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Integration of Sustainable Technologies and Social Innovation: Building Regional Ecosystems

Mauro Muniz de Oliveira[1*], de Medeiros Fernandes dos Santos[2], Breno Henrique Azevedo Bezerra De Sousa[3], Debora Cristina Almeida Cruz de Oliveira[4], Elclesio Duarte de Oliveira[4], Lizandra de Oliveira Ricardo Fernandes[5], Magda de Souza Santos Melo Silva[6], Rafael Soares Cardoso[7], Isidro José Bezerra Maciel Fortaleza do Nascimento[8]

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ABSTRACT

Contemporary socio-environmental transformations intensify the urgency of strategies that integrate sustainable technologies and social innovation to address complex development challenges. Recent literature highlights that digital and social innovation ecosystems constitute central arrangements for articulating science, policy, business, and society around solutions that reconcile economic growth, social inclusion, and environmental sustainability. For this reason, the article aims to analyze the integration of sustainable technologies and social innovation in the construction of regional ecosystems, investigating how these dimensions complement each other and what implications they bring to territorial policies and practices of inclusive development. The findings show that digital technologies such as IoT, blockchain, and artificial intelligence, combined with co-creation processes and participatory governance, drive circular ecosystems and strengthen the generation of public value. Results also indicate that cross-cutting policies, socio-environmental education and enlarged helix models are determinants for regional sustainability. It is concluded that collaborative, digital and green ecosystems are indispensable for social innovation, but gaps in measurement, mobilization in peripheral territories and institutionalization of fair practices persist. These limits reinforce the need for adaptive public policies and robust metrics to consolidate legitimate, inclusive, and sustainable regional ecosystems.

INTRODUCTION

The contemporary debate on sustainable technologies and social innovation gains urgency in the face of global and regional socio-environmental crises. Recent studies indicate that social innovation, coupled with digital technologies, emerges as an effective mechanism to address complex challenges — especially through participatory governance, co-creation with multiple stakeholders, and adaptation to specific local contexts (Jareh *et al.*, 2025). In addition, social entrepreneurship combined with sustainable technological solutions has demonstrated a positive impact on the inclusive development of communities, in line with the Sustainable Development Goals (Raman *et al.*, 2025). Additional evidence points to digital innovation ecosystems — involving companies, universities, data, and public policies — are key to promoting regional green development (Li *et al.*, 2024), while recent systematic reviews reveal that social innovation ecosystems involve diverse actors and generate significant value to combat inequalities (Franco & Antony, 2023).

For this reason, this article aims to analyze the Integration of Sustainable Technologies and Social Innovation: Building Regional Ecosystems, highlighting how these dimensions interact in the current context and what are their implications for inclusive and sustainable territorial development.

To achieve this objective, an integrative literature review was developed, a method that enables the systematization of different theoretical and empirical perspectives on the subject, allowing the identification of convergences, consolidated contributions and gaps still present in recent scientific production.

LITERATURE REVIEW

According to Truffer *et al.* (2022), sustainable transitions are processes of systemic change that require adaptive institutional arrangements capable of articulating science, policy, and society in a coordinated manner. In the same vein, Shajari and David (2025) introduce the concept of twin transition, which posits that sustainability and digitalization should not be viewed as separate, but rather as complementary and interdependent dimensions. This convergence indicates that sustainable transitions go beyond the restricted environmental debate and configure

[1] Metropolitan University of Science and Technology, USA
[2] Metropolitan University of Science and Technology, USA
[3] Universidade Federal Fluminense, Brazil
[4] Metropolitan University of Science and Technology, Brazil
[5] Universidade Federal Fluminense, Brazil
[6] Insitituto Federal do Triangulo Mineiro, Brazil
[7] Fundação Cesgranrio, Brazil
[8] Universidade de São Paulo, Brazil
[*] Corresponding author's e-mail: edson_nogueira@ufam.edu.br

an agenda that simultaneously involves technological, social and institutional transformation.

The integration between digitalization and sustainability has been conceptualized as a new type of organizational ecosystem. Florek-Paszkowska and Ujwary-Gil (2025) develop the notion of the Digital-Sustainability Ecosystem, in which emerging technologies such as artificial intelligence, blockchain, and the internet of things constitute central enablers for sustainable innovation. Cuel (2024) complements by arguing that digital platforms should be understood as agents of social and ecological transformation, and not just as technical tools. This articulation demonstrates that digital is not an accessory, but the foundation of contemporary sustainable innovation.

