Recibido: 15/11/2025 | **Aceptado:** 27/02/2026 | **Publicado:** 05/03/2026

RESEARCH ARTICLE

Governance of genetic resources and traditional agricultural knowledge in Colombia: a food sovereignty approach

Gobernanza de los recursos genéticos y los conocimientos agrícolas tradicionales en Colombia: un enfoque basado en la soberanía alimentaria

Governança dos recursos genéticos e do conhecimento agrícola tradicional na Colômbia: uma abordagem de soberania alimentar

https://doi.org/10.21803/penamer.19.39.1010

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Abstract

Introduction: Although food sovereignty depends largely on control of agrobiodiversity and traditional knowledge, Colombia faces significant threats, such as biodiversity loss, dependence on commercial seeds, and unregulated bioprospecting. **Objective:** This article analyzes the relationship between genetic resource governance and food sovereignty in Colombia. **Methodology:** Through qualitative documentary analysis, this research evaluates how current agricultural policies and regulatory frameworks impact genetic diversity and the country's ability to achieve autonomous food security. **Results:** The results reveal that traditional knowledge systems are fundamental to local adaptation, in situ conservation, and community empowerment; therefore, their erosion and biopiracy directly threaten these fundamental pillars. **Conclusions:** The analysis demonstrates that a governance model that prioritizes sustainable use and local control of genetic resources, together with the recognition of farmers' rights, is essential to strengthening food sovereignty. Ultimately, the article advocates for legal reforms that integrate an "ecology of knowledge," fostering dialogue between scientific and traditional systems to build resilient food systems for all Colombians.

Keywords: Ecology of Knowledge; Environmental Governance; Food Sovereignty; Genetic Resources; Traditional Knowledge.

Resumen

Introducción: Si bien la soberanía alimentaria depende en gran medida del control de la agrobiodiversidad y los conocimientos tradicionales, Colombia se enfrenta a importantes amenazas, como la pérdida de biodiversidad, la dependencia de semillas comerciales y la bioprospección no regulada. **Objetivo:** Este artículo analiza la relación entre la gobernanza de los recursos genéticos y la soberanía alimentaria en Colombia. **Metodología:** Mediante un análisis documental cualitativo, esta investigación evalúa cómo las políticas agrícolas y los marcos normativos actuales repercuten en la diversidad genética y en la capacidad del país para alcanzar la seguridad alimentaria autónoma. **Resultados:** Los resultados revelan que los sistemas de conocimientos tradicionales son fundamentales para la adaptación local, la conservación in situ y el empoderamiento de las comunidades; por lo tanto, su erosión y la biopiratería amenazan directamente estos pilares fundamentales. **Conclusiones:** El análisis demuestra que un modelo de gobernanza que priorice el uso sostenible y el control local de los recursos genéticos, junto con el reconocimiento de los derechos de los agricultores, es fundamental para fortalecer la soberanía alimentaria. En última instancia, el artículo aboga por reformas legales que integren una «ecología del conocimiento», fomentando el diálogo entre los sistemas científicos y tradicionales para construir sistemas alimentarios resilientes para todos los colombianos.

Palabras clave: Ecología del conocimiento; Gobernanza ambiental; Soberanía alimentaria; Recursos genéticos; Conocimientos tradicionales.

¿Cómo citar este artículo?

Vargas-Chaves; I., López-Oliva; J. y Luna-Galván; M. (2026). Governance of genetic resources and traditional agricultural knowledge in Colombia: a food sovereignty approach. *Pensamiento Americano, e#:1010. 19*(39), DOI: https://doi.org/10.21803/penamer.19.39.1010

