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Review

The Governance of Innovation Processes in Agricultural System

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Abstract: Contemporary agrarian systems are increasingly shaped by complex and interrelated challenges arising from climate change, market volatility, technological transformation and institutional constraints. These dynamics require a re-examination of how innovation in agriculture is conceptualised and governed. In this context, innovation can no longer be understood as isolated technological improvements, but rather as a systemic process whose developmental effects depend on the coordination of multiple actors, institutional arrangements and governance mechanisms. This paper examines the governance of innovation processes in agrarian systems through the perspective of innovation governance, analysing how formal and informal rules, institutions and coordination models influence the development, diffusion and implementation of agricultural innovations. The study is based on a theoretical and conceptual review of contemporary literature on agricultural innovation systems and innovation management. The analysis indicates that developmental outcomes are not determined solely by technological attributes, but largely by the quality of governance arrangements that enable coordination, collective learning and adaptive capacity under increasing uncertainty. This perspective underscores the importance of innovation governance for enhancing the resilience, sustainability and long-term stability of agrarian systems.

Keywords: *Innovation governance; innovation management; agrarian systems; agricultural innovation systems; actor coordination; institutional frameworks; agricultural resilience.*

1. Introduction

Contemporary agrarian systems are undergoing profound economic, technological and social transformations that shape food production, resource management and the long-term sustainability of agriculture. Climate change, increasing food demand, market volatility and accelerated technological change intensify the need for continuous innovation. Yet agriculture's ability to respond to these pressures depends not only on technological availability, but on how innovation processes are governed, coordinated and institutionally embedded. As climatic, economic and geopolitical pressures increasingly disrupt food systems, innovation governance emerges as a strategic prerequisite for resilient and sustainable agricultural development [1]. This highlights the need to approach innovation not as an isolated technical intervention, but as a systemic and policy-relevant process. Innovation therefore needs to be addressed as a systemic and policy-relevant process rather than a purely technical intervention.

Empirical evidence indicates that climate change exerts long-term and differentiated effects on the resilience of agri-food supply chains. System resilience depends on production structures, technological capacity, and institutional mechanisms that facilitate coordination among actors and the implementation of adaptive strategies [2]. Resilience is therefore increasingly viewed as the outcome of strategic governance rather than ad hoc responses. Innovation in agrarian systems

extends beyond technical advancement to include organisational, institutional, and managerial change. Digitalisation, precision agriculture, and biotechnological solutions underscore the need for integrated innovation approaches based on cooperation and coordinated action. Experience from European agrarian systems shows that the developmental impact of such innovations is closely linked to institutional support, infrastructure, knowledge organisation, and planning capacity [3], confirming that technological progress alone is insufficient to ensure sustainable outcomes.

The growing complexity of agrarian systems further highlights the need for approaches that integrate innovation, sustainability, and risk management. Digital innovations and sustainable development objectives require alignment with institutional and governance frameworks to ensure long-term system resilience and stability. Integrated risk management, grounded in institutional preparedness and adaptability, is increasingly recognised as a key pillar for the development of innovation processes under conditions of heightened uncertainty [4], positioning risk management as an integral component of innovation governance in agriculture.

Innovation governance is increasingly employed as an analytical framework for examining formal and informal rules, institutions, and coordination mechanisms shaping the development, diffusion, and implementation of innovations. In agrarian systems, innovation governance assumes particular relevance due to actor heterogeneity, spatial dispersion of production, and the strong influence of public policies on innovation dynamics. This paper focuses on the governance of innovation processes in agrarian systems, analysed through institutional, organisational, and managerial mechanisms. The objective is to provide a theoretical examination of innovation governance models in the agrarian context, with emphasis on actor coordination, governance arrangements, and the developmental effects of innovation governance in strengthening sustainability and resilience of agrarian systems.

