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THE ROLE OF REGIONAL INNOVATION SYSTEMS IN ACHIEVING THE SDGS: EVIDENCE FROM SELECTED AGRICULTURAL REGIONS IN CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Purpose: The motivation behind this research stems from the need to deepen the understanding of how Regional Innovation Systems (RIS), as place-based innovation structures, can contribute to sustainable development outcomes in regions less industrialised and agriculture-dependent.
Design/methodology/approach: This study applies a comparative case study approach to examine the role of RIS in supporting the implementation of selected Sustainable Development Goals (SDGs 2, 8, 9, 11, 12) in rural and agriculturally intensive regions of Central and Eastern Europe. Multi-criteria and multi-method approach enables identification of key barriers and enablers for aligning RIS activities with sustainable development priorities in rural areas.
Findings: The analysis revealed that while all three countries use similar EU innovation frameworks, Poland demonstrates the most effective integration of RIS with rural SDG implementation, while Hungary and Romania face significant structural, governance, and institutional challenges that limit their impact.
Research limitations/implications: This study has several limitations that should be acknowledged. First, the analysis is constrained by the availability and comparability of regional secondary data in Central and Eastern European (CEE) countries. Second, the concept of Regional Innovation Systems (RIS) is inherently context-dependent and difficult to quantify uniformly.
Practical implications: Strengthening Institutional Capacity in Rural Regions to improve RIS performance in less-developed areas, it is essential to invest in local innovation infrastructure, support networks (e.g., innovation hubs, agricultural knowledge centres) and human capital development tailored to local needs and sustainability challenges.
Social implications: The development of Regional Innovation Systems in agricultural regions of Central and Eastern Europe has significant social implications, particularly in promoting more inclusive and equitable rural development**.** By improving access to innovation, education, and technological support, RIS can help reduce territorial disparities and improve social cohesion.
Originality/value: This paper offers a novel comparative perspective on how Regional Innovation Systems in Poland, Hungary, and Romania contribute to rural SDG implementation, providing valuable insights for policymakers, researchers, and regional development actors focused on sustainable and inclusive innovation.
Keywords: Regional Innovation Systems, Sustainability, Sustainable Development Goals, rural areas.
Category of the paper: Case study, Viewpoint.

1. Introduction

The purpose of this article is to examine how Regional Innovation Systems (RIS) support the implementation of selected Sustainable Development Goals (SDGs) in regions with a strong agricultural structure, with a particular focus on rural areas of Eastern Poland. Despite their significant natural and productive potential, these regions often face structural challenges such as limited economic diversification, underdeveloped infrastructure, and outmigration of human capital. In this context, RIS—understood as mechanisms that coordinate collaboration between science, business, public administration, and civil society—can play a crucial role in fostering innovative and sustainable development tailored to local conditions.

The selection of SDG 2 (Zero Hunger), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, innovation and Infrastructure), SDG 11 (Sustainable Cities and Communities) and SDG 12 (Responsible Consumption and Production) is based on their direct relevance to the challenges and opportunities characteristic of rural areas. These goals reflect the need to ensure food security and agricultural development (SDG 2), create decent jobs and strengthen local economies (SDG 8), and develop infrastructure and technologies (SDG 9). They also encompass efforts to improve the quality of life in small towns and villages (SDG 11) and promote a more efficient and responsible use of resources (SDG 12). The article assumes that the synergistic use of RIS can contribute to more effective achievement of these goals, while enhancing social cohesion and long-term competitiveness of rural regions (tab. 1).

Table 1.
The main proposal to examine the goals

SDG goals	**The main proposal of the SDG goals chosen**	
SDG 2 – Zero Hunger	Food security and improved nutrition, and promote sustainable agriculture for all	(Huang et al., 2020); (D'Adamo, Rossi, 2025); (Miao et al., 2025); (Lehoux et al., 2018); (Leal Filho et al., 2022); (Cheshmehzangi, Zou, 2024); (Martinez-Gutierrez et al., 2025), (Godlewska-Majkowska et al., 2025), (Czupryna-Nowak, 2024)
SDG 8 – Decent Work and Economic Growth	Promote sustained, inclusive and sustainable economic growth, full and productive employment, and decent work for all	
SDG 9 – Industry, Innovation and Infrastructure	Resilient infrastructure, promote inclusive and sustainable industrialisation, and foster innovation	
SDG 11 – Sustainable Cities and Communities	Cities and human settlements are inclusive, safe, resilient, and sustainable	
SDG 12 – Responsible Consumption and Production	Sustainable consumption and production patterns by improving resource efficiency and reducing waste	

Note. (Leal Filho et al., 2022); (Cheshmehzangi, Zou, 2024); (Czupryna-Nowak, 2024), (Godlewska-Majkowska et al., 2025).

Source: Own research.

The importance of Regional Innovation Systems (RIS) for rural areas' development can be understood through the lens of selected Sustainable Development Goals (SDGs), which reflect key challenges and growth potential. In this context, RIS can play a strategic role as a tool to integrate knowledge, policy, and local resources in the pursuit of sustainable development.

SDG 2 – Zero Hunger – Rural areas, especially those with a strong agricultural profile, are directly involved in food production. RIS can support innovations in agriculture, agrotechnology, agribusiness and food logistics, thus increasing efficiency (Klerkx, Rose, 2020; Ramirez et al., 2019), quality, and sustainability of agricultural production while reducing food losses (Drabik et al., 2019). SDG 8 – Decent Work and Economic Growth Peripheral regions often face issues such as unemployment, labour migration, and limited economic diversification (Wurster, Ladu, 2020; Rodríguez-Pose, 2018). RIS can support the development of small companies, rural entrepreneurs and the creation of new jobs through innovative business models, particularly in the agri-food sector, tourism, and local services (Jiang et al., 2019). SDG 9 – Industry, Innovation and Infrastructure Rural areas often suffer from underdeveloped infrastructure and a weak network of institutions supporting innovation (Townsend et al., 2017). RIS can act as integrators of local actors (Asheim, Isaksen, 2002), enhance innovation infrastructure (e.g., incubators, competence centres, knowledge networks), and support the adoption of modern technologies in traditional sectors. SDG 11 – Sustainable Cities and Communities. Although this goal mainly applies to urban areas, its components—such as spatial planning, mobility, energy, and access to services—are equally important for smaller towns and rural regions. RIS can support smart and sustainable land-use strategies, as well as initiatives such as the "smart village" (Godlewska-Majkowska et al., 2025; Czupryna-Nowak, 2024). SDGs 12 – Responsible Consumption and Production Production and consumption in rural areas can become more sustainable through innovations in precision agriculture (Silva, Gerhard, 2025). Recent studies show that RIS plays a vital role in localising and operationalising the SDGs through territorial innovation, knowledge diffusion, public-private cooperation, and smart specialisation strategies. These systems improve regional competitiveness, enable circular economies, promote sustainable infrastructure, and facilitate community-driven innovation ecosystems. They also provide targeted responses to food security, urban sustainability, and inclusive economic growth—each directly related to SDGs 2, 8, 9, 11 and 12.

