digitization in rural areas

**Table 3** (continued)

Competent ministry	Indicator for monitoring
Ministry of Tourism and Youth	Scholarships for the education and upskilling of young people from rural areas Migration of young people and women from rural areas Subsidies and incentives for rural areas
Ministry of Finance	Investment in rural areas GDP in rural areas Subsidies and incentives for rural areas

resources; new products from surplus or unwanted food; new products from by-products; material recycling; giving resources a new life; nutrient and energy cycling.

During the COVID-19 pandemic, many businesses have recognized the need to reconsider resilience and competitiveness of their supply chains. The implementation of circular economy principles in the food industry can contribute to many benefits, including improved security of the supply chain, more economically efficient production, new opportunities for value creation, new consumption experiences for consumers, and additional sources of income for companies from the sale of by-products.

Key strategies for improving the production and consumption of agricultural resources in RS include the use of sustainable production raw materials, improved optimization processes, prevention of waste generation, reduced use of materials and reduced consumption.

Extending product shelf life, food redistribution, equipment sharing, better storage and transportation of food and agricultural products is recommended and can be achieved with cold chain infrastructure. This not only affects the shelf life of the products, but also reduces their perishability and thus the amount of waste. Long-distance transportation of products, especially in animal husbandry, leads to reduced quality and nutritional value of products. Advanced transport logistics by applying innovations in the field of artificial intelligence and scientific achievements, can increase efficiency and fluidity.

Basic recommendations on which the circular economy strategy in RS should be based are as follows: identification of relevant actors in RS such as the Ministry, Statistical Office, national agencies; improving the knowledge of the public sector and other stakeholders about the definition of the circular economy and its basic principles; raising awareness about successful examples of the circular economy, its positive economic, ecological and social impacts, as well as the needs and requirements for the transition to a circular economy within the framework of the rules and regulations of RS. Moreover, it is essential to mention the need to harmonize laws and regulations currently in force in Serbia, related to the circular economy. This includes action plans, national strategies,

national goals related to the circular economy, specific laws or policies or other government documents.

Despite the many potential benefits of moving towards circular economy principles in agriculture and in rural areas, there are many barriers to their adoption.

The main obstacles identified through the literature review refer to market, financial factors, regulatory and political, technological, and infrastructural, cultural and research barriers.

Market barriers largely come from external sources that affect prices of food production, manufacturing, transportation, consumption, and disposal of the resulting waste. Agricultural and agri-food companies, with a focus on small and medium-sized enterprises, often lack the capital and financial resources needed to develop more circular processes, products and business models. This could be due to various reasons, the most common being the problems in terms of the amount of capital required to realize the possibilities of industrial composting and providing recycling facilities. Regulatory and political barriers are reflected mostly through inadequate legal acts that have not yet included the principles of the circular economy.

As the agricultural and agri-food systems are closely related to the areas of health, nutrition, environment, natural resources, finance, trade, and waste management, which are under the jurisdiction of different institutions; a lack of communication between them can lead to the situation in which each institution focuses on solutions that unconsciously act against each other, instead of achieving holistic solutions.

Technological barriers usually arise as the absence of technical solutions or limited acceptance and use of available and cost-effective solutions. In addition, the principles of the circular economy require available infrastructure such as internet access, crop residue recording equipment, cold stores, efficient transport and logistics systems, recycling, and energy recovery facilities.

Thus, the absence of adequate infrastructure can act as an obstacle for the adoption and integration of circular economy principles. Building the infrastructure needed for circular agriculture and the agri-food economy can be

particularly challenging in RS, especially in underdeveloped rural areas.

There are barriers among consumers due to lack of information and unwillingness to change habits such as excessive purchase of perishable foods, purchase of food products with usable resources such as meat and dairy products, purchase of processed foods and beverages or foods in non-plastic packaging, because of the perception and quality. While new information and awareness can help overcome some cultural barriers, complementary intervention strategies are typically needed for long-term behavior change. Campaigns aimed at raising public awareness, activating marketing, setting competitive prices, introducing new regulations and strategies can be cited as potential solutions.

In terms of research, the following is missing: assessment of the capacities of agriculture and rural areas of RS for the transition to circularity (the subject of this research), mapping of productive agricultural practices that would be easily adopted; mapping of hotspots where the greatest food losses and waste generation were observed; analysis of successful measures that lead to reduced waste generation; mapping of organic waste flows; identification of alternative methods for material reuse; the possibility of raising people's awareness about balanced diet based on foods produced from agriculture that applies the principles of circularity.