2. Governance of innovation processes in agrarian systems

The governance of innovation processes in agrarian systems is shaped by the specificities of agriculture, heterogeneous actor structures, and high exposure to natural, market, and institutional risks. Unlike industrial sectors, agricultural innovation unfolds under persistent uncertainty, spatial dispersion, and uneven producer capacities, which limits the applicability of linear technology transfer models. Recent studies emphasize that innovation outcomes depend on effective coordination, clear role allocation, and structured knowledge exchange, confirming the interactive and interdependent nature of agrarian innovation processes [5]. These characteristics highlight the central role of governance and institutional arrangements in steering innovation towards sustainable and resilient development pathways.

Effective innovation governance requires the integration of technological, organisational, and institutional elements, supported by mechanisms that facilitate learning, knowledge exchange, and risk management. Empirical studies show that knowledge creation and sharing enhance innovative capacity, while innovation links knowledge management with organisational performance [6]. From this perspective, innovation governance extends beyond operational concerns and assumes strategic importance for long-term resilience, competitiveness, and sustainability in agriculture.

2.1. Innovations in contemporary agricultural systems

Innovations in contemporary agricultural systems encompass technological, organisational, and institutional changes aimed at improving productivity, sustainability, and resilience. Although innovation in agriculture is often linked to digital tools, precision farming, and biotechnological solutions, recent research highlights the rapid expansion of digitalisation and smart farming systems. Technologies such as artificial intelligence, the Internet of Things, and precision agriculture support more efficient resource management and system resilience [7]. Their development effects, however, depend on how innovation processes are organised and institutionally supported, indicating that technology alone does not guarantee successful agricultural innovation.

Empirical studies indicate that technological innovations achieve their full potential only when accompanied by organisational change, skills development, and adaptive management practices. Digital innovations also generate economic, social, and ethical challenges, including uneven benefit

distribution, which highlights the role of public policies and governance mechanisms in steering innovation, particularly in structurally diverse agricultural systems [8], where coordinated action remains essential.

Contemporary literature shows that innovation in agricultural systems arises from interactions among multiple actors, where technical change intertwines with institutional and social transformations. The direction and scope of innovation depend on coordination among farmers, research and educational institutions, advisory services, market actors, and the public sector [9]. In such settings, innovation processes are non-linear and interdependent, highlighting the need for appropriate models of innovation governance in agricultural systems.

2.2. Models of innovation process governance

Governance of innovation processes in agricultural systems has evolved alongside changing understandings of innovation. Traditional hierarchical models, based on centralised planning and linear knowledge transfer from research institutions to farmers, were important in earlier phases of agricultural modernisation. Increasing system complexity and the need to respond to local agro-ecological and socio-economic conditions have, however, encouraged the shift towards network-based and participatory models of innovation governance.

Network-based models emphasise collaboration and knowledge exchange among diverse actors, assigning farmers a more active role in innovation processes. Contemporary approaches highlight open and participatory innovation, where solutions are co-created and knowledge is applied in a context-specific manner, overcoming the limits of traditional hierarchical governance models [10]. While such models enhance flexibility and collective learning, they require clear coordination mechanisms and adequate institutional support, particularly in systems dominated by small and medium-sized producers.

Recent conceptual approaches to innovation management in agricultural systems adopt a systemic perspective, in which hierarchical and participatory mechanisms are viewed as complementary elements of a broader innovation ecosystem. Such a framework facilitates the connection of actors, the alignment of rules, and the adaptation of innovations across different levels of development, thereby creating space for hybrid models of innovation governance [11]. In this setting, innovation effectiveness depends on the ability of governance arrangements to integrate diverse institutional and social logics into a coherent framework for action.

Hybrid models of innovation management combine hierarchical and network-based approaches by linking strategic coordination with decentralised and adaptive innovation practices. In these models, institutions provide a stable governance framework that supports collaboration, reduces uncertainty, and aligns innovation activities with long-term development goals. By integrating innovation practices with elements of traditional management and evolving actor capabilities, such models strengthen coherence and the long-term sustainability of innovation processes in complex agricultural systems [12]. This confirms the central role of innovation governance in ensuring continuity and strategic direction in agricultural innovation.