In the field of green ecosystems, Zhou and Li (2024) argue that the notion of value emergence explains how value is generated from dynamic interactions and feedback loops in innovation environments. Santos *et al.* (2024) expand this understanding by showing that complex collaborative networks enhance the diffusion of green practices, expanding the capacity for environmental transformation. The combination of these perspectives reinforces that sustainability is not an individual product, but a collective result of relational arrangements that dynamize green innovation ecosystems.

Ecosystem modeling is another essential point in recent conceptual construction. Da Silva (2023) proposes the ARA Framework, which allows mapping actors, knowledge flows, and organizational structures in an integrated way. Miah (2025), when discussing digital entrepreneurship ecosystems, points out that these conceptual arrangements need to be contextualized as dynamic environments of sustainable innovation, connecting theory and practice. Together, these contributions demonstrate that ecosystems are more than metaphors, they are analytical structures that explain and guide innovation processes.

The debate on governance has been strengthened by the application of different theoretical models. Granstrand and Holgersson (2020) characterize ecosystems as evolutionary systems composed of complementary actors and interdependent institutions, emphasizing the complexity of interactions. In a similar vein, Shajari and David (2025) highlight that models such as the Quadruple and the Quintuple Helix are fundamental to balance digital, social, and environmental dimensions. In this way, the governance of innovation ecosystems comes to be understood as adaptive coordination, essential to generate systemic resilience.

The discussion on interinstitutional collaboration reinforces this perspective. Monteiro *et al.* (2025) argue that open innovation depends on the circulation of knowledge among multiple actors and the legitimacy of collaborative practices to promote sustainability. This view converges with Florek-Paszkowska and Ujwary-Gil (2025), who point to the need to align digitalization with sustainability. Thus, it is evident that sustainable innovation requires articulation between institutional and technological actors, consolidating itself as an essentially collective practice.

In the field of entrepreneurial ecosystems, Babburoglu (2025) shows that innovation hubs work as catalysts for startups by offering resources, networks, and strategic support. However, the author also warns of structural challenges such as limited funding and restrictive policies, which can compromise these environments. This view converges with Miah (2025), when he highlights that digital ecosystems and entrepreneurs need robust institutional support to sustain innovation at scale.

Finally, Zhou and Li (2024) reinforce that the emerging value in green ecosystems only materializes when the digital and sustainable dimensions are integrated systemically. Shajari and David (2025) reaffirm this position by arguing that the twin transition is the most promising conceptual path to unite digitalization and sustainability in innovative processes. By bringing together these perspectives, a theoretical framework is consolidated that begins with systemic transition, proceeds through digital integration, emerging value, modeling and governance, institutional collaboration, and innovation hubs, culminating in a synthesis that highlights the importance of integrated and interdependent ecosystems for sustainability.

MATERIALS AND METHODS

This study adopts the integrative literature review approach, suitable for synthesizing recent scientific productions and identifying convergences between different fields of knowledge. The choice of the method is justified by the need to integrate theoretical concepts and empirical evidence about the integration of sustainable technologies and social innovation, composing a comprehensive and articulated view on the construction of regional ecosystems.

The search process was carried out in recognized databases, such as Web of Science, Scopus, Scielo, MDPI and journals indexed in open repositories (E-Palli, IOSR, among others). Articles published between 2020 and 2025 were considered in order to ensure the timeliness of the evidence, with a focus on studies that addressed social innovation, sustainable technologies, digital ecosystems, and regional governance. The inclusion criteria prioritized peer-reviewed articles with thematic adherence to the object of the study, while duplicate publications or those without access to full text were excluded.

The analysis of the articles followed the logic of the conceptual funnel, starting with the broad discussion on sustainable innovation and digitalization, to the specificity of regional ecosystems and social innovation. Subsequently, the results of the research group's articles were triangulated with the findings of the international literature, in order to identify convergences, advances, and gaps. This strategy ensured theoretical consistency and empirical relevance in the composition of the discussion. The dependence on indexed databases is recognized as a limitation, which may restrict the scope of studies not

published in journals with greater visibility. In addition, the integrative review, by its nature, does not exhaust all methodological possibilities, but offers a robust synthesis to understand the paths and challenges of integration between social innovation, sustainable technologies, and regional ecosystems.

RESULTS AND DISCUSSION

In the axis of social innovation and ecosystems as generators of public value, Santos *et al.* (2025) highlight that green technologies, such as IoT, blockchain, and renewable energy, drive circular ecosystems by promoting traceability, efficiency, and integration between strategic sectors. This highlights the central role of digital ecosystems in promoting green sustainability, while social innovation emerges through inclusive public policies and initiatives in vulnerable communities. This finding reinforces the generation of public value in regional contexts, being effective when articulated by integrated approaches that align social, technological, and political factors, in the logic of collaborative ecosystems.

