DOI 10.5335/hdtv.26n.1.18075

HISTÓRIA
debates e tendências

UPF
PPGH - PROGRAMA DE
PÓS-GRADUAÇÃO EM HISTÓRIA

e-ISSN 2238-8885

SOIL, COMMUNITIES, AGROECOLOGY AND SUSTAINABILITY: SOCIO-ENVIRONMENTAL CHALLENGES AND PERSPECTIVES FOR SUSTAINABLE CITIES

Solo, comunidades, agroecologia e sustentabilidade: desafios socioambientais e perspectivas para cidades sustentáveis

Suelo, comunidades, agroecología y sostenibilidad: desafíos socioambientales y perspectivas para ciudades sostenibles

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Abstract:

This study analyzes the rural territory of the Zona da Mata region in Minas Gerais, Brazil, focusing on agricultural soil as a key yet often undervalued element in rural development strategies. The research adopts an interdisciplinary theoretical approach combining Geography, Soil Science, and Agroecology. The analysis is structured around three axes: socio-environmental challenges of regional agriculture, socio-spatial vulnerabilities associated with intensive soil use and degradation, and agroecological perspectives to strengthen resilience in family farming systems. Results indicate that inadequate soil management practices intensify erosion, fertility loss, and environmental degradation. Conversely, agroecological practices such as organic fertilization, vegetation cover, composting, and conservation soil management contribute to greater productive stability and natural resource conservation. The study highlights soil as a living system and a strategic component for sustainable rural territorial development.

DOI 10.5335/hdtv.26n.1.18075

Keywords: Family farming. Socio-environmental resilience. Soil conservation.

Resumo:

Este estudo analisa o território rural da Zona da Mata de Minas Gerais, Brasil, com foco no solo agrícola como elemento central, porém frequentemente subvalorizado, nas estratégias de desenvolvimento rural. A pesquisa adota uma abordagem teórica interdisciplinar que integra Geografia, Ciência do Solo e Agroecologia. A análise organiza-se em três eixos: desafios socioambientais da agricultura regional, vulnerabilidades socioespaciais associadas ao uso intensivo e à degradação dos solos e perspectivas agroecológicas para fortalecer a resiliência dos sistemas agrícolas familiares. Os resultados indicam que práticas inadequadas de manejo do solo intensificam processos de erosão, perda de fertilidade e degradação ambiental. Em contrapartida, práticas agroecológicas como adubação orgânica, cobertura vegetal, compostagem e manejo conservacionista do solo contribuem para maior estabilidade produtiva e conservação dos recursos naturais. O estudo destaca o solo como sistema vivo e componente estratégico para o desenvolvimento territorial rural sustentável.

Palavras-chave: Agricultura familiar. Conservação do solo. Resiliência socioambiental.

Resumen:

Este estudio analiza el territorio rural de la Zona da Mata de Minas Gerais, Brasil, con énfasis en el suelo agrícola como un elemento central, aunque frecuentemente subvalorado, en las estrategias de desarrollo rural. La investigación adopta un enfoque teórico interdisciplinario que integra Geografía, Ciencia del Suelo y Agroecología. El análisis se estructura en tres ejes: desafíos socioambientales de la agricultura regional, vulnerabilidades socioespaciales asociadas al uso intensivo y la degradación del suelo, y perspectivas agroecológicas para fortalecer la resiliencia de los sistemas agrícolas familiares. Los resultados indican que prácticas inadecuadas de manejo del suelo intensifican procesos de erosión, pérdida de fertilidad y degradación ambiental. Por el contrario, prácticas agroecológicas como la fertilización orgánica, la cobertura vegetal, el compostaje y el manejo conservacionista del suelo contribuyen a una mayor estabilidad productiva y a la conservación de los recursos naturales. El estudio destaca el suelo como un sistema vivo y un componente estratégico para el desarrollo territorial rural sostenible.

Palabras clave: Agricultura familiar. Conservación del suelo. Resiliencia socioambiental.