2. Methodology

Selection of Countries to Study the Impact of Regional Innovation Systems (RIS) on the implementation of selected Sustainable Development Goals (SDGs) in regions with a strong agricultural structure. Using a mixed-method approach that combines comparative analysis and case studies, the research explores how institutional arrangements, innovation support mechanisms, and knowledge networks in less-developed regions contribute to sustainable transformation. The selection of countries to study the impact of Regional Innovation Systems (RIS) on the implementation of selected Sustainable Development Goals (SDGs) in regions

with a strong agricultural structure should be based on clearly defined criteria that allow a comparable and reliable analysis. The following is a proposed methodology to select countries for the study.

Geographical and Macro-Regional Criteria

Focus on countries in Central and Eastern Europe (CEE), such as Poland, Hungary, Slovakia, Czech Republic, Romania, Bulgaria, Lithuania, Latvia, Estonia, Croatia, and Slovenia.

These countries share the following characteristics:

- A similar history of economic transformation after 1989,
- Structural challenges in the development of rural areas,
- Membership in the EU (providing access to common RIS and SDG programmes),
- Significant agriculture or employment in peripheral regions.

The following matrix presents the selection criteria to identify countries to be included in the study of the role of Regional Innovation Systems (RIS) in supporting the implementation of selected Sustainable Development Goals (SDG 2, 8, 9, 11, 12) in areas with a strong agricultural structure in Central and Eastern Europe. Based on the evaluation using selected criteria, three countries were chosen for further comparative analysis. The methodology of country selection based on the Likert scale (1-5) enables a transparent and comparative assessment of multidimensional indicators. Three countries were selected for analysis (tab. 2).

Table 2.
Country Selection Matrix (scale: 1 = low level, 5 = high level)

Country	Agriculture share in the economy	Rural population share	RIS maturity	Availability of regional data	Progress in SDG implementation	TOTAL
Poland	4	4	5	4	4	21
Romania	5	5	3	3	3	19
Hungary	3	3	4	3	4	17
Czechia	1	1	4	4	5	15
Lithuania	4	3	3	3	3	16
Bulgaria	3	1	2	3	2	11
Slovakia	1	5	3	3	4	16

Notes: Agriculture, Forestry and fishing, value added **(%GDP):** In 2023-24, agriculture had the largest share of GDP in Romania (3.3%) and Bulgaria (2.1%), a moderate share in Lithuania (2.6%) and Hungary (2.4%), and the smallest in Poland (2.6%), Slovakia (2.0%), and Czechia (1.5%), reflecting the diverse economic structures of the region; **Rural population (% of total population)** In 2024, Slovakia (45.6%) and Romania (44.6%), followed by Poland (39.7%) and Lithuania (31.0%). In Hungary, the rural population accounted for 27.3%, in Czechia 25.3%, while the smallest share was observed in Bulgaria (23.4%) (World Bank Open Data, n.d.); **RIS maturity (RIS maturity is often assessed along several dimensions: Governance structures, University-industry-government collaboration, Integration with EU funds, etc.)** Poland, demonstrate higher RIS maturity through decentralization, strong institutions; Czechia, Hungary and partly Lithuania, Slovakia, Romania represent medium maturity with existing but weakly coordinated structures; while Bulgaria show lower maturity due to fragmented implementation, low institutional capacity, and limited stakeholder engagement; **Availability of regional data:** The availability of regional data across Central and Eastern Europe exhibits significant variation, with Poland and Czechia offering comprehensive and systematically disaggregated statistics, Hungary, Lithuania, Slovakia Romania and Bulgaria providing moderately developed but partially centralized datasets, displaying the lower levels of data granularity; **Progress in SDG implementation** among the selected Central and Eastern European countries reflects a gradient of progress, with Czechia leading due to strong and consistent performance across

economic, social, and environmental goals. Poland and Hungary occupy middle positions, displaying mixed results—stronger in economic indicators but lagging in environmental and social areas. Slovakia and Lithuania follow, showing solid progress in aligning national policies with EU SDG strategies, particularly in health and education. Romania ranks lower due to persistent challenges in infrastructure, inequality, and governance, while Bulgaria is placed last, consistently underperforming across multiple SDG dimensions, especially in environmental and institutional indicators (Širá et al., 2021), (Ionescu et al., 2021).

Source: Own research.

Poland: Highest overall score; strong agricultural sector and well-developed RIS structure, especially in Eastern Poland; high availability of regional data. Romania: a very high share of agriculture and rural population, less developed RIS – allows identifying barriers and development opportunities. Hungary: Average level of progress of RIS and SDG, agricultural profile in some regions – serves as a good reference point for comparison with Poland and Romania. Selected countries and regions for analysis (tab. 3).

Table 3.
The main Rural Regions taken into consideration for Case Studies

Country	Example Rural Region	RIS Status	Agricultural Profile
Poland	Lubelskie, Podkarpackie, Świętokrzyskie	Strong RIS infrastructure	Extensive agri- & bio-economy
Hungary	Southern Great Plains (Dél-Alföld)	Mid-level RIS, active universities	Grain, horticulture, livestock
Romania	North-East, South Muntenia	Weak RIS, opportunity for growth	Rural majority, subsistence agriculture

Note. (Adamowicz, 2021), (Serbanica, 2021), (Fieldsend et al., 2017), (Borychowski et al., 2020), (Borychowski et al., 2020).