The existence of the above-mentioned barriers indicates that the pace of this transition to circular agriculture will be slow without the support of the government sector.

The transition itself represents a multidimensional and complex challenge that requires systemic changes including the application of innovative practices, technologies, products, business methods and socio-cultural practices. Applying the principles of the circular economy presents a huge opportunity to innovate and redesign our agricultural and agri-food systems in a way that reconciles economic growth with our environmental constraints. However, without adequate support at the state level, this transition will proceed very slowly. Further research is necessary in this area from the aspects of governance, environment, agriculture, economy, employment, etc.

## Conclusions

The main goal of this conceptual research is to propose a novel scientific approach to solving the problem faced by decision-makers in RS in their efforts to develop the country in a more sustainable way, in accordance with its specificities and capacities. The problem refers to the lack of information about the capacity and readiness of rural areas to apply the principle of circular economy, especially in agriculture activity.

Bearing in mind that EU membership is a strategic commitment of RS it is necessary to harmonize all areas with EU regulations, including sustainable development and other EU strategies. The transition to a circular economy is foreseen and highlighted in the EU Green Deal as a long-term strategy for the development of Europe until 2050, with the aim of strengthening self-sufficiency and decarbonization. The ability of the European countries to adapt to the above and implement it on their territories is very different and depends on an impact of many factors. Agriculture is an activity of special importance for every country and humanity, but it is associated with high pollution and an impact on climate change that occurs consequently.

For countries such as RS, with a lower level of development, considerable agricultural potential, and a large population living in rural areas, transitioning to sustainable development, in which the concept of circularity is employed, is certainly an appropriate development model. Regardless of its commitment to sustainable development, RS faces a large number of various problems—from the absence of a legal framework and strategies, and lack of financial resources, to the absence of data that would indicate the state and perspective of this change.

The study presented in this paper was carried out in two parts. The first part of the research included a review of present regulations and initiatives, resulting in the demonstration of their inadequacy, including a lack of basic monitoring. Studies on the possibilities and acceptability of transitioning to the concept of circularity in the rural areas of RS have not been conducted; so this paper represents the first research of its kind. Therefore, in the second part of the research, a proposal for a solution to the mentioned problem is presented, that is, the concept of the study that aims to obtain input data necessary for policymakers and decision-makers in the early stages of introducing circularity. The research proposed a set of indicators, an index for measuring capacity of agriculture and rural areas for circularity, as well as basic monitoring guidelines for monitoring the implementation of the circular economy in RS in the future.

Bearing in mind the characteristics of the study and the fact that the problem addressed therein is not clearly defined, further research is needed and should be aimed at a clearer definition of the framework for the introduction of circularity in RS, with all its specificities, advantages and limitations. Specifically, the transition to the concept of circularity represents a major change with long-term consequences, which requires the participation of a large number of stakeholders in all phases. Therefore, planning and implementation control must be carried out continuously, necessarily with the use of modern monitoring tools that must be



adapted to the specificities of each country where the principles of circularity are to be introduced. The proposed index for measuring capacity of agriculture and rural areas for circularity is defined in accordance with the specificities of RS, but with certain modifications, it can be considered for application in other countries that are in the early stages of introducing circularity in their economy.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13705-023-00413-4>.

**Additional file 1.** QUESTIONNARY.

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## Author contributions

SM and GR prepared a draft of the study. IV, DĐ and VT participated in manuscript revision. All authors read and approved the final manuscript.

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Not applicable.

## Declarations

## Ethics approval and consent to participate.

Not applicable.

## Consent for publication

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## Competing interests

The authors declare that they have no competing interests.