Resumo

Introdução: Embora a soberania alimentar dependa em grande parte do controle da agrobiodiversidade e do conhecimento tradicional, a Colômbia enfrenta ameaças significativas, como a perda da biodiversidade, a dependência de sementes comerciais e a bioprospecção não regulamentada. **Objetivo:** Este artigo analisa a relação entre a governança dos recursos genéticos e a soberania alimentar na Colômbia. **Metodologia:** Por meio de uma análise documental qualitativa, esta pesquisa avalia como as políticas agrícolas e os marcos regulatórios atuais afetam a diversidade genética e a capacidade do país de alcançar a segurança alimentar autônoma. **Resultados:** Os resultados revelam que os sistemas de conhecimento tradicional são fundamentais para a adaptação local, a conservação in situ e o empoderamento da comunidade; portanto, sua erosão e a biopirataria ameaçam diretamente esses pilares fundamentais. **Conclusões:** A análise demonstra que um modelo de governança que priorize o uso sustentável e o controle local dos recursos genéticos, juntamente com o reconhecimento dos direitos dos agricultores, é essencial para fortalecer a soberania alimentar. Por fim, o artigo defende reformas legais que integrem uma "ecologia do conhecimento", promovendo o diálogo entre os sistemas científicos e tradicionais para construir sistemas alimentares resilientes para todos os colombianos.

Palavras-chave: Ecologia do Conhecimento; Governança Ambiental; Soberania Alimentar; Recursos Genéticos; Conhecimento Tradicional.

1. INTRODUCTION

Food sovereignty has emerged as a critical paradigm for addressing global food security challenges, particularly amid increasing pressure on natural resources and the escalating impacts of climate change. It represents the right of peoples to define their own agricultural and food policies, ensuring sustainable production, distribution, and consumption. This concept, unlike the more limited focus of food security, is concerned not only with food availability but also with the power structures controlling the food system (Windfuhr & Jonsén, 2005). It is inherently connected to the access and control over a nation's genetic diversity and the preservation of vital ecosystems.

In a nation like Colombia, celebrated for its vast biodiversity and rich cultural heritage, the interplay between food sovereignty and the management of genetic resources assumes strategic importance. The defense of these resources becomes a defense of the territory and culture itself, as argued by Fernandes (2017). However, the current agricultural landscape presents a complex picture. The nation faces the progressive loss of agrobiodiversity, driven largely by monoculture expansion and a growing dependence on a limited range of commercial seeds. This trend, a legacy of the "Green Revolution" (Ceccon, 2008), diminishes the resilience of Colombian food systems and curtails their ability to adapt to changing environmental conditions, a concern highlighted by Holt-Giménez and Altieri (2013).

Furthermore, deficiencies in regulating access to genetic resources can foster technological and economic dependencies, eroding the country's autonomy. Unregulated bioprospecting and the threat of biopiracy also present significant challenges to national interests and the rights of local communities. These issues are compounded by a development model that often prioritizes export-oriented agribusiness over food production for local consumption, a dynamic shaped by neoliberal policies that have restructured agrarian economies to the detriment of small farmers (Harvey, 2007).

This paper, derived from the research project "Peasants as Subjects of Special Constitutional Protection," delves into this intricate nexus. It seeks to understand how the governance of genetic resources influences Colombia's capacity to achieve food sovereignty. The study investigates how prevailing agricultural policies affect genetic diversity and, in turn, how this diversity underpins the nation's ability to ensure food security in an autonomous and sustainable manner. Special attention is given to the critical role of traditional practices in managing agrobiodiversity and their potential to foster resilient food systems.

The concept of food sovereignty, which gained prominence in the 1990s, offered a holistic alternative to the narrower approach of food security. The 2007 Declaration of Nyéléni solidified food sovereignty as the right of peoples to healthy and culturally appropriate food produced through ecologically sound methods. This research adopts this comprehensive understanding, expanding it to underscore the symbiotic relationship between genetic resources and associated traditional knowledge as a foundational pillar. Genetic resources form the biological basis of food systems, but their potential is only realized when managed in synergy with the generational knowledge of farmers and indigenous communities (Berkes et al., 2000).