Source: Own research

Poland and Romania have a large share of family farms, with Poland distinguished by fruit-growing, while Romania stands out for maize and sunflower cultivation. Hungary is concentrated on the Great Hungarian Plain, where agriculture is the most developed (vegetable production, cereals, fruits).

Research Questions:

1. Which components of regional innovation systems (institutions, policies, infrastructure) are most relevant for supporting agriculture and the food sector in the context of SDG 2 – Zero Hunger?
2. To what extent do RIS contribute to the creation of decent jobs and the stimulation of economic growth (SDG 8) in rural regions?
3. How and to what extent do RIS facilitate the development of infrastructure, innovation, and industry (SDG 9) in peripheral rural areas?
4. What forms of RIS support enable the implementation of sustainable and “smart” rural community development strategies (SDG 11)?
5. In what ways do RIS promote responsible consumption and production (SDG 12) by supporting technological, social, and organizational innovations at the local level?

Concluding questions:

6. How do the strategies and effectiveness of RIS vary across selected Central and Eastern European countries (e.g. Poland, Romania, Hungary) in supporting the implementation of the SDG in rural areas?
7. What are the key barriers and enablers for effectively aligning RIS activities with the SDG agenda in agriculturally oriented regions?

The set of research questions directly operationalizes emphasises the role of localised learning, institutional structures, and cooperative networks in enhancing regional competitiveness and economic development (Pidorycheva et al., 2020) Regional Innovation Systems (RIS) – *are analytical frameworks describing how regional actors interact to foster innovation, whereas Research and Innovation Strategies for Smart Specialisation (RIS3) are EU policy instruments that operationalise these dynamics by prescribing place-based priorities for investment and development* (Lopes et al., 2019) — in implementing the 2030. Agenda in agricultural regions of Central and Eastern Europe, and the set of research questions directly operationalises this perspective: identifies which RIS components—institutions, policies, and infrastructure—most strongly support agriculture and food security (SDG 2), assesses the degree to which they translate into decent work and economic growth in rural areas (SDG 8), and how they shape the development of infrastructure, innovation, and industry in peripheral rural areas (SDG 9). The questions also address forms of RIS support that facilitate the implementation of sustainable and "smart" community development strategies (SDG 11) and mechanisms that promote responsible consumption and production through technological, social, and organisational innovations at the local level (SDG 12). The comparative perspective (Poland, Romania, Hungary) provides information that reveals differences in RIS strategies and effectiveness in the context of the implementation of the SDG, while the analysis of barriers and enabling factors identifies the conditions to effectively align RIS activities with the sustainable development agenda in agricultural regions.

3. Discussion in relation to the research questions

Which components of regional innovation systems (institutions, policies, infrastructure) are most relevant for supporting agriculture and the food sector in the context of SDG 2 – Zero Hunger?

Institutions are central to agricultural innovation, with research centres, universities, and advisory services developing locally adapted technologies such as drought-resistant crops and precision farming. Cooperatives and producer organisations support knowledge sharing, collective investment, and stronger market positions, while financial institutions provide credit and insurance to enable adoption. Effective policies further drive sustainable agriculture by

promoting R&D, public–private partnerships, agricultural education, and digital skills, while trade policies should ensure fair market access for small producers. Climate adaptation strategies are also critical for environmentally friendly practices. Finally, physical and digital infrastructure underpins innovative systems: transport networks, storage facilities, irrigation, and renewable energy improve efficiency and sustainability, while internet access and mobile tools connect farmers to forecasts, prices, and expertise. Industrial parks and hubs foster collaboration between science, business, and producers (tab. 4).

Table 4.
Regional innovation systems in the context of SDG 2 – Zero Hunger (SWOT analysis)

SWOT Type	Poland	Hungary	Romania
Strengths	Strong research base; well-developed advisory system; coherent digitisation policies; solid infrastructure.	Growing investment in digitalisation and agricultural modernisation; policy support and access to EU funding.	Strong involvement in EU programmes; increasing role of NGOs and private advisory; large infrastructure investments.
Weaknesses	Uneven collaboration between science and practice; limited infrastructure in rural areas.	Weak advisory system and limited knowledge transfer; low level of regional collaboration.	Institutional incoherence; poor infrastructure in many regions.
Opportunities	Potential to enhance knowledge transfer; development of precision agriculture and renewable energy supported by EU funds.	Development of digital infrastructure; better use of the potential of agricultural universities.	Reduction of regional disparities; increase in technology transfer.
Threats	Risk of marginalising small farms; outmigration of rural youth.	Farm fragmentation; underinvestment in rural areas.	Dependence on EU funding; difficulties in implementing policies locally.

Source: Own research.

Achieving Sustainable Development Goal 2 – Zero Hunger – requires effective regional innovation systems (RIS) that integrate institutional, policy, and infrastructure components to support agriculture and food systems. In **Poland**, RIS efforts have progressed through initiatives such as Smart Villages, which strengthen collaboration between research institutions and local producers (Adamowicz, Zwolińska-Ligaj, 2020; Adamowicz, 2021). Yet, rural ICT and logistics infrastructure remain uneven. **Romania** faces more systemic weaknesses of RIS, including fragmented institutional coordination and underdeveloped rural infrastructure (Bădîrcea et al., 2025). Nonetheless, European Regional Development Fund (ERDF) — *one of* the main financial instruments of the European Union's Cohesion Policy, established to reduce economic disparities between regions by funding infrastructure, innovation, environmental protection, and support for small and medium-sized enterprises (SMEs) in less developed areas (Bădîrcea et al., 2025b) — supported programs have recently targeted innovation in sustainable agriculture. **Hungary** shows stronger institutional capacity, supported by national agricultural research centers and active S3 in food and bioeconomy (Shvets et al., 2023). However, regional disparities and limited integration of environmental objectives remain. Across all three countries, key RIS components for SDG 2 include robust research-practice linkages, regionally

aligned agri-innovation policies, and improved rural infrastructure such as irrigation and digital access. Strengthening governance and targeted funding is essential to transforming the agricultural sector into a more resilient and food-secure system in Central and Eastern Europe.

