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CIRCULAR ECONOMY MODELS FOR SMALL-SCALE FARMERS IN MOUNTAINOUS AREAS: CHALLENGES AND OPPORTUNITIES

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Abstract. *The transition from coal to sustainable agriculture in mountainous areas presents unique challenges and opportunities for small-scale farmers. This study explores the application of circular economy models in small-scale farming within these regions, aiming to identify sustainable practices that can enhance economic viability and environmental resilience. The research highlights the principles of circular economy, their benefits, and the specific challenges faced by farmers in mountainous areas. The research adopts a mixed-methods approach, combining qualitative and quantitative data to provide a comprehensive understanding of the subject. Key methods include literature review, data and case study analysis, which together offer a robust framework for exploring the potential of circular economy practices in mountainous areas. Through the case studies of successful implementations, the study provides practical insights and lessons learned, emphasizing the potential for replicating these models in similar contexts. Policy recommendations are also discussed, focusing on the role of institutions in supporting the adoption of circular economy practices. The findings contribute to the broader discourse on sustainable agriculture and offer a pathway for small-scale farmers to achieve a just transition from coal dependency. Supporting small-scale farmers in mountainous areas is not just an agricultural or environmental issue, it is a question of social justice.*

Keywords*: Circular economy, Small-scale farming, Mountainous areas, Sustainable agriculture, Just transition*

INTRODUCTION

The concept of just transition has gained prominence as societies seek to shift from fossil fuel-dependent economies to sustainable, low-carbon systems. In mountainous areas historically reliant on coal mining, this transition poses both significant challenges and opportunities. Agriculture, particularly sustainable agriculture, emerges as a viable economic alternative capable of supporting rural revitalization and ecological restoration (ADELABU ET AL., 2020). Sustainable agriculture, grounded in principles of resource efficiency and environmental stewardship, aligns closely with the objectives of the circular economy. Circular models in agriculture emphasize reducing waste, recycling organic matter, and optimizing resource use, contributing to both economic resilience and ecological balance (ALI & ALI, 2024; HAMAM ET AL., 2021). Practices such as agroforestry, organic farming, and integrated pest management have proven effective in enhancing soil fertility, conserving biodiversity, and strengthening local food systems (CHINNICI ET AL., 2021; BARROS ET AL., 2023).

In mountainous areas, small-scale farmers play a critical role in maintaining cultural landscapes and ecosystem services. However, they face unique constraints, including fragmented landholdings, difficult terrain, limited market access, and vulnerability to climate change impacts (SEKOT, 2000; KOTYAL, 2023). Addressing these challenges requires innovative policy

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frameworks, investment in infrastructure, and the promotion of knowledge transfer systems tailored to local conditions (DAUGBJERG & SWINBANK, 2012; DARJEE, 2023).
This study explores how sustainable agriculture can support the just transition in mountainous, coal-dependent areas. By analyzing successful case studies and integrating insights from existing literature, the research aims to: (1) identify sustainable agricultural practices suitable for post-coal landscapes, (2) assess barriers to implementation, and (3) propose policy recommendations to foster a resilient, inclusive rural economy. Through a mixed-methods approach combining qualitative and quantitative analyses, the paper contributes to the broader discourse on climate neutrality, rural development, and territorial justice (MULYA ET AL., 2024; DHILLON, 2023). The findings are intended to inform policymakers, practitioners, and researchers about the potential of sustainable agriculture as a strategic pillar in the just transition, particularly in vulnerable mountainous regions across Europe and beyond (KUMAR, 2023; SAHU, 2013).

METHODOLOGY

To explore the role of sustainable agriculture in supporting a just transition from coal in mountainous regions, this study employs a mixed-methods approach. By combining qualitative and quantitative methods, the research aims to provide a nuanced understanding of both the opportunities and obstacles faced by small-scale farmers (MULYA ET AL., 2024).