To address these challenges, the primary objective of this paper—derived from the research project titled 'INV-DER-4255 La protección de los conocimientos tradicionales en el marco de la implementación del Tratado de Cooperación Amazónica en Colombia,' funded by the Universidad Militar Nue-

va Granada—is to analyze how the governance of genetic resources and the protection of traditional knowledge influence Colombia's capacity to achieve comprehensive food sovereignty. To achieve this, the study employs a qualitative narrative review based on a rigorous documentary analysis. This methodological approach is highly pertinent for this research, as it allows for a critical triangulation of legal frameworks, public policies, and socio-ecological case studies. By systematically analyzing these diverse sources, the method provides a robust and necessary synthesis of the systemic barriers and power dynamics that shape the governance of biological heritage.

The central findings of this review reveal that the progressive erosion of agrobiodiversity—driven by industrial agricultural models and insufficiently enforced regulations—presents a severe structural threat to national autonomy and food security. Conversely, the results demonstrate that traditional knowledge systems and community-led conservation practices offer a critical source of resilience.

2. METHODOLOGY

This research was developed through a qualitative documentary analysis, structured as a narrative review. The study focuses on understanding how the governance of genetic resources and the protection of traditional knowledge influence the capacity to achieve food sovereignty in Colombia. To guarantee a comprehensive and reproducible data collection process, a systematic search was executed across specialized academic databases, including Scopus, Web of Science, Hein, and SciELO, alongside primary sources from official Colombian legal repositories.

The search was delimited to documents published between 1990 and 2024 to capture the conceptual evolution of food sovereignty, which gained prominence in the 1990s, and the legal transformations following the 1991 Colombian Constitution. To optimize precision and ensure thorough coverage, specific Boolean search equations were applied across the databases. These included combinations such as "traditional knowledge" OR "saberes ancestrales" AND "Colombia" AND "genetic resources" OR "recursos genéticos"; "farmers' rights" OR "derechos de los agricultores" AND "Colombia" AND "seeds" OR "semillas"; "bioprospecting" OR "biopiratería" AND "Colombia" AND "regulation" OR "legislación"; and "Convention on Biological Diversity" OR "Nagoya Protocol" AND "Colombia" AND "implementation".

To maintain the thematic focus and academic rigor of the analysis, strict selection criteria were established. The inclusion criteria required documents to be peer-reviewed articles, academic books, doctoral dissertations, or technical reports focusing on the Colombian context, explicitly addressing the relationship between agricultural policies, genetic diversity, and sustainable food security, or relevant national and international legal norms and policy documents. Conversely, the exclusion criteria filtered out literature lacking a clear empirical or methodological foundation, opinion pieces, non-academic reports, general media articles, and studies focused exclusively on the technical or agronomic aspects of biotechnology without addressing social, legal, or governance implications.

To manage the volume of retrieved documents efficiently, specialized reference management and qualitative data analysis software, such as Mendeley, Zotero, or Atlas.ti, was utilized. This software facilitated the organization, deduplication, and systematic screening of the literature. Following the extensive data collection, the research proceeded to a phase of systematization and integrated analysis. Data

from the various sources was triangulated to synthesize the information effectively. Detailed content and thematic analyses were conducted to identify significant patterns within the textual information.

3. RESULTS

The documentary analysis, guided by a framework of food sovereignty, political ecology, and natural resource governance, has yielded significant insights. The results confirm the central hypothesis: a management approach that promotes the conservation, sustainable use, and local control of genetic resources, grounded in the recognition of traditional knowledge and farmers' rights, demonstrably strengthens food sovereignty in Colombia by enhancing the resilience of productive systems, diversifying food sources, and reducing dependence on external inputs and corporate-controlled technologies.

3.1 The Imperative of Food Sovereignty and its Link to Genetic Resources

The research underscores that food sovereignty is a political and social alternative to the dominant discourse of food security, which is often co-opted by corporate interests (Schanbacher, 2010). It is defined as the right of peoples to culturally appropriate and nutritious food, produced sustainably, and their right to define their own food systems. This contrasts with food security, which has historically overlooked critical aspects of access, sustainability, and community control (Jarosz, 2014). The analysis reveals that achieving food sovereignty is inextricably linked to the availability, access, and control over the diversity of genetic resources for food and agriculture.