2.3. The role of institutions and public policies in innovation governance

Institutions and public policies are central to shaping the conditions under which innovations emerge and are implemented in agricultural systems. Regulatory frameworks, incentive mechanisms, advisory services, and public investment influence not only actors' readiness to adopt new technologies and practices but also their ability to manage innovation-related risks. The overall quality and coherence of the institutional environment therefore play a decisive role in innovation diffusion and in determining the long-term developmental outcomes of innovation in agriculture.

Innovation governance in agriculture requires coordination across agricultural, technological, educational, and development policies. Digital innovations generate pronounced spatial and spillover effects that shape not only individual farm performance but also the broader organisation of agricultural production, which calls for territorially differentiated and coordinated institutional steering [13]. Fragmented policy approaches and weak coordination can reduce innovation

effectiveness even in strong institutional settings, as rigid and misaligned measures constrain adaptability and competitiveness in agricultural systems [14], thereby underscoring the importance of integrated and adaptive policy frameworks.

Systematic literature reviews show that the adoption of innovative and sustainable practices is often constrained by economic, social, and institutional barriers, including high investment costs, regulatory inconsistencies, and insufficient educational support and policy coherence [15]. Similarly, the transition towards Agriculture 4.0 and the wider use of open innovation principles are limited by gaps in knowledge, skills, and initial investment, which points to the need for coordinated institutional and policy support [16]. When innovation policies prioritise technical efficiency without parallel investment in local capacities and stakeholder participation, developmental outcomes tend to remain uneven, reinforcing the need for inclusive and institutionally coherent approaches to innovation governance in agricultural systems [17]. This highlights that successful innovation-driven transformation in agriculture depends on long-term, inclusive, and well-aligned governance frameworks rather than isolated technological advances.

Institutions in agricultural systems mediate between global technological trends and their local application, shaping the integration of innovations into existing production and social structures. In this context, Agricultural Knowledge and Innovation Systems (AKIS) provide a key institutional coordination mechanism for linking research, advisory services, and farmers, particularly in sustainable natural resource management [18]. This strengthens the alignment between innovation processes and long-term sustainability goals, positioning innovation governance as a strategic driver of agricultural system resilience.

3. Actors, models and developmental effects of innovation governance

Innovation governance in agricultural systems is shaped by interactions among actors involved in production, knowledge exchange, and decision-making. Farmers, research and educational institutions, advisory services, private-sector actors, and public authorities contribute to innovation with distinct roles and capacities, while the quality of their coordination strongly influences innovation development and uptake. System-based approaches show that innovation unfolds through interconnected subsystems of research, training, advisory support, and sustainability [19]. The plurality of theoretical perspectives reflects changing actor roles and underscores the need for coordinated governance frameworks in contemporary agricultural systems [20]. Such coordination is crucial for achieving sustainable development effects.

Models of innovation governance determine how actors are coordinated and how knowledge and resources are mobilised within innovation processes. Evidence shows that multi-actor partnerships play a key role in knowledge exchange and co-creation, with their effectiveness shaped by institutional settings and network structures [21]. The choice of governance model therefore directly affects innovation outcomes, particularly in terms of the resilience and sustainability of agricultural systems.

3.1.. Key actors in agricultural innovation processes

Agricultural innovation involves multiple actors whose roles vary across institutional contexts and innovation governance models. Farmers play a central role, as their willingness to experiment, adapt, and adopt new solutions directly influences innovation outcomes. Participatory approaches increasingly position farmers as co-creators rather than passive users of innovation, as demonstrated by collaborative innovation platforms [22]. Such interaction underscores that agricultural innovation emerges through cooperation and shared responsibility among diverse actors,

Although the role of producers in innovation processes has become increasingly prominent, their innovation potential largely depends on available resources, farm structure, and access to knowledge and finance. Empirical research indicates that in systems dominated by small and medium-sized farms, limitations in innovation infrastructure and support often result in lower innovation intensity and slower adaptation to change [23]. Strengthening producers' innovation capacities therefore emerges as a key priority of contemporary agricultural policy.