The qualitative component involved an extensive review of recent literature on circular economy models in agriculture, with particular emphasis on their application in challenging, mountainous contexts (ALI & ALI, 2024; HAMAM ET AL., 2021). Studies that focused on resource efficiency, waste reduction, and agroecological practices were analyzed, helping to frame the broader theoretical background (CHINNICI ET AL., 2021; BARROS ET AL., 2023). Furthermore, special attention was given to initiatives that addressed the socio-economic realities of farmers in post-coal landscapes (ADELABU ET AL., 2020). Case study analysis formed another core part of the methodology. Regions where sustainable farming practices had demonstrably contributed to economic renewal and environmental recovery were selected for closer examination (MARCHANT, 2013; BARROS ET AL., 2023). These case studies provided concrete examples of what has worked — and why — offering valuable lessons for similar territories undergoing transition.

Quantitative analysis relied on secondary data sources, such as agricultural productivity reports, land use statistics, and environmental impact studies. The aim was to identify measurable changes linked to the adoption of sustainable agricultural practices in areas affected by the decline of coal industries (DHILLON, 2023). Throughout the research process, triangulation was used to validate findings, ensuring that insights from different sources and methods were cross-checked and corroborated (SAHU, 2013). This comprehensive methodological framework strengthens the study's conclusions and enhances its relevance for policymakers, practitioners, and local communities alike.

CIRCULAR ECONOMY MODELS IN AGRICULTURE

Sustainable agriculture and circular economy principles share common ground in their focus on resource efficiency, waste minimization, and environmental stewardship. In agriculture, the circular economy promotes practices that close nutrient loops, valorize organic waste, and optimize inputs to create more resilient and productive systems (ALI & ALI, 2024; HAMAM ET AL., 2021). Among the most widespread applications are composting, crop rotation, agroforestry, and the integration of renewable energy sources on farms. These practices not only

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enhance soil fertility and biodiversity but also help farmers reduce their dependence on external inputs such as synthetic fertilizers and pesticides (CHINNICI ET AL., 2021; BARROS ET AL., 2023). In mountainous areas, where access to industrial inputs can be limited and costly, these models offer particularly valuable alternatives (ADELABU ET AL., 2020). Adopting circular practices in small-scale farming brings several tangible benefits. Beyond improving resource efficiency and environmental health, it can enhance farmers' economic resilience by diversifying income streams — for example, through biogas production, local value-added processing, or eco-tourism initiatives (HAMAM ET AL., 2021). Moreover, by aligning farming systems more closely with natural cycles, circular models contribute to climate change mitigation and adaptation, crucial goals in vulnerable mountain regions (ALI & ALI, 2024).

Nevertheless, the transition to circular agriculture is not without challenges. Many small-scale farmers face financial barriers, limited access to technical knowledge, and a lack of supportive infrastructure or policies (KOTYAL, 2023). Overcoming these obstacles requires targeted interventions, including training programs, financial incentives, and collaborative networks that facilitate knowledge exchange (DHILLON, 2023). What emerges clearly is that circular economy models are not just about new technologies or techniques — they are about rethinking farming as part of a living, dynamic landscape where economic, social, and ecological processes are deeply interconnected. In mountainous areas transitioning away from coal, embracing these models offers a pathway towards regeneration and renewed rural vitality (MARCHANT, 2013; MULYA ET AL., 2024).

SMALL-SCALE FARMERS IN MOUNTAINOUS AREAS

Small-scale farmers are at the heart of rural life in mountainous areas, where agriculture is deeply intertwined with cultural identity, biodiversity conservation, and local economies. In these regions, farmers often manage fragmented plots of land, practicing diversified agriculture that combines crop cultivation, livestock raising, and forestry activities in an integrated way (MARCHANT, 2013). Such diversification not only optimizes the use of limited resources but also enhances resilience to climatic and economic shocks. Steep slopes, thin soils, and unpredictable weather patterns pose serious challenges, requiring farming practices that are both adaptable and sustainable (ADELABU ET AL., 2020). Traditional knowledge systems, refined over generations, play a vital role in managing these landscapes, offering valuable insights for contemporary sustainability efforts.