Introduction

Rural areas of the Zona da Mata region in Minas Gerais have undergone profound transformations resulting from interconnected economic, social, and environmental dynamics that characterize the twenty-first century. Traditionally marked by family farming, coffee production, and landscapes with rugged topography, the region faces complex challenges that

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include productive intensification, environmental degradation, and the socioeconomic vulnerability of rural communities. Structural changes in agriculture, such as modernization based on external inputs and partial mechanization, combined with land fragmentation and increasing pressure on natural resources, directly affect the resilience of productive systems and the stability of local ecosystems (LEÃO, 2025; OLIVEIRA et al., 2025b; RENK; TONI, 2025).

In this context, the analysis of rural soil assumes a strategic role, not only as the physical support for agricultural production but also as a living element that sustains fertility, water regulation, and ecological balance. Inappropriate land use on slopes, removal of vegetation cover, and poorly conservative management practices have intensified erosion, nutrient loss, and sedimentation of watercourses, compromising productivity and environmental quality. Understanding soil as a living system therefore allows for an integrated perspective on rural challenges, considering both the impacts of agricultural practices and the sustainability and resilience strategies available to communities in the Zona da Mata of Minas Gerais (FIGUEIREDO; WILSON, 2024).

This perspective reflects an interdisciplinary approach that connects Rural Geography, Soil Science, and Agroecology, and aligns with critical reflections present in debates on mobility and vulnerability (ASSIS; SILVEIRA; SILVA, 2021). Just as contemporary migration reveals social, economic, and environmental interdependencies, rural transformations expose connections between soil management, food security, environmental justice, and the permanence of families in rural territories (RENK; TONI, 2025). This study therefore proposes to analyze these dimensions in an integrated manner, recognizing that the challenges faced in rural areas are simultaneously productive, socioeconomic, and environmental, requiring responses that reconcile sustainability, equity, and territorial conservation.

Within this scenario, agroecology emerges as an approach capable of integrating agricultural production, environmental conservation, and the strengthening of rural communities (ASSIS; SILVEIRA; SILVA, 2021). Practices such as organic fertilization, composting, vegetation cover, agroforestry systems, and conservation-oriented soil management contribute to the recovery of soil fertility, the reduction of erosion, and the increase of biodiversity within productive systems. Moreover, these strategies strengthen the autonomy of family farmers and promote agricultural systems that are more resilient to climate change and economic pressures. By valuing soil as a living and strategic resource, agroecology offers concrete pathways for building a more sustainable and socially just rural development model in the Zona da Mata of Minas Gerais.

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In the Zona da Mata region, several initiatives developed by family farmers, community associations, and rural extension programs have demonstrated the transformative potential of agroecology in strengthening rural territories (OLIVEIRA et al., 2025b). Experiences involving diversified production systems, agroecological home gardens, composting, and organic soil management show that sustainable practices can simultaneously contribute to the recovery of soil fertility, diversification of production, and appreciation of local knowledge. These initiatives strengthen the autonomy of rural communities and represent important alternatives to conventional agricultural models.

Understanding the socio-environmental challenges of contemporary rural areas requires an interdisciplinary approach that connects agrarian geography, soil science, and agroecology. The process of agricultural modernization (LEÃO, 2025), widely discussed in the literature on rural development, is characterized by the intensification of external inputs, productive specialization, and increasing integration into markets. Although it has promoted productivity gains in certain contexts, this model has also been associated with environmental degradation, simplification of agroecosystems, and increased socioeconomic vulnerability among family farmers (BLACHA, 2022; CARVALHO et al., 2021).

In the Zona da Mata of Minas Gerais, these processes are expressed through intensive soil use practices, expansion of monocultures, and reduction of vegetation cover, particularly in areas of rolling relief and hillsides. In these contexts, rural vulnerability goes beyond economic issues and is intrinsically linked to environmental degradation and declining soil quality. Phenomena such as water erosion, reduction of organic matter, and sedimentation of rivers and streams become recurrent when inadequate management practices are applied in territories naturally susceptible to degradation (FIGUEIREDO; WILSON, 2024).