Control over seeds is a foundational pillar of sovereignty, representing a tangible connection to territory and cultural autonomy (Fernandes, 2017). Current policies in Colombia often fail to secure this link, thereby impacting the nation's ability to guarantee food security in an autonomous manner. The work of Gómez Lee (2017) highlights how the disconnect between policy and practice creates significant barriers for local communities to exercise their rights to food sovereignty. This reflects a lack of coherence in agrarian public policy that favors industrial models over local, sustainable systems, a tension that has become a global rallying cry for social movements (Rosset, 2003).

This conceptual divide has profound material consequences. When policy focuses solely on national food availability, it can justify large-scale, export-oriented monocultures that displace small farmers and erode local food systems (Giraldo, 2015). In contrast, a food sovereignty framework prioritizes local markets, ecological sustainability, and the rights of producers, challenging the power structures that dominate the global agri-food system (Domínguez, 2015). The struggle for food sovereignty is therefore a struggle for democratic control over the very basis of life: food, land, water, and seeds.

This struggle is further contextualized by what Edelman (2014) describes as the forgotten genealogies of the concept, which emerged from peasant movements in the Global South as a direct response to neoliberal globalization. The framework thus inherently critiques the global development model, which McMichael (2012) argues has consistently undermined local food systems in favor of integrated, corporate-led supply chains. Food sovereignty seeks to reverse this trend by re-localizing food systems and re-asserting community control over productive resources.

The ethical dimension of this right is paramount. Ramírez et al. (2019) argue for the ethical foun-

dation of the right to food sovereignty in Colombia, linking it to principles of social justice, dignity, and the collective rights of peoples. This perspective moves beyond a purely economic or technical understanding of food systems, framing it instead as a fundamental human right that is essential for the realization of other rights, a position supported by various international instruments (United Nations, 1948; 1966).

Moreover, the political claim for food sovereignty is a claim for a different kind of state-society relationship. As Rosset and Martínez (2014) articulate, it is a global demand from peasant movements for states to protect local agriculture from the volatility of international markets and to implement policies that support small-scale, agroecological production. This requires a fundamental reorientation of public policy away from supporting agribusiness and towards empowering peasant and indigenous food producers.

Ultimately, the imperative for food sovereignty in Colombia is also a response to historical and ongoing agrarian conflicts. The concentration of land and the violent dispossession of rural communities are central to understanding the country's food system (Cruz et al., 2018). Food sovereignty, therefore, is not just about food; it is intrinsically linked to the broader struggles for land reform, territorial rights, and peace, making it an important component of any project for a more just and sustainable rural future in the country.

3.2 Agrobiodiversity: A Pillar of Resilience in Decline

Colombia's status as a megadiverse country is paradoxically juxtaposed with a documented loss of agrobiodiversity. This loss is primarily driven by the widespread adoption of monoculture systems and a heavy reliance on a limited portfolio of commercial seed varieties. This trend is a direct legacy of the Green Revolution, which promoted high-yield varieties that required significant chemical inputs, leading to genetic erosion and soil degradation (Chilon, 2017). The expansion of these monocultures, especially for biofuels and export commodities, not only displaces food production but also generates profound social and environmental impacts (Borras et al., 2010).

Such trends are a significant threat to the resilience of Colombian food systems and their adaptive capacity to climate change. Dependence on commercial seeds also raises concerns about corporate control of the food chain, a phenomenon that has accelerated in recent decades (Bonny, 2017). This directly challenges the tenets of food sovereignty. Previous research has documented the richness of Colombian agrobiodiversity and the threats it faces from industrial agriculture, deforestation, and the introduction of genetically modified organisms (León Vega, 2014). This study confirms that these dynamics directly impair the exercise of the country's food sovereignty, a point also made by Micarelli (2018).