However, small-scale farmers in mountainous regions face a complex set of constraints. Limited access to markets, infrastructure deficits, and financial barriers often hinder their ability to modernize practices or invest in sustainability (SEKOT, 2000). Climate change further exacerbates existing vulnerabilities, leading to soil erosion, water scarcity, and more frequent extreme weather events (ALI & ALI, 2024).

Despite these difficulties, opportunities for sustainable development are emerging. Practices such as agroforestry, organic farming, and the application of circular economy principles can significantly improve farm productivity and environmental outcomes (MULYA ET AL., 2024). Moreover, strengthening local value chains — through cooperative models, direct-to-consumer sales, or agritourism — can help farmers capture greater value and stabilize their incomes (DHILLON, 2023).

Supporting small-scale farmers in mountainous areas requires more than technical solutions; it demands holistic approaches that recognize the social, economic, and ecological dimensions of farming systems. Investments in education, infrastructure, and policy support are

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essential to empower these farmers as active agents of change in the just transition from coal-dependent economies (KOTYAL, 2023). By building on their unique strengths and knowledge, small-scale farmers can become key drivers of sustainable development in some of the most fragile and valuable ecosystems in the world.

CASE STUDIES

This section presents case studies of successful implementations of circular economy models in small-scale farming. The examples illustrate how sustainable agricultural practices grounded in circular economy principles can support the just transition in mountainous, post-coal regions. This section highlights three relevant case studies where small-scale farmers have successfully adapted their systems to enhance both economic resilience and environmental sustainability.

1. Agroforestry Systems in the Maloti–Drakensberg Mountains, Southern Africa

In the Maloti–Drakensberg mountain range, smallholder farmers have embraced agroforestry as a strategy to combat soil erosion, enhance biodiversity, and diversify their income sources (ADELABU ET AL., 2020). By integrating tree planting with crop cultivation and livestock grazing, these farmers created multifunctional landscapes that improve soil fertility and protect water sources. Local communities reported increased agricultural yields and improved ecosystem stability, illustrating how traditional knowledge and ecological restoration can go hand in hand in fragile environments.

2. Organic Farming Networks in the Italian Alps

In several mountainous regions of Italy, small-scale farmers organized into organic cooperatives to promote sustainable agriculture and rural development (CHINNICI ET AL., 2021). These cooperatives implemented crop rotation, composting, and reduced chemical input practices, resulting in improved soil health and higher product quality. Additionally, by tapping into niche organic markets and agro-tourism initiatives, farmers managed to increase their incomes while reinforcing local food systems. The Italian experience demonstrates the importance of collective action and value chain innovation in overcoming the structural disadvantages of remote mountain farming.

3. Circular Economy Initiatives in Latin American Highlands

In parts of the Andean highlands, farmers have adopted circular economy models that valorize agricultural waste, such as converting crop residues into biogas or organic fertilizers (BARROS ET AL., 2023). By closing nutrient loops and minimizing dependence on external inputs, these initiatives have helped to increase farm profitability and reduce environmental degradation. Training programs and microcredit schemes, often supported by NGOs and local governments, were crucial in scaling these solutions across communities. This case highlights the pivotal role of institutional support in enabling the transition toward sustainable rural economies.

Across these examples, a few common lessons emerge. First, local knowledge and cultural practices must be central to any sustainable farming model (MARCHANT, 2013). Second, technical innovations must be matched with accessible financing and strong cooperative structures (ALI & ALI, 2024). Taken together, they offer valuable insights into how small-scale farmers in mountainous areas can become catalysts for sustainable, post-coal development — provided they receive the right support at the right time. The potential for replicating successful circular economy models in other mountainous regions is significant. By adapting the practices and strategies highlighted in the case studies to local conditions, small-scale farmers can achieve similar benefits in terms of sustainability and productivity (MULYA et al., 2024). For instance,

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the principles of agroforestry and organic farming can be tailored to different climatic and geographical contexts, providing a flexible framework for sustainable agriculture (DHILLON, 2023). Finally, replicability depends on flexible adaptation to specific ecological, social, and economic contexts (MULYA ET AL., 2024; DHILLON, 2023), supportive policies and institutional frameworks that facilitate knowledge transfer and resource allocation (SAHU, 2013).