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## References

- Gaffney J, Bing J, Byrne PF, Cassman KG, Ciampitti I, Delmer D, Habben J, Lafitte HR, Lidstrom UE, Porter DO, Sawyer JE (2019) Science-based intensive agriculture: sustainability, food security, and the role of technology. *Glob Food Sec* 23:236–244. <https://doi.org/10.1016/j.gfs.2019.08.003>
- Pawlak K, Kolodziejczak M (2020) The role of agriculture in ensuring food security in developing countries: considerations in the context of the problem of sustainable food production. *Sustainability* 12:5488. <https://doi.org/10.3390/su12135488>
- Gajić A, Krunic N, Protić B (2021) Classification of rural areas in Serbia: framework and implications for spatial planning. *Sustainability* 13:1596. <https://doi.org/10.3390/su13041596>
- Stojanović V, Pantelić M, Savić S (2022) Environmental issues in Serbia: pollution and nature conservation. In: Manić E, Nikitović V, Djurović P (eds) *The geography of Serbia*. World Regional Geography Book Series. Springer, Cham. [https://doi.org/10.1007/978-3-030-74701-5\\_20](https://doi.org/10.1007/978-3-030-74701-5_20)
- Baldos ULC, Fuglie KO, Hertel TW (2020) The research cost of adapting agriculture to climate change: a global analysis to 2050. *Agric Econ* 51(2):207–220. <https://doi.org/10.1111/agec.12550>
- Prosekov AY, Ivanova SA (2018) Food security: the challenge of the present. *Geoforum* 91:73–77. <https://doi.org/10.1016/j.geoforum.2018.02.030>
- Arora NK (2019) Impact of climate change on agriculture production and its sustainable solutions. *Environ Sustain* 2(2):95–96. <https://doi.org/10.1007/s42398-019-00078-w>
- Bathaei A, Štreimikienė DA (2023) Systematic review of agricultural sustainability indicators. *Agriculture* 13:241. <https://doi.org/10.3390/agriculture13020241>
- Schlör H, Schubert SA (2022) SDG 8 and the food–energy–water nexus: a two-country dynamic computable general equilibrium CGE model. *Energ Sustain Soc* 12:43. <https://doi.org/10.1186/s13705-022-00369-x>
- Seid A, Andualem B (2021) The role of green biotechnology through genetic engineering for climate change mitigation and adaptation, and for food security: current challenges and future perspectives. *J Adv Biol Biotechnol* 24(1):1–11. <https://doi.org/10.9734/jabb/2021/v24i130192>
- Rosa L, Rulli MC, Ali S, Chiarelli DD, Dell'Angelo J, Mueller ND, Scheidel A, Siciliano G, D'Odorico P (2021) Energy implications of the 21st century agrarian transition. *Nat Commun* 12(1):2319. <https://www.nature.com/articles/s41467-021-22581-7>
- Práválie R, Patriche C, Borrelli P, Panagos P, Roșca B, Dumitrașcu M, Nita IA, Săvulescu I, Birsan MV, Bandoc G (2021) Arable lands under the pressure of multiple land degradation processes. A global perspective. *Environ Res* 194:110697. <https://doi.org/10.1016/j.envres.2020.110697>
- Kuik O, Reynès F, Delobel F, Bernardi M (2011) "FAO-MOSAICC: the FAO Modelling System for Agricultural Impacts of Climate Change to support decision-making in adaptation. Conference papers 332121, Purdue University, Center for Global Trade Analysis, Global Trade Analysis Project.
- Vazhenina L, Magaril E, Mayburov I (2023) Digital management of resource efficiency of fuel and energy companies in a circular economy. *Energies* 16:3498. <https://doi.org/10.3390/en16083498>
- Malhi GS, Kaur M, Kaushik P (2021) Impact of climate change on agriculture and its mitigation strategies: a review. *Sustainability* 13:1318. <https://doi.org/10.3390/su13031318>
- Yang M, Chen L, Wang J, Msigwa G, Osman AI, Fawzy S, Rooney DW, Yap PS (2023) Circular economy strategies for combating climate change and other environmental issues. *Environ Chem Lett* 21:55–80. <https://doi.org/10.1007/s10311-022-01499-6>
- Knez S, Štrbac S, Podbregar I (2022) Climate change in the Western Balkans and EU Green Deal: status, mitigation and challenges. *Energ Sustain Soc* 12:1. <https://doi.org/10.1186/s13705-021-00328-y>
- Velasco-Muñoz JF, Mendoza JMF, Aznar-Sánchez JA, Gallego-Schmid A (2021) Circular economy implementation in the agricultural sector: definition, strategies and indicators. *Resour Conser Recycl* 170:105618. <https://doi.org/10.1016/j.resconrec.2021.105618>
- Castro CG, Trevisan AH, Pigosso DCA, Mascarenhas J (2022) The rebound effect of circular economy: definitions, mechanisms and a research agenda. *J Clean Prod* 345:131136. <https://doi.org/10.1016/j.jclepro.2022.131136>
- Kullmann F, Markewitz P, Stolten D, Robinius M (2021) Combining the worlds of energy systems and material flow analysis: a review. *Energ Sustain Soc* 11:13. <https://doi.org/10.1186/s13705-021-00289-2>
- van Langen SK, Vassillo C, Ghisellini P, Restaino D, Passaro R, Ulgiati (2021) Promoting circular economy transition: a study about perceptions and awareness by different stakeholders' groups. *J Clean Prod* 316:128166. <https://doi.org/10.1016/j.jclepro.2021.128166>
- Ashton WS, Fratini CF, Isenhour C, Krueger R (2022) Justice, equity, and the circular economy: introduction to the special double issue. *Local Environ* 27:10–11. <https://doi.org/10.1080/13549839.2022.2118247>