Soil, often viewed merely as a physical support for agricultural production, plays a central role in the sustainability of agroecosystems. When degraded, it loses the capacity to regulate water flows, cycle nutrients, and sustain microbial biodiversity, thereby compromising both agricultural productivity and environmental stability (MISHRA et al., 2025). Understanding soil as a living system is therefore essential for developing management strategies that promote environmental conservation, resilience of productive systems, and territorial sustainability.

In this context, agroecology emerges as an approach capable of integrating agricultural production, environmental conservation, and the social strengthening of rural communities. Agroecological systems based on productive diversification, the use of organic fertilization, composting, and the maintenance of vegetation cover contribute to the recovery of soil fertility and reduce dependence on external inputs. Furthermore, these practices promote increased

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biodiversity, strengthen food security, and enhance the resilience of productive systems in the face of environmental change (ALTIERI, 2012; GLIESSMAN, 2025; ZANELLI; LEÃO, 2024).

The adoption of agroecological practices is also connected to contemporary perspectives on rural territorial development, recognizing that rural sustainability depends on the articulation between environmental conservation, social justice, and the valorization of local communities. In this sense, agroecology is no longer understood merely as a set of agricultural techniques but rather as a systemic approach capable of transforming relationships between society, production, and nature (ALTIERI, 2012).

Therefore, addressing the challenges of sustainable rural development requires approaches that integrate socioeconomic inequalities, environmental vulnerabilities, and responsible management of natural resources (BLACHA, 2022). By combining contributions from agrarian geography, soil science, and agroecology, it is possible to develop strategies that strengthen agricultural systems that are more resilient, productive, and environmentally balanced.

In this context, this study proposes to analyze the rural territory of the Zona da Mata of Minas Gerais through the intersection of agrarian geography, soil science, and agroecology, seeking to understand: (i) how soil use and management models influence the sustainability of productive systems; (ii) how soil degradation contributes to environmental and productive vulnerabilities; and (iii) how agroecological practices can offer pathways for building more sustainable, resilient, and socially inclusive agricultural systems. By recognizing soil as a living and strategic resource for family farming, this study contributes to the debate on sustainable rural development and to the formulation of strategies that integrate agricultural production, environmental conservation, and the quality of life of rural communities.

Methodology

This study adopts a qualitative and critical approach, integrating concepts from Agrarian Geography, Soil Science, and Agroecology in order to understand the socio-environmental challenges of rural areas in the Zona da Mata region of Minas Gerais. The proposal seeks to analyze the relationships between land use, productive systems, and sustainability in territories predominantly occupied by family farming, considering the importance of agroecological practices for strengthening agroecosystems and rural communities (ALTIERI, 2012; SILVA; BRASILEIRO, 2022). The methodology was structured in three main stages, integrating theoretical analysis, socio-environmental assessment, and the identification of sustainable soil management practices.

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The first stage consisted of a bibliographic and documentary review, involving the analysis of scientific articles, books, and institutional reports related to land use, family farming, and agroecology. Technical documents and databases from public institutions, such as the Brazilian Institute of Geography and Statistics (IBGE), were also consulted, in addition to materials produced by research institutions and rural extension organizations. This stage made it possible to understand transformations in land use and the productive organization of rural areas, as well as to identify the main socio-environmental challenges faced by farmers in the region (PORTO-GONÇALVES, 2006; MISHRA et al., 2025).

The second stage involved the socio-environmental analysis of the rural territory, using secondary data on land use and land cover, predominant agricultural practices, environmental degradation, and productive vulnerabilities. Information on erosion, soil conservation, agricultural management, and the availability of natural resources was analyzed together with socioeconomic indicators related to family farming. This approach allowed the relationship between the physical characteristics of the soil and the productive and social dynamics of the territory to be examined, highlighting areas more susceptible to environmental degradation and productive instability (WORKIE et al., 2025).