POLICY AND INSTITUTIONAL FRAMEWORK

Effective policies and strong institutions are essential for supporting small-scale farmers in their transition toward sustainable agricultural systems, particularly in mountainous areas affected by the decline of coal industries. While significant efforts have been made at national and international levels, important gaps remain that must be addressed to enable a truly just transition.

At the European level, instruments such as the Common Agricultural Policy (CAP) include specific measures designed to promote environmentally friendly farming practices and support rural development (DAUGBJERG & SWINBANK, 2012). These policies offer financial incentives for organic farming, agri-environmental schemes, and diversification projects that can be particularly beneficial for farmers in marginalized mountain regions (DARJEE, 2023).

However, the implementation of such policies often encounters obstacles. Many small-scale farmers face difficulties accessing funding programs due to administrative complexity, lack of technical assistance, or inadequate outreach in remote areas (KUMAR, 2023). Moreover, the coherence between climate policies, rural development strategies, and agricultural support measures is frequently weak, reducing their overall effectiveness (DAUGBJERG & SWINBANK, 2012). To bridge these gaps, several key policy recommendations emerge from the research. First, there is a need to simplify access to funding mechanisms and tailor support schemes to the specific needs of mountainous areas. Second, enhancing the capacity of local institutions — such as agricultural advisory services, rural development agencies, and farmers' cooperatives — is critical to ensure effective knowledge transfer and technical support (DARJEE, 2023). International organizations such as the Food and Agriculture Organization (FAO) and the International Fund for Agricultural Development (IFAD) also play an important role in promoting sustainable practices through funding, training, and pilot projects (DARJEE, 2023). Strengthening collaboration between public institutions, research bodies, and civil society organizations can significantly enhance the adoption of circular economy models among small-scale farmers (KUMAR, 2023).

Ultimately, achieving a just transition in mountainous, coal-dependent areas requires integrated policies that not only support agricultural transformation but also address broader issues such as infrastructure development, education, and climate resilience. Institutional frameworks must be designed to empower local communities as active agents of change, rather than passive recipients of top-down initiatives. Without a concerted effort to align policies, strengthen institutions, and build local capacities, the potential of sustainable agriculture to drive inclusive rural regeneration risks remaining largely untapped.

CONCLUSIONS

This study has explored how sustainable agriculture can serve as a pillar of the just transition from coal in mountainous regions. By applying circular economy principles and

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building on the knowledge and resilience of small-scale farmers, it is possible to foster economic renewal and environmental restoration in some of the most vulnerable landscapes.

The findings show that practices such as agroforestry, organic farming, and the valorization of agricultural waste can significantly enhance the sustainability and profitability of small-scale farms (ALI & ALI, 2024; HAMAM ET AL., 2021). Case studies from Southern Africa, Italy, and Latin America illustrate that success depends not only on technical innovation but also on strong community engagement, institutional support, and flexible adaptation to local contexts (ADELABU ET AL., 2020; CHINNICI ET AL., 2021; BARROS ET AL., 2023). However, major barriers persist. Limited access to financial resources, technical expertise, and supportive infrastructure continue to constrain the adoption of sustainable practices (DAUGBJERG & SWINBANK, 2012; DARJEE, 2023). Without coherent, inclusive policies and strong institutions capable of addressing these structural challenges, the potential of sustainable agriculture to drive a just transition will remain under-realized (KUMAR, 2023).