In Colombia, traditional farming practices such as mixed cropping and agroforestry are being displaced by market demands for "improved" seeds. This is evident in regions like Montes de María, where the expansion of oil palm has transformed landscapes and livelihoods, often at the expense of local food security (Aguilera, 2013; Ojeda et al., 2015). The culture and agrobiodiversity of Afro-Colombians in the Darién region, who practice subsistence agriculture with a variety of species, and the diversification of agriculture by Andean settlers, demonstrate the valuable productive and ecological heritage being lost (Álvarez-Salas & Gálvez-Abadía, 2014).

The push for biofuel production, often framed as a "green" alternative, has had particularly severe consequences for agrobiodiversity and food security in Colombia. As Acosta and Chaparro-Giraldo (2009) highlight, the expansion of crops like oil palm and sugarcane for ethanol displaces staple food crops, increases land concentration, and often leads to forced displacement of rural communities. This dynamic creates a direct conflict between energy policy and the right to food, further eroding the foundations of food sovereignty.

The environmental impact of this industrial model extends beyond genetic erosion. The intensive use of agrochemicals in monoculture systems leads to significant environmental contamination. Benítez and Miranda (2013) document the widespread contamination of surface water by pesticide residues in Latin America, a problem that affects not only ecosystem health but also public health in rural areas. This chemical dependency is a hallmark of the Green Revolution model, which Harwood (2009) notes often ignored the long-term ecological consequences in its pursuit of short-term yield increases.

Furthermore, the introduction of genetically modified (GM) crops presents another layer of threats to agrobiodiversity. González (2006) argues that GM organisms can lead to genetic contamination of native varieties through cross-pollination, representing an irreversible loss of genetic heritage. This is a particularly acute risk in centers of crop origin and diversity like Colombia. The intellectual property regimes associated with GM seeds also restrict farmers' rights to save and exchange seeds, deepening their dependence on multinational corporations (Action Group on Erosion, Technology and Concentration, 2007).

The socio-economic impacts of this declining agrobiodiversity are profound. As traditional, diverse farming systems are replaced by monocultures, rural livelihoods become more precarious and vulnerable to market shocks and climate events. Castellanos-Navarrete et al. (2021) detail how the expansion of oil palm in Latin America, while creating some employment, often leads to a net loss of livelihood options and increased social inequality. This process of depeasantization undermines the very social fabric upon which resilient local food systems are built.

3.3 Traditional Knowledge: The Key to Synergistic Resource Management

A central finding is the critical, often undervalued, role of traditional knowledge held by indigenous, Afro-descendant, and peasant communities in the conservation and sustainable use of genetic resources. This knowledge represents complex, locally rooted systems of ecological, cultural, and social understanding. The worldview of traditional farming in Latin America is based on centuries of accumulated empirical knowledge about ecosystems, which also informs their belief systems (Parraguez-Vergara et al., 2018). The research highlights a symbiotic relationship: genetic resources provide the biological foundation, but their potential is maximized when managed in synergy with traditional knowledge (Berkes et al., 2000).

The specific contributions of traditional knowledge to food sovereignty are multiple. Traditional landraces exhibit superior adaptation to local agroecological conditions. Traditional agricultural systems are often characterized by a high diversity of crops, leading to more nutritious diets and lower vulnerability to market fluctuations (Altieri & Toledo, 2011). Sustainable traditional practices contribute directly to the in-situ conservation of agrobiodiversity. Traditional knowledge is dynamic, evolving through continuous community-based experimentation, which fosters local solutions and promotes

self-sufficiency. Control over seeds and associated knowledge empowers communities, strengthening their autonomy and reducing dependence on external inputs (Wittman, 2011).

The erosion of this traditional knowledge, linked to the homogenization driven by industrial agriculture, is a direct threat to food sovereignty. The relevance of this knowledge in Colombia is evident in the Andean region of Boyacá, where heterogeneous traditional practices persist (Clavijo Ponce et al., 2011). Although Andean tubers are not a priority for public policies, they represent the identity and culture of the people. Despite the wide variety of crops in Colombia, rice is one of the most consumed foods, yet the production decisions of rice farmers are largely controlled by the agroindustry, limiting their autonomy (Torres Rivera & Córdoba Cantero, 2022).