The third stage consisted of analyzing agroecological experiences developed in the region, including practices such as composting, organic fertilization, agroforestry systems, vegetation cover, and productive diversification in family farming properties. The evaluation of these experiences was conducted based on documentary records, farmers' reports, information from rural extension projects, and initiatives developed by organizations focused on agroecology (ZANELLI; LEÃO, 2024). The approach was inspired by participatory research principles, recognizing that knowledge about sustainable soil management results from the interaction between scientific knowledge and the traditional knowledge of rural communities (FALS BORDA, 1987; RUAS et al., 2006; GLIESSMAN, 2025).

This methodology makes it possible to integrate the critical analysis of transformations in rural areas, the assessment of vulnerabilities associated with inadequate land use, and the identification of agroecological practices as strategies for environmental recovery and the strengthening of family farming. In this way, the study contributes to the formulation of sustainable rural development strategies capable of reconciling agricultural production, conservation of natural resources, and the appreciation of rural territories (ALTIERI, 2012; PORTO-GONÇALVES, 2006). The study is part of a project approved by the Ethics Committee of Faculdade UNA de Uberlândia, under the Certificate of Ethical Review Submission (CAAE): 64203822.900005704.

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Results and discussion

Vulnerability and soil management in rural areas

The socio-spatial analysis of rural areas in the Zona da Mata region of Minas Gerais reveals persistent patterns of territorial inequality and socio-environmental vulnerability, highlighting how the distribution of infrastructure, access to public policies, and productive resources reflects historical processes of regional occupation and development. In many municipalities in the region, areas with better access to services, technical assistance, and productive infrastructure concentrate greater investments and economic opportunities, while more isolated rural communities face limitations related to infrastructure, market access, and institutional support—factors that directly affect the sustainability of family farming systems (SANTANA; FARIAS, 2021).

This pattern of territorial inequality is also reflected in how soil use and management occur on rural properties. In several municipalities of the Zona da Mata, the expansion of agricultural activities in areas with rugged terrain, combined with the absence of conservation practices, has contributed to processes of environmental degradation and declining soil quality (RAMOS et al., 2025). In many farms, particularly small-scale production units, limited technical and financial resources hinder the adoption of adequate management practices, increasing both productive and environmental vulnerability.

A large portion of the region's agricultural areas is characterized by soils susceptible to erosion and by undulating to mountainous relief, conditions that require careful management to ensure soil and water conservation. When inadequate practices are adopted – such as intensive soil preparation, lack of vegetation cover, and cultivation on slopes without conservation measures – processes such as water erosion, nutrient loss, and sedimentation of watercourses become frequent. The interaction between the biophysical characteristics of the territory and forms of productive land use can therefore intensify the socio-environmental vulnerability of rural communities (RENK; TONI, 2025).

The analysis of these conditions demonstrates that vulnerabilities in rural areas are not limited to economic or productive factors but are deeply related to the physical characteristics of the territory and to the way natural resources are managed. In this sense, understanding the interactions between soil, topography, agricultural practices, and socioeconomic organization becomes fundamental for planning strategies for sustainable rural development (SOBRINHO, 2025).