Research and educational institutions play an important role in developing knowledge and human capital, yet their function in contemporary innovation systems extends beyond the production of scientific outputs alone. The growing demand for applicable and context-specific knowledge encourages closer collaboration with producers, advisory services, and the private sector, thereby narrowing the gap between research and practice. Literature reviews indicate that processes of knowledge co-creation most often lead to incremental, rather than transformative, changes in agricultural practice [24]. This dynamic further highlights the importance of long-term institutional frameworks and continuity in learning.

Advisory services and public institutions play a central role in coordinating innovation processes, facilitating knowledge dissemination, and shaping regulatory and institutional frameworks. Evidence from comparative analyses of AKIS across national contexts indicates that their effectiveness depends on the capacity to link research, education, advisory support, and producers, while complex legal arrangements and structural constraints may hinder innovation dynamics [25]. Moreover, where governance mechanisms and coordination are weak, innovations tend to remain poorly aligned with local needs, resulting in limited and uneven developmental outcomes [26]. This underscores the critical role of institutional coherence in innovation governance within agricultural systems.

3.2. Models of innovation process governance

Innovation process governance in agricultural systems is shaped by how actors are connected, coordinated, and institutionally steered within innovation networks and knowledge systems. Contemporary research emphasises that agricultural innovations do not emerge through linear technology transfer, but through interactive and iterative processes integrating scientific knowledge, practical experience, and institutional arrangements. In this perspective, network structures, feedback mechanisms, and collective learning serve as key governance mechanisms through which innovation processes are organised and sustained in agricultural systems.

Recent theoretical work on agricultural innovation shows a clear shift towards sectoral and systemic models of innovation governance, in which agrarian and agri-food systems are treated as technologically, institutionally, and socially specific. These approaches indicate that knowledge and innovation emerge within diverse research and practice-based communities, drawing on both evolutionary innovation theory and perspectives rooted in rural sociology and development economics. Their coexistence underscores the complexity of innovation governance in agriculture and the need for models that integrate technological and social dimensions of innovation [20], viewing innovation as a process of co-evolution between knowledge, institutions, and markets

Models of innovation governance directly influence the functioning and performance of innovation networks. Empirical analyses of collaborative networks linking industry, universities, and research institutions indicate that innovation success depends on actor connectedness, partner diversity, and the network's ability to integrate resources and knowledge. While public and governmental support remains important, its impact is limited without effective coordination and functional network structures [27]. This confirms that coherent governance design is essential for realising the full innovation potential of network

Empirical evidence from multi-actor co-innovation partnerships indicates that innovation governance in agriculture cannot be reduced to a single, universally applicable model. Experiences from European initiatives demonstrate that innovation processes may be effectively governed through diverse institutional and organisational arrangements, shaped by partnership objectives, actor capacities, and the surrounding institutional context. The effectiveness of innovation governance therefore depends primarily on the alignment of governance models with specific contextual conditions rather than on their formal design [28]. This highlights the importance of flexible, context-responsive approaches to innovation governance, particularly in heterogeneous agricultural systems characterised by uneven development constraints.

Extending a systemic perspective to the bioeconomy further exposes the limitations of traditional, technology-centred approaches to innovation governance. Research shows that effective

governance in this domain requires models capable of integrating interdisciplinary collaboration, complex knowledge flows, and intensive interaction among multiple actors. Bioeconomy knowledge and innovation system frameworks therefore stress the need to align innovation processes with market dynamics and ethical considerations in both the development and implementation of innovations [29]. This underscores innovation governance as a central mechanism for connecting knowledge, policy, and markets in complex transformation processes.