The authors identify greenwashing, global inequality, and the absence of metrics as persistent challenges, which demand innovative and inclusive governance networks, linking local and transnational actors. Thus, the transformative potential of these technologies is only fully realized when there is multisectoral cooperation, expanding the impact on circularity and regional sustainability (Santos *et al.*, 2025).

According to Silva *et al.* (2024), cross-cutting agendas in the public budget reinforce collaborative ecosystems by integrating policies that combine social innovation, multisectoral governance, and sustainable development. Well-articulated institutional networks generate public value through the integration of actions in health, education and the environment. The research shows that sustainable digital ecosystems are made possible when sectoral policies are aligned with adaptive processes that provide budgetary efficiency, social inclusion, and equity, pillars of social innovation. Themes such as gender, "One Health" and school feeding exemplify this potentiality, especially when digital platforms and flexible governance structures strengthen regional sustainability. However, fiscal-social conflicts and lack of evaluation tools remain obstacles, reaffirming the importance of ecosystems capable of resource sharing, innovation and rapid response to crises.

Viana *et al.* (2025) argue that coercive isomorphism significantly influences the adoption of environmental practices, especially in robust regulatory ecosystems, evidencing the role of collaborative ecosystems in generating public value in regional sustainability. Connected environments favor convergence to environmental standards, through digital platforms and knowledge flows that enhance green sustainability. However, legal impositions only gain real impact when articulated with collaborative networks and institutional learning, aligning social innovation with environmental governance. In peripheral regions, ritualized responses denounce the insufficiency of these networks, reinforcing the need to strengthen regional ecosystems to overcome cultural and institutional limits in the diffusion of sustainability.

In the theoretical-practical field, Nascimento *et al.* (2025) reinforce that the Quintuple Helix model expands governance to integrate university, government, industry, civil society, and the environment in an interactive ecosystem. This perspective shows that the generation of public value and regional sustainability depend on policies and institutions that are sensitive to local realities, which are capable of aligning diverse interests and ensuring socio-environmental justice. The model, therefore, directly connects the empirical findings on inter-institutional collaboration (Monteiro *et al.*, 2025) and social innovation (Silva *et al.*, 2024), consolidating the view that sustainable regional ecosystems require dense articulation between sectors, social participation, and ecological regeneration.

In the business context, Campana *et al.* (2025) show that environmental accounting contributes decisively to corporate sustainability: transparency and strengthening of governance enhance innovative ecosystems and promote stakeholder integration, favoring public value. Environmental accounting practices, combined with digital technologies, improve operational efficiency and attract sustainable investments, consolidating digital ecosystems focused on green sustainability. Harmonised standards, financial incentives and independent audits are essential to transform environmental accounting into a tool for sustainable development. However, standardization challenges, costs, and greenwashing risks require collaborative ecosystems between companies, government, and civil society, ensuring the transformative impact of these mechanisms.

Monteiro *et al.* (2025) underlines that inter-institutional collaborations in open innovation are key to building sustainable regional ecosystems. The flow of knowledge between universities, companies, and government enhances both social innovation and the generation of public value. Digital platforms and technological diversity are key elements for the resilience of these environments, which depend on collaborative processes and transformative leadership. Advances in sustainability require overcoming regulatory barriers and strengthening diversity management, as well as public policies aimed at stable connection between regional actors. The alignment between technological diffusion and collective strategies transforms environmental challenges into opportunities, strengthening digital ecosystems oriented to green sustainability.

In the study on smart cities, Silva *et al.* (2025) analyze Palmas-TO and find that the success of smart cities depends on technological integration and innovative governance, forming regional ecosystems focused on sustainability and public value. Investments in connectivity, sanitation, and education are decisive for

collaborative and inclusive environments. Digital urban management platforms – such as Big Data, IoT, and AI – are essential for effective resource monitoring and citizen participation, reinforcing the role of digital ecosystems in regional green sustainability. Structural challenges persist, requiring government strategies to consolidate dynamic and inclusive urban ecosystems.

Pereira *et al.* (2025), when addressing sustainability education and socio-environmental skills, show that the development of systems thinking and collaboration is central to forming innovative and sustainable ecosystems. Active pedagogical strategies and digital methodologies strengthen educational ecosystems aligned with green sustainability. Curriculum integration, teacher training and coherent evaluations ensure that skills are transmitted and internalized, promoting citizens able to act in collaborative ecosystems and regional social innovation.

Sousa *et al.* (2025) emphasize that integrating the SDGs into environmental policies depends on collaborative ecosystems between government, the productive sector, and civil society, with the public value generated by institutional articulation and social innovation that ensures inclusion and environmental justice. Digital mechanisms, active participation, and flexible governance enhance green ecosystems, connecting environmental policies with emerging technologies. The effectiveness of the strategies requires coherence and integration between the scales of governance, aligning innovative policies with regional sustainability goals.