This traditional ecological knowledge is not static; it is a dynamic and adaptive system that evolves in response to environmental and social changes. However, as Gómez-Baggethun (2009) points out, the process of globalization poses a significant threat to its persistence and transmission. The influx of external technologies and market pressures can devalue local knowledge, leading to its gradual abandonment by younger generations and disrupting the intergenerational transfer that is important for its survival.

The connection between traditional knowledge, territory, and identity is fundamental. For many indigenous communities in Colombia, their agricultural practices are inseparable from their cultural and spiritual worldview. Micarelli (2020) explores this ontological dimension, arguing that food sovereignty for indigenous peoples is not just about producing food but about reproducing their culture and their relationship with the land. The defense of traditional knowledge is therefore a defense of their very existence as distinct peoples.

Community-based initiatives for the conservation and revitalization of traditional knowledge are crucial for strengthening food sovereignty. Gutiérrez Escobar (2015) describes the work of the Free Seeds Network in Colombia, a grassroots organization that promotes the exchange of native seeds and associated knowledge among peasant communities. These networks create spaces for social learning and collective action, empowering communities to resist the pressures of the industrial food system and build autonomous, resilient local food systems.

Recognizing the value of traditional knowledge also has implications for research and development. An agroecological approach, as championed by Altieri (2010), emphasizes the importance of farmer-led research and the co-creation of knowledge between scientists and local communities. This collaborative approach can help to validate and strengthen traditional practices, while also developing innovative solutions that are adapted to local contexts and needs, thereby fostering a more endogenous and empowering model of agricultural development.

3.4 Governance, Legal Frameworks, and Systemic Challenges in Colombia

Although international instruments like the Convention on Biological Diversity and its Nagoya Protocol provide a framework for conservation and benefit-sharing, their effective implementation in Colombia faces hurdles. The Colombian Constitution (1991) recognizes the nation's ethnic and cultural diversity, yet the coherent articulation of regulations to strengthen food sovereignty remains a challenge. Key challenges include a lack of policy cohesion. Agricultural policies often lack alignment,

sometimes inadvertently undermining agrobiodiversity and food sovereignty. Greater integration is needed between policies governing biodiversity, agriculture, and intellectual property.

Land use and access is a key component for food sovereignty, especially in a country with high land concentration (Sarmiento, 2018). The Colombian legal framework has granted special status to Afro-Colombian and indigenous peoples, but in some cases, this has created conflicts, as in the department of Cauca between peasants and the Nasa community. Unregulated bioprospecting and the appropriation of genetic resources and associated traditional knowledge without prior informed consent (biopiracy) are significant concerns (Rosset, 2003). These practices constitute an ethical injustice and actively undermine the food sovereignty of local communities, a threat articulated globally by scholars like Shiva (1997).

The rights of farmers to save, use, exchange, and sell farm-saved seeds are not always adequately safeguarded, often overshadowed by intellectual property regimes that favor commercial breeders. This directly impacts local seed systems, as evidenced in the controversies surrounding Resolution 970 of the Colombian Agricultural Institute (Grupo Semillas, 2016). Mechanisms for the active participation of local communities in the governance of genetic resources are often insufficient. Effective food sovereignty requires these communities to be central to decision-making processes regarding the resources they have traditionally managed.

However, cases of resistance are emerging, for instance, in the Cañamomo Lomaprieta indigenous reserve, which highlights the efforts of local communities who have organized to consolidate food sovereignty (Rey-Lema & Peña-Galindo, 2024). This is a political process of autonomy in defense of territory, culture, and seeds. Furthermore, two cases in Colombia portray alternative types of governance. First, in Riosucio (Caldas), the San Lorenzo Seed Custodians Network promotes association for the conservation of native seeds. The second case is about peasant women in Cauca, who created the ACIT Association, which has been building a peasant political agenda including issues such as autonomy and food sovereignty.