23. European Commission (2020) A new Circular Economy Action Plan For a cleaner and more competitive Europe, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN>
24. Fidélis T, Cardoso AS, Riaz F, Miranda AC, Abrantes J, Teles F, Roebeling PC (2021) Policy narratives of circular economy in the EU—assessing the embeddedness of water and land in national action plans. *J Clean Prod* 288:125685. <https://doi.org/10.1016/j.jclepro.2020.125685>
25. European Commission (2022) EU policy framework on biodegradable and compostable plastics, [https://environment.ec.europa.eu/system/files/2022-12/COM\\_2022\\_682\\_1\\_EN\\_ACT\\_part1\\_v4.pdf](https://environment.ec.europa.eu/system/files/2022-12/COM_2022_682_1_EN_ACT_part1_v4.pdf)
26. Regional Cooperation Council (2020) Sofia Declaration on the Green Agenda for the Western Balkans, <https://www.rcc.int/docs/546/sofia-declaration-on-the-green-agenda-for-the-western-balkans-rn>
27. Regional Cooperation Council (2020) Action Plan for the Implementation of the Sofia Declaration on the Green Agenda for the Western Balkans 2021–2030, <https://www.rcc.int/docs/596/action-plan-for-the-implementation-of-the-sofia-declaration-on-the-green-agenda-for-the-western-balkans-2021-2030>
28. Stojanović Ž (2022) Agriculture in Serbia. In: Manić E, Nikitović V, Djurović P (eds) *The Geography of Serbia*. World Regional Geography Book Series. Springer, Cham. [https://doi.org/10.1007/978-3-030-74701-5\\_15](https://doi.org/10.1007/978-3-030-74701-5_15)
29. Republic of Serbia, Ministry of Mining and Energy (2016) Energy sector development strategy of the Republic of Serbia for the period by 2025 with projections by 2023, <https://meemp-serbia.com/wp-content/uploads/2018/09/Legislative-Energy-Sector-Development-Strategy-of-the-Republic-of-Serbia-for-the-period-by-2025-with-projections-by-2030.pdf>
30. UNDP Serbia (2021) The Roadmap for Circular Economy in Serbia, <https://www.undp.org/serbia/publications/roadmap-circular-economy-serbia>
31. Pavlović M, Vulić M, Pavlović A (2020) Circular economy in Republic of Serbia and Region. In: Ghosh S (ed) *Circular economy: global perspective*. Springer, Singapore. [https://doi.org/10.1007/978-981-15-1052-6\\_18](https://doi.org/10.1007/978-981-15-1052-6_18)
32. UNECE project (2021–2024) 1st National Policy Dialogue on the Circular Economy in the Agri-Food Sector, <https://unece.org/trade/CircularEconomy/UNDAProject>
33. Predojević-Despić JR (2021) The population change in Serbia in the post-Yugoslav period (1991–2017): significant demographic aspects. *Sociološki pregled* 53(3), 1183–1216, [https://www.academia.edu/81519825/The\\_population\\_change\\_in\\_Serbia\\_in\\_the\\_post\\_Yugoslav\\_period\\_1991\\_2017\\_Significant\\_demographic\\_aspects?f\\_r=64336](https://www.academia.edu/81519825/The_population_change_in_Serbia_in_the_post_Yugoslav_period_1991_2017_Significant_demographic_aspects?f_r=64336)
34. European Commission, Joint Research Center, Ispra, Italy (2008) Handbook on Constructing Composite Indicators—Methodology and User Guide, <https://www.oecd.org/sdd/42495745.pdf>
35. World Bank, <https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=RS>, Accessed 28 July 2023.

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