To what extent do RIS contribute to the creation of decent jobs and the stimulation of economic growth (SDG 8) in rural regions?

Regional Innovation Systems (RIS) have increasingly become essential mechanisms in promoting SDG 8 — "decent work and economic growth" — particularly in rural regions across Poland, Hungary, and Romania (tab. 5). These systems, characterized by coordinated interactions among local actors (universities, firms, governments, etc.), foster innovation-led development, reduce regional disparities, and stimulate job creation. However, the degree of impact varies due to national policy frameworks, historical legacies, structural inequalities, and institutional readiness.

Table 5.
Sustainable Development Goal 8 – Decent Work and Economic Growth (SWOT Analysis)

SWOT Dimension	Poland	Hungary	Romania
Strengths	Strong EU funding absorption; Decentralized RIS; Agricultural base for agri-tech innovation.	Established RIS policy frameworks; Industry-agriculture innovation potential; Regional cluster support.	High agricultural potential; Emerging university-local economy links; EU integration benefits.
Weaknesses	Innovation gap in rural areas; Brain drain; Low private R&D investment.	Centralized governance; Low institutional trust; Uneven rural infrastructure.	Weak rural innovation systems; Institutional fragmentation; Skills mismatch.
Opportunities	Smart specialization strategies; Digital agriculture; Green economy initiatives.	Rural entrepreneurship support; Diaspora engagement; Tourism innovation.	Digital rural hubs; Value-added agriculture; Public-private partnerships.
Threats	Aging population; RIS coordination issues; Dependence on EU funds.	Political influence on RIS; Youth unemployment; Climate risks.	Rural poverty; Migration trends; Corruption and weak governance.

Source: Own research.

In summary, on the role of RIS in supporting decent job creation and economic growth (SDG 8) in rural areas of Poland, Hungary and Romania. **Poland** has made extensive use of EU structural and cohesion funds, which have positively impacted rural region development. (Tiţa, Bătuşaru et al., 2015; Popescu, 2015). A key strength is the decentralised governance structure and a strong agricultural base that can be supported by agri-tech innovation. However, significant challenges remain, such as the innovation gap between urban and rural areas and the brain drain (Keene et al., 2024). Despite these obstacles, there are significant development opportunities through smart specialisation strategies, digital agriculture, and the green transition (Fragomeli et al., 2024). In the long term, risks include an ageing rural population and potential reductions in EU funding (Ahlmeyer, Volgmann, 2023). **Hungary** has a well-established formal RIS framework, but its practical implementation is hindered by centralised governance

and low trust among local stakeholders. The performance results of the companies in Hungary's food industry are largely shaped by regional location, sectoral characteristics, as well as the size and age of the companies (Nagy et al., 2025). In Hungary indicate three distinct types of regional innovation systems based on knowledge function synergy: Budapest functioning as an agglomeration economy; the north-western regions integrated into the European Union; and the southern and eastern regions, where central planning and public R&D continue to play a dominant role in shaping innovation system dynamics (Lengyel, Leydesdorff, 2011). **Romania** has substantial agricultural potential and vast rural areas, but their integration into innovation systems remains weak also Romanian labor productivity level is lower than that achieved in agricultural performance in the European Union (Teodor, 2015). The reduction of disparities between urban and rural areas in Romania is possible through government policies that support private investment, infrastructure development, and better use of resources in education and healthcare, which will allow agriculture to fully realise its potential (Mihai-Valentin-Cătălin, Elian-Gabriel, 2024). Romania could benefit from the development of digital rural centres, investments in value-added agriculture and public–private partnerships (Dumitru et al., 2021). However, persistent poverty and corruption (Timu, Vilcu, 2025), rural depopulation and lack of basic services, as well as population ageing, do not support the economic sustainability growth in Romanian agriculture (Vlad et al., 2024; Marioara, Armanca, 2019). In conclusion, Regional Innovation Systems in Poland, Hungary and Romania have the potential to drive decent job creation and economic growth in rural areas. However, their impact is highly shaped by national governance structures, institutional capacity, and the effective integration of local innovation with agri-tech and regional development strategies.

How and to what extent do RIS facilitate the development of infrastructure, innovation, and industry (SDG 9) in peripheral rural areas?

RIS play an increasingly central role in advancing SDG 9 — which focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization, and fostering innovation — especially in peripheral rural areas of Poland, Hungary, and Romania. These areas face distinct structural disadvantages, such as poor connectivity, limited institutional capacity, and weak presence of the private sector. However, RIS oriented policies and EU cohesion strategies have begun to reverse some of these trends. Here is a breakdown of how and to what extent RIS are facilitating development (tab. 6).

Table 6.
Sustainable Development Goal 9 - facilitate the development of infrastructure, innovation, and industry (SWOT Analysis)

SWOT Dimension	Poland	Hungary	Romania
Strengths	Strong alignment of RIS with regional development strategies; effective use of EU funds; growing innovation hubs in some rural regions.	Formal RIS framework and existing clusters; some success in food/agro-industrial sectors; national support for industrial parks.	EU support frameworks available; initial steps toward rural digital hubs; strong agricultural base for industry development.
Weaknesses	Persistent urban-rural infrastructure gap; limited private sector participation in rural innovation; uneven digital access.	Over-centralisation limits responsiveness to rural needs; low trust among actors; insufficient local innovation absorption.	Fragmented RIS structure; poor infrastructure and institutional capacity in rural peripheries; weak innovation networks.
Opportunities	Expansion of broadband and smart specialisation strategies; potential to develop agri-tech clusters in peripheral regions.	EU and national support for regional cluster expansion; rural tourism and bioeconomy sectors offer industrial potential.	Development of renewable energy and agro-industrial zones; digital transition could bridge rural divide.
Threats	Dependence on external funding; demographic decline in rural areas; risk of innovation concentration in urban cores.	Political interference; weak regional institutions; rural infrastructure lag impedes industrial diversification.	Corruption and governance issues; outmigration; limited scalability of pilot initiatives in rural zones.

Source: Own research.