Looking forward, future research should prioritize the development of context-specific strategies to enhance resource efficiency, mitigate climate impacts, and strengthen local food systems. Particular attention should be paid to innovative financing models, participatory governance approaches, and the long-term monitoring of sustainability outcomes (SAHU, 2013; GRASSLAND, 2020). Ultimately, supporting small-scale farmers in mountainous areas is not just an agricultural or environmental issue — it is a question of social justice. Empowering these communities through sustainable agriculture offers a pathway to economic dignity, ecological resilience, and a truly just transition for generations to come.

BIBLIOGRAPHY

1. ADELABU, D.B., CLARK, V.R., BREDENHAND, E., 2020 – Potential for Sustainable Mountain Farming: Challenges and Prospects for Sustainable Smallholder Farming in the Maloti–Drakensberg Mountains. Mountain Research and Development, 40 (1): A1-A11.
2. ADELABU, D.B., CLARK, V.R., BREDENHAND, E., 2020 – Potential for Sustainable Mountain Farming: Challenges and Prospects for Sustainable Smallholder Farming in the Maloti–Drakensberg Mountains. Mountain Research and Development, 40 (1): A1-A11.
3. ALI, J., ALI, T., 2024 – Circular economy and agriculture: mapping scientific productivity, research pattern and future research direction. Environment, Development and Sustainability, 26: 30063–30108. https://doi.org/10.1007/s10668-023-03963-x.
4. BARROS, M.V., SALVADOR, R., PIEKARSKI, C.M., DE FRANCISCO, A.C., 2023 – Circular Economy Practices in Agriculture: From Waste to Energy. Journal of Cleaner Production, 289: 125-136.
5. CHINNICI, G., PECORINO, B., MAESANO, G., D'AMICO, M., 2021 – Circular Economy Models in Agro-Food Systems: A Review. Sustainability, 13 (6): 3453.
6. DARJEE, D.K., 2023 – A Review on Policy Initiatives, Institutional Mechanism and Support for Organic Farming in India with Special Reference to North-east States. IJRAR.
7. DAUGJBERG, C., SWINBANK, A., 2012 – Introduction to the 'new' politics of agriculture and food. Policy and Society, 31 (4): 259-270. https://doi.org/10.1016/j.polsoc.2012.10.002.
8. DHILLON, R.; MONCUR, Q., 2023 – Small-Scale Farming: A Review of Challenges and Potential Opportunities Offered by Technological Advancements. Sustainability, 15, 15478. https://doi.org/10.3390/su152115478.
9. HAMAM, M., CHINNICI, G., DI VITA, G., PAPPALARDO, G., PECORINO, B., MAESANO, G., D'AMICO, M., 2021 – Circular Economy Models in Agro-Food Systems: A Review. Sustainability, 13 (6): 3453. https://doi.org/10.3390/su13063453.
10. KOTYAL, K., 2023 – Circular Agriculture: Sustainable Farming Practices for Zero Waste. Environmental Reports, 5 (1): 08-12. https://doi.org/10.51470/ER.2023.5.1.08.
11. KUMAR, S., 2023 – Towards more evidence-based agricultural and food policies. Q Open, 3 (3): qoad003.

http://doi.org/10.59463/RJAS.2025.2.05

12. MARCHANT, C., 2013 – Mountain Farming is Family Farming. Food and Agriculture Organization of the United Nations, Centre for Development and Environment, University of Bern.
13. MULYA, S.P., HUDALAH, D., SALIM, W. ET AL., 2024 – Review of the Circular Economy Implementation in the Agriculture Sector: A Regional Development Approach. Circ.Econ.Sust.. https://doi.org/10.1007/s43615-024-00463-6.
14. SAHU, P.K., 2013 – Research Methodology: A Guide for Researchers In Agricultural Science, Social Science and Other Related Fields. Springer.
15. SZARZYNSKI, J., ALCÁNTARA-AYALA, I., NÜSSER, M., & SCHNEIDERBAUER, S., 2022 – Addressing Challenges of Hazards, Risks, and Disaster Management in Mountain Regions. Mountain Research and Development, 42(2), 1-3. https://doi.org/10.1659/mrd.4202.