Overall, models of innovation process governance in agricultural systems are increasingly shifting away from hierarchical and sectorally closed structures towards network-based, adaptive, and participatory forms of coordination. Their effectiveness depends on the capacity to integrate diverse knowledge sources, enable functional collaboration among actors, and align institutional mechanisms with the practical needs of producers and markets, thereby supporting broader and long-term sustainable innovation outcomes.

3.3. Developmental and sustainability effects of innovation governance

The developmental effects of innovation governance in agricultural systems cannot be assessed solely through technological improvements in production or productivity growth. Contemporary approaches indicate that the way innovation processes are governed has a direct impact on broader economic, social, and territorial outcomes, including the resilience of agricultural systems, the sustainability of rural communities, and the distribution of innovation benefits. Innovation governance is therefore increasingly understood as a mechanism for steering long-term developmental change in agriculture. Empirical evidence shows that innovation processes based on coordinated, network-based, and participatory models generate more pronounced developmental effects than fragmented and hierarchical approaches. Systems in which actors are functionally connected and engaged in the joint design of solutions demonstrate a greater capacity to adapt to market, climatic, and technological changes, a pattern that is particularly evident in agricultural systems built on multi-actor partnerships [21]. This confirms that the quality of coordination represents a key determinant of resilience and competitiveness in agricultural systems.

Within sustainability-oriented frameworks, innovation governance produces particularly strong developmental effects, as innovations serve to align economic, environmental, and social objectives. Evidence from sustainable resource management indicates that these effects depend on the coherence of economic instruments, regulatory frameworks, and actor behaviour, while policy fragmentation and institutional incoherence constrain transformative potential [30]. By contrast, differentiated approaches, long-term investment, and tailored support policies enable a more balanced distribution of benefits and foster inclusive development along the agricultural value chain [17], linking innovation to strengthened social cohesion in rural areas.

A further dimension of developmental effects concerns the institutional capacity to embed innovations within existing social and production structures. Studies indicate that innovations with high technical potential may achieve limited impact when governance frameworks are rigid or poorly adapted to local conditions, as such contexts undermine coordination across actors and stages of the innovation process. Governance arrangements that overlook interdependencies among projects, organisations, and institutional levels tend to slow broader transformative effects, underscoring the need for systemic and coordinated approaches to innovation governance [31]. Similar conclusions emerge from research viewing agricultural systems as complex land-use systems, in which climate adaptation, food security, and sustainable resource management are inseparable from the quality of governance mechanisms [32]. Long-term sustainability therefore depends on innovation governance that balances standardisation with flexibility in the implementation of innovations.

4. Conclusions

Innovations in contemporary agricultural systems should not be understood as isolated technological interventions, but as complex and systemic processes shaped by the interaction of diverse actors, institutional arrangements, and the broader socio-economic environment. Both theoretical and empirical research indicates that the effectiveness of innovation processes in

agriculture depends on the system's capacity to integrate technological, organisational, and institutional dimensions, while accounting for local conditions, available resources, and the innovation capacities of stakeholders. A particularly significant shift has occurred from linear models of technology transfer towards participatory and interactive approaches, in which innovations are co-created through coordinated engagement among farmers, research and educational institutions, advisory services, the private sector, and public authorities.

From this perspective, agricultural innovation systems operate as interconnected networks of actors and practices, where coordination, collective learning, and institutional coherence are essential for achieving sustained developmental outcomes. Innovation governance thus emerges as a central element of contemporary agricultural development. The analysis of actor roles, coordination mechanisms, and institutional frameworks demonstrates that the developmental impact of innovation is determined not only by its technological content, but also by the quality of governance arrangements that guide innovation processes. This perspective allows innovation to be conceptualised as a key mechanism linking sustainability, resilience, and the long-term stability of agricultural systems.

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