Poland has achieved notable progress in aligning Research and Innovation Strategies for Smart Specialisation (RIS3) with rural development, particularly in its eastern regions such as Podkarpackie, Lubelskie, and Świętokrzyskie. Once peripheral, these areas are increasingly integrated into broader innovation networks through EU and national policies. Infrastructure investments—particularly in transportation through the Via Carpathia corridor and broadband access—have improved with support from EU Cohesion and ERDF funds, although rural digital gaps persist (Adamowicz, 2021; Bădîrcea et al., 2025). RIS3 in Poland has spurred innovation clusters in agri-tech, smart energy, and bioeconomy, with grassroots engagement facilitated by Local Action Groups (LAGs) and innovation hubs. In contrast, **Hungary's** RIS3 landscape reflects centralised governance, with Budapest shaping much of the innovation agenda. Peripheral regions such as Szabolcs-Szatmár-Bereg and Baranya often remain disconnected from the country's innovation sector, facing inadequate transport and broadband infrastructure (Surówka at al., 2021). Here's a polished academic-style paragraph (acapit) based on your draft.

Although Hungary's Smart Specialisation Strategies (S3) place strong emphasis on information and communication technologies (ICT) and the green economy—reflecting the concept of fostering innovation through strategic investment (Kopczynska, Ferreira, 2020) — the benefits are unevenly distributed across the country. Rural regions in particular gain less from these initiatives due to the absence of local innovation brokers and technology transfer offices (Meyer et al., 2022). In addition, industrial modernisation beyond major urban centres remains constrained by weak university–industry links and the limited availability of venture

capital. As Korniyenko (Korniyenko, 2024) highlights, Hungary's rural development potential will remain underutilized unless more decentralized support mechanisms are established. **Romania** presents a more fragmented picture. Regions like Teleorman, Vaslui, and Olt suffer from chronic underdevelopment, institutional inefficiencies, and limited absorptive capacity. Despite formal RIS3 structures, their implementation varies drastically by region, often reflecting local administrative strength or weakness (Ionescu et al., 2023; Claudia, Mihaela, 2022). EU-backed infrastructure projects have improved road and digital access in some areas, but long-term sustainability remains a concern. Innovation in agriculture and renewable energy shows promise, especially in cities such as Cluj and Timișoara, yet most rural industries still depend on traditional sectors of low-productivity (Zamborsky, 2023). In addition, institutional fragmentation and inconsistent regional strategies continue to obstruct the implementation of cohesive innovation policy (Kruse et al., 2023). Across these countries, a common pattern emerges: S3 have opened important opportunities for rural development, but success hinges on local capacity, infrastructure, and governance decentralisation. As such, while Poland shows signs of meaningful RIS3 integration, Hungary and Romania struggle with institutional and geographic asymmetries that dilute the impact of innovation-driven policies.

What forms of RIS support enable the implementation of sustainable and "smart" rural community development strategies (SDG 11)?

The development of sustainable and "smart" rural communities under SDG 11 — which emphasizes inclusive, safe, resilient, and sustainable settlements — in Poland, Hungary, and Romania is increasingly supported by RIS. These systems provide a range of enabling mechanisms that link local governance, innovation actors, and EU structural funding to foster localized smart development in rural regions. Detailed review of how RIS support manifests in each country (tab. 7).

Table 7.
SWOT Analysis of RIS Support for SDG 11 in Poland, Hungary, and Romania

SWOT Category	Poland	Hungary	Romania
Strengths	Decentralized RIS supports regional adaptation. Active grassroots projects via LAGs. Strong local university collaboration.	Centralized RIS gives strategic direction. Digital hubs play a role in supporting pilot projects in rural areas. One example of success is the use of Internet of Things (IoT) technologies in agriculture.	Alignment of RIS with Smart Villages. EU-funded pilots in energy and e-gov.
Weaknesses	Regional fragmentation in RIS execution. Heavy reliance on EU funding. Tech disparity in remote areas.	Limited rural academic capacity. Urban bias in RIS resource distribution. Low local autonomy in planning.	RIS implementation is nascent. Fragmented governance, low capacity. Weak rural innovation infrastructure.

Cont. table 7.

Opportunities	Scale successful S3 pilots nationally. Deepen municipal-university synergies. Expand RIS into climate adaptation.	Decentralize elements of RIS for rural fit. EU/Horizon funding for rural gaps. Engage NGOs and rural SMEs.	Leverage Smart Villages to scale RIS. Boost digital inclusion via EU funding. Enhance RIS via university networks.
Threats	Uneven regional outcomes due to autonomy. Political shifts affecting decentralization. Overlapping projects from weak coordination.	RIS centralism may limit rural innovation. Funding risk from EU governance concerns. Institutional resistance to change.	Low fund absorption could stall projects. Rural depopulation threatens scale. Institutional inertia and low innovation culture.

Source: Own research.

Poland's decentralised RIS model enables rural regions to customise their (S3) based on local potential. Regions like Lubelskie and Podkarpackie emphasise sustainable agriculture, renewable energy, and digital services (Adamowicz, 2021). Through EU funds like the Rural Development Programme (RDP) — *is a policy and funding framework primarily designed by the European Union to promote sustainable development in rural areas. It aims to enhance the competitiveness of agriculture, ensure sustainable management of natural resources, and support inclusive growth and quality of life in rural regions* (Czyżewski et al., 2018), these areas have introduced living labs, smart mobility services, and renewable microgrids (Wieliczko et al., 2021). RIS support has also enabled Local Action Groups (LAGs) — *these groups bring together local stakeholders; such as residents, businesses, NGOs, and local authorities to foster sustainable rural development, social cohesion, and economic diversification through bottom-up approaches* (Gargano, 2021) — to initiate participatory projects such as digital public platforms, smart irrigation, and green building. These projects are especially active in Małopolska and Świętokrzyskie, where RIS interacts with municipal planning and local universities (Surówka et al., 2021). This regional and bottom-up alignment reflects how Poland's RIS fosters sustainable innovation at the grassroots level.