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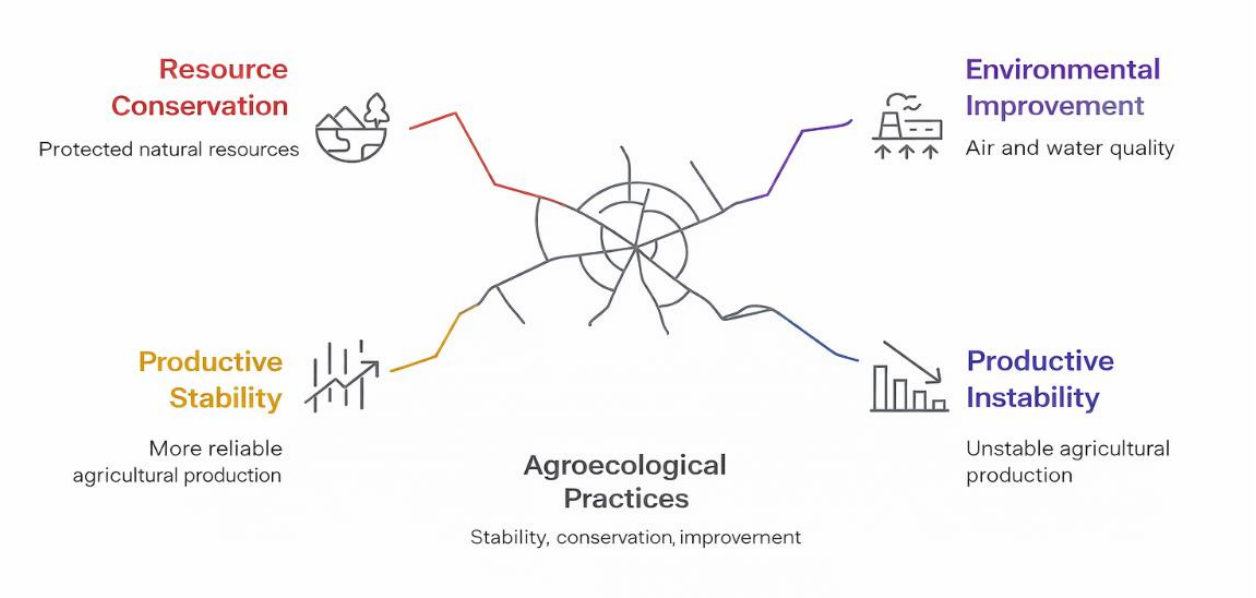
These findings reinforce the need for integrated public policies that simultaneously consider soil conservation, the strengthening of family farming, and the promotion of sustainable productive practices. Rural development strategies should incorporate conservation soil management, the recovery of degraded areas, and incentives for agroecological practices capable of reducing environmental risks and increasing the resilience of agroecosystems (Fig. 1).

In this context, it becomes evident that the construction of more sustainable rural territories depends on the integration of natural resource management, territorial planning, and the strengthening of local communities (DOMENEGHINI, 2025). Considering the biophysical characteristics of soils, topography, and productive systems is essential for reducing vulnerabilities, promoting sustainable land use, and ensuring greater economic and environmental stability for family farming in the Zona da Mata of Minas Gerais.

Figure 1: Soil management practices and agricultural productivity: Agroecological soil management promotes environmental conservation and productive stability, while inadequate practices contribute to environmental degradation and unstable agricultural production.



Soil degradation and socio-environmental vulnerability

Soil degradation in rural areas of the Zona da Mata region of Minas Gerais manifests in different ways, reflecting both the intensification of certain agricultural practices and the natural limitations of the territory. Inadequate soil management, associated with the removal of vegetation cover, intensive land preparation, and cultivation on slopes without conservation measures, compromises water infiltration into the soil and increases surface runoff (ARORA et

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al., 2023). As a consequence, processes of water erosion become more frequent, promoting nutrient loss, reduced soil fertility, and the sedimentation of watercourses. These conditions directly affect the sustainability of productive systems and the environmental security of rural communities.

Erosion in agricultural areas with undulating or mountainous relief constitutes one of the main environmental challenges in the region. The replacement of native vegetation with simplified agricultural systems, combined with the absence of soil conservation practices (MUREITHI et al., 2025), intensifies terrain instability and the loss of the topsoil layer, which is the richest in organic matter and nutrients. In many rural properties, particularly in family farming, limited access to technical assistance and financial resources makes it difficult to adopt appropriate management techniques, thereby increasing environmental and productive vulnerability.