The analysis of governance must also consider the power dynamics that shape policy outcomes. Del Castillo Matamoros and Ramírez Noy (2017) conduct an analysis of governance and territory in Colombia, revealing how powerful actors, including large landowners and agribusiness corporations, often exert significant influence over policy-making processes. This corporate capture of the state can lead to the formulation of policies that favor their interests at the expense of small-scale producers and food sovereignty objectives.

Recent legislative developments, such as the Zidres Law (Law 1776 of 2016), exemplify these tensions. Rodríguez Sánchez (2017) critiques this law, arguing that it promotes the economic exploitation of vast territories by large-scale agribusiness projects, potentially threatening the food sovereignty and security of peasant communities who have historically occupied these lands. This highlights a persistent policy bias towards an export-oriented, large-scale agricultural model, despite constitutional recognition of the importance of peasant agriculture.

The legal protection of ethnic territories, while a significant achievement, also presents governance challenges. The Observatory of Ethnic Territories has documented numerous conflicts over land and resources, not only between ethnic communities and external actors but also among different ethnic

groups (Ramírez & Tobón, 2013). These complex inter-ethnic dynamics require nuanced governance arrangements that can mediate conflicts and ensure equitable access to resources for all rural inhabitants, including peasant communities who may not have the same level of legal recognition as indigenous or Afro-descendant groups.

Furthermore, the intellectual property system itself poses a systemic challenge. Perelmuter (2018) analyzes how intellectual property rights construct seeds as appropriate goods, facilitating their enclosure by corporations. This logic is fundamentally at odds with the traditional practices of seed saving and exchange that form the basis of local food systems. The struggle for food sovereignty therefore necessarily involves a struggle to create legal and political spaces for alternative, non-commodified ways of managing seeds and agricultural knowledge.

3.5 The Imperative of an "Ecology of Knowledge"

The research strongly supports the integration of an "ecology of knowledge" perspective. This approach recognizes the diversity of knowledge systems and underscores the importance of intercultural dialogue between Western scientific knowledge and traditional ecological knowledge for the sustainable management of agrobiodiversity. Exploring and fostering the complementarities between these knowledge systems can significantly strengthen the resilience of food systems and enhance community autonomy, a point central to agroecological thinking. This expanded conceptual framework provides a more holistic understanding of the intricate links between genetic resources, traditional knowledge, and food sovereignty.

This perspective challenges the dominant paradigms that often devalue or ignore local expertise (Escobar, 2014). It calls for a more horizontal relationship between different ways of knowing, where scientific research can support and learn from community-led innovation rather than imposing top-down solutions. This aligns with the concept of "good living" (Buen Vivir), which emphasizes harmony between humans and nature and is often embedded in indigenous worldviews (Gutiérrez Escobar, 2011). An ecology of knowledge is therefore not just about combining different data sets; it is about respecting diverse ontologies and fostering a more pluralistic approach to problem-solving.

The case of Inzá, Colombia, evidences the intertwined dynamics among peasants, food sovereignty, and rights. The food sovereignty practices in this case show a model of social transformation led by rural women (González Torres & Pachón Ariza, 2022). By taking into account territorial processes and community proposals, it is possible to achieve better conditions to coexist in rural areas. Food sovereignty is an opportunity to guarantee the realization of the rights of this population, allowing them to ensure dignified living conditions through community self-management. This demonstrates different forms of social, territorial, and cultural expression, recognizing diversity as a characteristic of social systems.

This approach requires a critical look at the history of agricultural development in Colombia. Fajardo (2018) provides a historical overview of agriculture, peasants, and food from 1980 to 2010, showing how state policies have consistently favored a model of modernization that devalues peasant knowledge and production systems. An ecology of knowledge seeks to reverse this historical trend by revalorizing the contributions of peasant agriculture to food security, biodiversity conservation, and rural development.