Hungary centralised RIS meets rural fragmentation. Hungary's RIS structure is notably centralised, with national ministries and Budapest-based agencies controlling much of innovation funding and strategic direction. This top-down approach results in an unequal distribution of innovation support, often favouring urban or capital regions. Peripheral counties experience weak integration into RIS governance due to underdeveloped infrastructure and institutional isolation. Although Hungary's S3 framework emphasises digital technologies and green economy transitions, few rural areas have benefited meaningfully. The implementation of EU funding and Smart Specialisation Strategies (S3) is frequently channeled through sectoral calls that lack sufficient territorial differentiation. This approach often overlooks the specific innovation ecosystems of peripheral regions, where the absence of localized innovation intermediaries—such as innovation brokers or technology transfer hubs—significantly constrains the effective deployment and regional impact of RIS3. Industrial development is similarly skewed, with rural industrial zones underutilized and lacking links to universities or

venture capital ecosystems. RIS implementation remains fragmented due to minimal rural stakeholder engagement and limited absorptive capacity at the municipal level. **Romania's** rural peripheries—such as Teleorman, Vaslui, and Olt—are among the most underdeveloped in the EU, facing deep-rooted structural challenges. Although RIS have been introduced across regions, their implementation suffers from fragmentation and low institutional capacity at the local level. Infrastructure gaps remain severe: many communes lack quality roads and digital connectivity. Although EU investments have expanded access, concerns about long-term sustainability and governance remain. Innovation outcomes are uneven across regions. Although Timișoara and Cluj have developed robust innovation ecosystems—including smart agriculture, digital services, and green energy integration—other rural areas struggle with low absorptive capacity and a lack of RIS-aligned support structures. Regional Development Agencies (RDAs) — *are publicly funded institutions tasked with promoting economic development and regeneration in specific geographic areas* (Danson et al., 1998) — the main intermediaries for RIS in Romania, have limited staff and insufficient budget autonomy. Industrial modernization remains confined to urban pilot zones, with most rural economies still relying on low-productivity agriculture or extractive sectors.

Academic actors engage with the components of RIS through diverse and multilayered interactions that critically shape the performance of regional innovation processes and the implementation of S3, particularly in rural or less-developed regions. In decentralised systems such as Poland, universities and research institutes often collaborate directly with local governments, businesses, and civil society through platforms, e.g. LAGs. These actors contribute by co-developing applied research, facilitating technology transfer, and training local talent aligned with regional S3 priorities (e.g., renewable energy or sustainable agriculture). Conversely, in centralised systems like Hungary, academic actors often have fewer institutional linkages with rural RIS components (Lengyel, Leydesdorff, 2011b; Zsibók, 2011) due to the concentration of innovation governance in Budapest. This leads to underdeveloped triple helix interactions between universities, industry, and government actors in peripheral regions, where universities are underfunded and less engaged in regional development. In Romania, while academic actors in urban hubs (like Cluj and Timișoara) are deeply embedded in innovation ecosystems. Rural universities serve as pivotal regional anchors for knowledge dissemination, innovation, and community engagement, positioning them as strategic actors within place-based development and territorial cohesion frameworks (Ciocan et al., 2024). In general, the degree of academic interaction with the RIS components is shaped by governance models, funding mechanisms, and the presence (or absence) of collaborative infrastructures at the regional level.

In what ways do RIS promote responsible consumption and production (SDG 12) by supporting technological, social, and organizational innovations at the local level?

In recent years, RIS have emerged as critical instruments for embedding sustainable development principles into regional policy and practice throughout the European Union. As the urgency to achieve the SDG intensifies—particularly SDG 12, which emphasises responsible consumption and production—countries are increasingly using RIS as platforms for eco-innovation, social engagement, and governance reform. This comparative analysis examines how three Central and Eastern European countries—Poland, Hungary, and Romania—are operationalising RIS to support sustainability transformations. Despite differing political and economic contexts, all three countries demonstrate growing alignment between innovation ecosystems and sustainable development agendas (tab. 8). Through technological innovation, social participation, and organisational restructuring, these RIS models reveal diverse but converging pathways toward systemic change. Drawing on recent scholarship and policy developments, this overview highlights how RIS can serve as a facilitator of regional resilience and long-term ecological transition.

Table 8.
RIS from consumption and production (SDG 12) perspective

SWOT	Poland	Hungary	Romania
Strengths	Strong EU policy alignment; eco-innovation clusters; smart governance.	Municipal-driven RIS; circular economy focus; digital public services.	University- ties; smart specialization; RIS consortia with SMEs.
Weaknesses	Dependence on EU funding; regional disparities; uneven innovation uptake.	Financial limits; political instability; regional implementation variance.	Innovation lag; fragmented governance; low public sustainability awareness.
Opportunities	Expand green tech partnerships; scale co-creation; boost specialization.	Strengthen local RIS resilience; increase EU funding use; enhance community projects.	Grow circular economy; expand SDG education; use RIS for regional development.
Threats	Bureaucratic inertia; EU funding risks; digital/green skills gap.	Overreliance on local governance; low R&D investment; economic volatility.	Policy discontinuity; limited innovation capital; urban-rural RIS divide.

Source: Own research.

Each country—Poland, Hungary, and Romania—explaining how their RIS support SDG 12: Responsible Consumption and Production through technological, social, and organisational innovations: **Poland's** RIS demonstrate a growing alignment with sustainable development, particularly in fostering responsible consumption and production. At the technological level, Poland has developed eco-innovation clusters focused on green manufacturing, digitalisation of industry, and environmental technologies. Social innovations are implemented through Responsible Research and Innovation (RRI), — *is a process that ensures science and innovation are conducted ethically, transparently and in the public interest, recognising their potential risks, uncertainties and social impacts* (Burget et al., 2017) — frameworks that involve local communities in co-creation activities, especially within