Soil degradation is also associated with the quality of water resources. The transport of sediments, fertilizers, and organic residues to streams and springs can compromise the quality of water used by rural communities, affecting both human supply and productive activities (LACKNER; BESHARATI, 2025; MISHRA et al., 2025; OLIVEIRA et al., 2025a). The absence or limitation of adequate rural sanitation systems, combined with improper management of agricultural and household waste, may intensify processes of water contamination, posing environmental and public health risks.

Another relevant aspect concerns the reduction of vegetation cover in agricultural areas and the fragmentation of natural ecosystems, processes that contribute to the decline of biodiversity and the loss of essential ecosystem services. Vegetation plays an important role in protecting soil against erosion, regulating the microclimate, and maintaining water infiltration into the soil. Its removal or replacement with poorly diversified agricultural systems can compromise the ecological stability of rural landscapes and increase environmental vulnerability (ASSIS; SILVEIRA; SILVA, 2021; RENK; TONI, 2025).

These dynamics highlight the need for public policies and management strategies that simultaneously consider soil conservation, water resource management, and the strengthening of family farming (ARORA et al., 2023; WALIA et al., 2024). The adoption of conservation practices such as terracing, contour planting, permanent vegetation cover, organic fertilization, and agroforestry systems can significantly contribute to the recovery of degraded areas and the improvement of soil quality (MUREITHI et al., 2025).

In addition, the expansion of productive systems based on agroecological principles has been identified as an important alternative for reducing environmental impacts and increasing the

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resilience of agroecosystems. Crop diversification, the use of organic waste through composting, and integrated soil and water management favor the maintenance of soil fertility and the productive stability of rural properties (ALTIERI, 2012; GLIESSMAN, 2025).

Environmental vulnerability in rural areas is also related to socioeconomic transformations affecting family farming. Pressure to increase productivity, dependence on external inputs, and economic instability may encourage management practices that prioritize short-term results at the expense of natural resource conservation (WALIA et al., 2024). In this context, public policies aimed at strengthening technical assistance, encouraging agroecology, and restoring degraded areas become fundamental for promoting more sustainable and resilient agricultural systems (MARTINS et al., 2023; OLIVEIRA et al., 2025a).

These phenomena demonstrate that vulnerability in rural areas is not only economic or productive but also edaphic and environmental. The interaction between physical soil factors—such as structure, texture, and water retention capacity – and social factors – such as management practices and access to agricultural technologies – directly influences the sustainability of productive systems (OLIVEIRA et al., 2025a). Therefore, rural development strategies must simultaneously consider the environmental characteristics of the territory and the social needs of agricultural communities.

To mitigate these impacts, it is essential to promote integrated public policies that encourage sustainable soil management, the restoration of degraded areas, and the adoption of productive practices based on agroecological principles. Initiatives involving participatory territorial planning, conservation of natural resources, and the appreciation of local knowledge can significantly contribute to the development of agricultural systems that are more resilient, environmentally balanced, and socially sustainable (ARORA et al., 2023; MARTINS et al., 2023).

Agroecology as a strategy for resilience

Experiences of rural agroecology in the Zona da Mata region of Minas Gerais have emerged as instruments of socio-environmental transformation in vulnerable agricultural territories, especially in small and medium-sized farms that are often affected by soil degradation and productive limitations (FIGUEIREDO; WILSON, 2024; OLIVEIRA et al., 2025b). Projects involving productive home gardens, agroforestry systems, and organic composting have contributed to the recovery of soil fertility, the increase in the diversity of fresh and healthy foods, and the reduction of dependence on chemical inputs and conventional supply chains (ARORA et al., 2023).

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In addition to promoting environmental and nutritional benefits, these initiatives encourage processes of collective learning, appreciation of traditional knowledge, and the consolidation of local networks of cooperation and self-management, strengthening the organizational capacity of rural communities. In this sense, rural agroecology emerges as a practice of resistance to the conventional agricultural model, characterized by the intensive use of external inputs, monocultures, and the predatory exploitation of soil. By revaluing soil as a living resource and promoting socio-environmental justice, these experiences point toward the construction of more resilient, sustainable, and socially just rural territories (RENK; TONI, 2025; ZANELLI; LEÃO, 2024).