Finally, Matos *et al.* (2025) argue that the Third Sector innovates socially through collaborative networks and multisectoral partnerships, valuing regional ecosystems capable of generating public value and implementing adaptive solutions for social inclusion and sustainability. Hybrid businesses promote the evolution of social ecosystems, integrating innovation with economic and environmental strategies, dialoguing with community demands. Digital technologies and collaborative platforms favor responsible environmental practices, reinforcing the role of digital ecosystems in green sustainability; Overcoming financial and structural challenges depends on collaborative networks, resilient leadership, and flexible governance.

In the theoretical triangulation axis, it is evident that sustainable transitions are processes of systemic change supported by adaptive institutional arrangements that articulate science, politics, and society in a coordinated way (Truffer *et al.*, 2022). The concept of twin transition, according to Shajari and David (2025), demonstrates that sustainability and digitalization are interdependent and complementary dimensions, and should be integrated as an inseparable part of the technological and institutional transformation agenda. Florek-Paszkowska and Ujwary-Gil (2025) go further, proposing the Digital-Sustainability Ecosystem, where emerging technologies such as AI, blockchain, and IoT enable sustainable innovation, being agents of social and ecological transformation, and not mere technical instruments (Cuel, 2024).

In green ecosystems, Zhou and Li (2024) state that value emergence is generated by dynamic interactions and feedback loops between actors, while Santos *et al.* (2024) show that collaborative networks increase the environmental impact of these practices. This articulation reinforces that sustainability is not an individual result, but a collective one. Da Silva (2023) proposes the ARA Framework to map actors and knowledge flows, while Miah (2025) shows that digital entrepreneurship ecosystems are dynamic environments that connect theory and practice. Modeling and governance, according to Granstrand and Holgersson (2020), depend on complementarity and evolutionary systems, and propeller models are essential to balance digital, social, and environmental dimensions (Shajari & David, 2025).

Monteiro *et al.* (2025) consolidate that open innovation and sustainability depend on the circulation of knowledge and legitimacy of collaborative practices, converging with Florek-Paszkowska & Ujwary-Gil (2025) in the demand for alignment between digitalization and sustainability. Innovation hubs, according to Babburoglu (2025), function as catalysts, but face challenges such as limited funding and restrictive policies, requiring robust institutional support (Miah, 2025). Zhou and Li (2024) reaffirm that emerging value is only realized with systemic integration of the digital and sustainable dimensions, while Shajari and David (2025) identify the twin transition as a conceptual path for innovative processes. This synthesis reinforces that sustainability depends on integrated and interdependent ecosystems.

By integrating these perspectives, it is verified that the group's results not only confirm what the theoretical contributions propose, but empirically strengthen the understanding that digital and green collaborative ecosystems are the foundation for social innovation and for the construction of regional public value. The literalness and density of the files and the theoretical framework reveal that advances, nuances, and challenges will only be overcome through flexible public policies, coordination between multiple actors, and strong institutional investment in digital platforms and adaptive governance. Gaps persist in the assessment of impacts and in the mobilization capacity of actors in peripheral territories, pointing to the need for regional strategies that consolidate socio-environmental justice and multisectoral innovation in integrated ecosystems.

CONCLUSIONS

This article aimed to analyze the integration of sustainable technologies and social innovation in the construction of regional ecosystems, highlighting how such dimensions can be articulated in favor of sustainability and the generation of public value. Based on an integrative review, key concepts and recent evidence were discussed that reinforce the relevance of collaborative institutional arrangements and digitalization as pillars of sustainable transformation. The findings indicate that social innovation, through collaborative

networks, cross-cutting policies and citizen participation, is a fundamental element for inclusive regional ecosystems oriented to public values. At the same time, the adoption of digital and green technologies, such as IoT, blockchain, and collaborative platforms, enhances sustainability by enabling circular models, efficiency in resource management, and new forms of governance. This convergence confirms that the twin transition — sustainability and digitalization — is inseparable to face contemporary challenges and consolidate robust regional strategies. It is concluded that the objective of the study was achieved, demonstrating that collaborative, digital and green ecosystems are indispensable for social innovation and regional sustainability. However, gaps remain in terms of impact measurement, the capacity to mobilize actors in peripheral territories, and the institutionalization of fair and inclusive practices. Such limitations reinforce the need for public policies sensitive to the local context, adaptive governance structures and greater investment in digital platforms, in order to consolidate sustainable, innovative and socially legitimate regional ecosystems.

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