regional labs and smart specialisation sectors. Organizationally, Polish municipalities are increasingly adopting "smart governance" models that integrate sustainability metrics into public procurement and local development plans. According to (Weresa, Kowalski, 2022), these shifts are aided by EU cohesion policies and strategic funding mechanisms that enable RIS to function as platforms for eco-conscious transformation. The convergence of public institutions, universities, and enterprises facilitates a coordinated push toward SDG 12. **Hungary's** RIS model integrates sustainability primarily through its decentralised governance and municipal engagement strategies. Technologically, Hungary has focused on improving resource efficiency, particularly through the integration of renewable energy systems and waste-reduction technologies at the municipal level. Socially, local governments are vital actors, using participatory mechanisms to co-develop sustainable practices such as localised circular economy initiatives and awareness campaigns on consumption behaviour. Organizational innovations in Hungary include the digital transformation of public services and the integration of SDG-aligned KPIs in local policy frameworks. Study (Nagy et al., 2018) emphasize that while financial constraints exist, many Hungarian cities have pioneered the use of RIS tools to embed sustainability into innovation policy. These tools help buffer against central political volatility by reinforcing bottom-up resilience in rural and urban municipalities. In addition, RIS-driven local strategies increasingly leverage EU programmes and sustainability indicators to align with SDG targets in areas like energy efficiency and public infrastructure (Brodny, Tutak, 2023). In **Romania**, RIS structures are increasingly geared towards enabling sustainable production and consumption through a combination of technological, social, and organisational advancements. Technologically, regional innovation is being directed towards supporting circular economy models, energy-efficient technologies, and low-waste production systems. Social innovation is evident in the promotion of community-university partnerships, where SDG literacy and participatory design are embedded in local projects and university curricula. Organisationally, Romania's RIS efforts are moving toward a more integrated governance model that links regional development agencies, academic institutions, and SMEs in sustainability-orientated consortiums. (Puiu, 2024) notes that although Romania still lags behind EU frontrunners, significant progress is being made through RIS-supported smart specialization strategies, which target local ecological and economic strengths for systemic innovation in support of SDG 12 (Suciu, Năsulea, 2019).

How do the strategies and effectiveness of RIS vary across selected Central and Eastern European countries (e.g., Poland, Romania, Hungary) in supporting SDG implementation in rural areas?

This SWOT analysis compares the strategies and effectiveness of RIS in supporting the SDGs in rural areas in three Central and Eastern European countries: Poland, Romania, and Hungary (tab. 9). The analysis identifies the strengths, weaknesses, opportunities, and threats each country faces in this context.

Table 9.
SWOT Analysis of RIS Strategies for SDG Implementation in Rural Areas

SWOT Category	Poland	Romania	Hungary
Strengths	Strong institutional frameworks for RIS. Effective use of EU funding. Advancing rural digitalization	RIS aligned with EU RIS3. Strong agricultural base. Growing IT sector supports smart rural initiatives.	Integration of RIS with national SDG goals. Rural innovation clusters and incubators. Agricultural innovation tradition.
Weaknesses	Limited rural governance capacity. Urban-biased RIS design. Low innovation uptake in rural SMEs.	Weak coordination across institutions. Poor RIS impact monitoring in rural areas. Infrastructure gaps in rural zones.	Centralized, top-down RIS planning. Limited attention to social SDGs. Political influence over regional decisions.
Opportunities	Agri-tech and bioeconomy development. EU Green Deal alignment. Public-private partnerships.	EU structural funds for capacity building. Smart villages and digital inclusion. Renewable energy in rural regions.	Cross-border rural innovation. Cultural and eco-tourism potential. Horizon Europe rural programs.
Threats	Youth outmigration. Centralization weakening local strategies. Dependence on EU funding.	Persistent rural poverty. Administrative fragmentation. Agricultural vulnerability to climate change	Democratic backsliding. Urban-rural digital divide. Regulatory and policy unpredictability.

Source: Own research.

Poland stands out for its strong institutional support for implementing RIS and effective use of EU funds, which fosters digital transformation in rural areas. However, the adoption of rural innovation is hindered by weak local governance capacity and urban-centric RIS design (Adamowicz, Zwolińska-Ligaj, 2020; Widomski, Musz-Pomorska, 2023). Demographic challenges like youth outmigration and dependency on EU funding present significant threats to sustainability. **Romania** shows strong alignment between RIS and SDG targets and has a strong agricultural base. However, the lack of coordination among institutions and administrative fragmentation weaken the effectiveness of rural RIS (Firoiu et al., 2019); (Bădîrcea et al., 2025). While benefiting from EU structural funds for digital infrastructure and renewable energy in rural areas, the country continues to face high rural poverty rates. However, Romania has strategic potential to advance smart villages and integrate renewable energy solutions into rural development (Mihai, Iatu, 2020). **Hungarian** RIS strategies are characterised by a centralised top-down approach, which limits the engagement of local stakeholders. Despite a strong tradition in agricultural innovation and existing rural clusters, Hungary faces serious challenges related to digital divides and regulatory instability (Nagy et al., 2018). However, the country has significant potential in cross-border cooperation, cultural tourism, and the use of EU programmes like Horizon Europe. However, political centralization and democratic backsliding pose critical threats to regional innovation governance (Gica et al., 2021).

What are the key barriers and enablers for effectively aligning RIS activities with the SDG agenda in agriculturally oriented regions?

To better understand the dynamics of aligning Research and Innovation Strategies (RIS) with Sustainable Development Goals (SDGs) in agriculturally orientated regions, table 10 presents a SWOT analysis identifying the key strengths, weaknesses, opportunities and threats that act as enablers or barriers to effective integration.

Table 10.
SWOT Table: RIS & SDG Alignment in Agriculturally Oriented Regions

SWOT Category	Poland	Romania	Hungary
Strengths	- Strong RIS institutions. - Efficient EU fund absorption. - Agri-tech and bioeconomy support.	- Large agricultural base. - SDG alignment in national plans. - Access to EU rural funds.	- Agricultural innovation clusters. - Tradition in rural R&D. - Sectoral RIS-SDG integration.
Weaknesses	- Urban-biased RIS focus. - Weak rural governance. - Low innovation in small farms.	- Institutional fragmentation. - Poor rural RIS monitoring. - Rural infrastructure deficits.	- Top-down planning. - Limited social SDG focus. - Weak stakeholder inclusion.
Opportunities	- Green Deal alignment. - Smart village development. - Digital agriculture expansion.	- Renewable energy in rural zones. - Smart village pilots. - EU funds for inclusion.	- Cross-border RIS initiatives. - Sustainable tourism. - Horizon Europe rural innovation grants.
Threats	- Youth outmigration. - Dependence on EU funds. - Regulatory implementation delays.	- Persistent rural poverty. - Climate-related agri risks. - Administrative inefficiencies.	- Democratic backsliding. - Digital rural-urban divide.- Unpredictable policy environment.