From an environmental perspective, these practices promote soil recovery, increasing fertility, water retention capacity, and local biodiversity (ABBASI, 2025; SADIQ et al., 2025). By integrating sustainable management techniques, intercropping, and composting, agroecology contributes to the restoration of degraded agricultural ecosystems and the mitigation of problems such as erosion, loss of organic matter, and water degradation. In this way, soil ceases to be merely a productive support and becomes a central element in ecological regeneration and the resilience of rural systems.

Beyond their environmental impacts, these initiatives strengthen food security and offer subsistence and income alternatives for rural families in vulnerable situations (CARVALHO et al., 2021). By linking environmental sustainability and social justice, rural agroecology demonstrates that local interventions, based on scientific knowledge and traditional practices, can generate broad positive effects and serve as models for public policies aimed at sustainable rural development.

Rural agroecology also represents an alternative to the productivist model imposed by the Green Revolution, which, although it increased agricultural productivity, deepened social inequalities and caused significant environmental damage. By adopting agroecological principles, these practices promote a more sustainable, inclusive, and resilient food production system aligned with environmental justice and the valorization of rural territories. In this way, they demonstrate that it is possible to reverse predatory dynamics and build productive systems that respect ecological limits and the needs of rural communities (CARVALHO et al., 2021; ZANELLI; LEÃO, 2024).

In this context, rural agroecology proposes a territorial development model that integrates soil management, socio-environmental resilience, and social justice. By valuing natural resources and promoting the active participation of communities in the management of their territories, these initiatives offer concrete alternatives for building more equitable, sustainable,

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and resilient rural spaces. The articulation between agroecological practices and public policies is essential to consolidate this model, ensuring that future rural territories can face challenges posed by climate change, environmental degradation, and social inequality.

Final considerations

Rural territories in the Zona da Mata region of Minas Gerais demonstrate that the production of agrarian space follows economic and productive dynamics that may intensify socio-spatial inequalities and weaken local ecosystems. Family farming areas located on slopes, riverbanks, and degraded soils reflect environmental and productive vulnerability, revealing losses of soil fertility, erosion, sedimentation, and hydrological instability. Recognizing rural soil as a living and strategic resource is essential, since its degradation compromises fundamental ecological functions such as water retention, nutrient cycling, and biodiversity maintenance, while simultaneously increasing the exposure of rural communities to environmental risks. This reinforces the need for integrated public policies that promote sustainable soil management and conservation.

In this context, rural agroecological practices such as agroforestry systems, composting, permanent vegetation cover, and crop diversification demonstrate that it is possible to redefine degraded areas by restoring soil fertility, increasing the production of healthy foods, and strengthening community ties and cooperation networks. These practices constitute concrete strategies of socio-environmental justice and resistance to the pressures of conventional agricultural models that prioritize monocultures and intensive use of external inputs. For sustainable rural development, territorial policies must integrate conservation-oriented soil management, the expansion of agroecological practices, the active participation of communities, and technical extension programs focused on environmental sustainability and productive resilience.

The study highlights that the articulation between soil science, agroecology, and critical rural geography provides forward-looking perspectives for more inclusive, sustainable, and resilient rural territories, where degraded areas become spaces of socio-environmental innovation and environmental and productive challenges are addressed through social justice, ecological sustainability, and the recognition of soil as a strategic resource for local development.

DOI 10.5335/hdtv.26n.1.18075

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Declaration of use of Artificial Intelligence:

In this article, the DeepSeek tool (Version 2025) was used to organize bibliographic references and perform grammatical corrections in accordance with scientific writing standards.

DOI 10.5335/hdtv.26n.1.18075

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