Source: Own research.

Poland has a well-developed institutional structure for RIS and effectively absorbs EU funds to support digital transformation and innovation in rural areas. Initiatives such as smart villages and the development of the bioeconomy are gaining momentum, and the country is making progress in implementing RIS3 strategies aligned with the Green Deal priorities. Strengths also include expanding digital infrastructure and the potential for public–private partnerships (Adamowicz, Zwolińska-Ligaj, 2020; Raszkowski, Bartniczak, 2019). Despite these advances, Poland faces major barriers, including limited local governance capacity, low innovation acceptance in rural SMEs, and an urban-biassed approach to policy design. Youth outmigration from rural areas weakens the capacity of the local community to implement the SDGs. Additionally, the lack of long-tethe caserm monitoring of RIS impact on sustainable development complicates effective alignment (Adamowicz, Zwolińska-Ligaj, 2020; Chmieliński, Gospodarowicz, 2018): Romania demonstrates strong alignment between national development plans and the Sustainable Development Goals, leading to increased use of EU structural funds to modernise rural infrastructure and renewable energy. Rural areas, rich in agricultural resources, are key beneficiaries of smart village projects supported by RIS policies (Firoiu et al., 2019; Mihai, Iatu, 2020). Efforts are also underway to strengthen digitalization and social inclusion in rural zones.

On the other hand, **Romania** continues to struggle with serious barriers: administrative fragmentation, poor institutional coordination, and a lack of effective monitoring systems for the impact of RIS on the SDGs. High rural poverty and limited innovation capacity between local farms are critical challenges to sustainable development. Climate-related issues, such as droughts and unstable crop yields, further hinder efforts to adapt RIS to the SDG framework (Bădîrcea et al., 2025). **Hungary** has a strong tradition of agricultural innovation and well-functioning rural clusters, some of which integrate the SDG goals with the RIS policy. Support from EU programmes such as Horizon Europe opens opportunities for cross-border projects and sustainable tourism development in rural regions. The country also employs digital tools in agriculture, especially for precision agriculture and resource efficiency (Brodny, Tutak, 2023). However, Hungary's RIS system remains highly centralised with low stakeholder participation at the local level. There is also a limited focus on social SDGs such as equality and education. Institutional backsliding and political instability create regulatory uncertainty and weaken long-term strategic planning. Significant digital divides between urban and rural areas also constrain the transformative potential of RIS (Gica et al., 2021; Nagy et al., 2018).

4. Summary

Regional Innovation Systems in Poland, Romania, and Hungary play an increasingly important role in supporting the implementation of Sustainable Development Goals (SDGs), particularly in agricultural and peripheral rural areas. A comparative analysis shows that while all three countries rely on similar EU policy tools, the effectiveness of their implementation and local adaptation vary significantly. **Poland** stands out with well-developed RIS institutions, effective absorption of EU funds, and a strong research and advisory base in the agricultural sector. Thanks to its decentralised governance model, many regions, especially in the east, are implementing innovations in areas such as agri-tech, the bioeconomy, and green energy. Nevertheless, Poland still faces challenges including low adoption of innovation among small farms, youth outmigration from rural areas, and resource concentration in urban regions. In **Hungary**, RIS operate mainly under a centralised model, where strategic decisions and financial resources are concentrated in Budapest. Although the country has a tradition of agricultural innovation and active local clusters, limited regional autonomy, weak institutional integration, and low innovation absorption significantly weaken the impact of RIS on local development. **Romania**, on the other hand, has significant agricultural potential and a growing IT sector, but suffers from poor coordination among institutions, fragmented implementation of RIS, and lack of local capacity. Projects like smart villages and investments in digital and renewable energy infrastructure show promising directions, but their effectiveness depends on improved implementation capacity.

All three countries face similar challenges: outmigration of youth from rural areas, dependence on EU funding, lack of long-term RIS impact monitoring, and limited participation of local communities in innovation processes**.** At the same time, development opportunities lie in the implementation of the European Green Deal, the advancement of the circular economy, the digitalisation of agriculture, and the strengthening of cooperation between universities, municipalities and the private sector. However, effective alignment of RIS with the SDG agenda requires, above all, decentralisation of governance, strengthening institutional capacity at the local level, and embedding innovation in the real needs of rural communities.

In all cases, the successful implementation of the SDG is based on decentralised governance, inclusive stakeholder engagement, and long-term sustainability planning within RIS frameworks.

5. Conclusion and recommendation

Common challenges in all three countries include the migration of young people from rural areas, a strong dependence on EU funding, the lack of long-term monitoring of RIS impacts, and the limited participation of local communities in innovation processes. At the same time, all three countries have opportunities to strengthen their systems by making fuller use of the possibilities offered by the European Green Deal—particularly in the fields of circular economy, renewable energy and digitalisation of agriculture.

In **Poland**, the priority should be to support small farms in adopting agricultural technologies and sustainable practices, while also fostering entrepreneurship and developing digital infrastructure in rural areas to counteract youth outmigration. It is equally important to direct RIS funding more strategically toward peripheral regions and to strengthen long-term monitoring of how these initiatives contribute to the Sustainable Development Goals. In **Hungary**, the key task is to decentralise RIS governance by granting more competences and resources to regions. Closer cooperation between universities, clusters and local development institutions is also necessary, in addition to creating conditions for greater innovation absorption through advisory services and pilot projects. Increasing the participation of municipalities and local communities in decision-making processes is vital to reduce the dominance of the top-down model. In **Romania**, policy should focus on improving coordination between national and regional levels and building the administrative capacity of local governments, particularly in implementing smart village concepts, digitalisation, and renewable energy projects. Rural innovation ecosystems also require support, which can be achieved through stronger cooperation between universities, municipalities, and the private sector. A further priority is to ensure easier and more transparent access to EU funds for SMEs and local communities.

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