The concept of peasant territoriality is central to this perspective. Díaz Avendaño and Pachón Ariza (2024) analyze peasant territoriality in the Colombian Massif, demonstrating how peasant communities construct and manage their territories through a complex interplay of social, cultural, and ecological practices. This territorial management is a form of knowledge in action, which is often invisible to conventional development planning. Recognizing and supporting these forms of peasant territoriality is essential for building food sovereignty from the ground up.

Implementing an ecology of knowledge also involves creating new institutional arrangements that facilitate dialogue and collaboration. This could include, for example, participatory plant breeding programs where farmers and scientists work together to develop new crop varieties that are adapted to local conditions and meet the needs of communities. It also requires a transformation of agricultural extension services, moving away from a top-down technology transfer model towards a more horizontal approach based on farmer-to-farmer learning and knowledge sharing.

Ultimately, ecology of knowledge is a political project. It challenges the cognitive injustice that has historically marginalized non-Western knowledge systems and seeks to build a more democratic and pluralistic food system. As such, it is closely aligned with the broader decolonial struggles of indigenous and peasant movements in Latin America, who are fighting not only for control over their lands and resources but also for the right to define their own paths of development based on their own knowledge and values.

3.6 Threats to Agrobiodiversity and Traditional Practices

The analysis confirms that the primary threats to agrobiodiversity in Colombia include the expansion of industrial agriculture, deforestation, and the introduction of genetically modified organisms. These pressures not only reduce genetic diversity but also marginalize traditional farming systems. The impact of drug trafficking on food sovereignty also causes detrimental effects on local knowledge and land tenure, eroding agroforestry practices. Regarding rice production, a threat of high dependency begins with agricultural inputs and ends in the dependency of buying all the food consumed daily by the family. This relates to developmentalist reformism that has meant a disruptive change in food sovereignty and peasant culture (Valencia Duarte, 2022).

The loss of traditional knowledge is critical, especially given that many ethnic cultures are endangered. The disconnection of peasants from their communities has led them to cede their autonomy to market pressures, as in Los Montes de María, where they abandoned food production for the monoculture of oil palm (Maza et al., 2017). Other aspects refer to the loss of native genetic lines and varieties. Second, the establishment of large monocultures with genetic homogeneity facilitated the advance of pathogens. Interconnected elements are the monopolization of water and the concentration of farmland, which impacts peasant food sovereignty.

Seeds also play a key role. Gutiérrez Escobar (2017) described that in the process of losing their territory, the Embera people lost their seeds, and by importing foreign seeds not adapted to the local ecosystems, these did not prosper and brought the danger of contamination by transgenics. This is a consequence of the lack of awareness among the indigenous reserve authorities themselves about the threats of genetically modified varieties. The practices that contribute to conservation, frequently rooted in traditional agriculture, are being eroded. The study highlights the urgent need to identify,

support, and revitalize traditional management practices that sustain agrobiodiversity.

The phenomenon of land grabbing represents a particularly acute threat. Borras and Franco (2010) argue for a broader view of the politics of global land grabs, which are not just about land but also about the control of water and other resources essential for food production. In Colombia, this process is often violent and displaces communities that are the primary custodians of agrobiodiversity, leading to the irreversible loss of both genetic resources and the traditional knowledge associated with them.

The impact of agribusiness on food sovereignty is another major threat. Ávila and Carvajal (2018) analyze the relationship between agribusiness and food sovereignty in Colombia, concluding that the expansion of large-scale, export-oriented agriculture systematically undermines local food systems and the livelihoods of small-scale producers. This model creates a food system that is highly dependent on global markets and corporate supply chains, directly contradicting the principles of local autonomy and control that are central to food sovereignty.

Public health is also at risk due to the intensive use of pesticides in industrial agriculture. Karam et al. (2004) reviews the evidence on the health impacts of pesticides, which range from acute poisoning to chronic diseases like cancer. Rural communities, and especially farm workers, are on the front lines of this exposure, bearing a disproportionate burden of the health costs of the industrial food system. This highlights the interconnectedness of environmental, social, and health issues in the struggle for food sovereignty.

Finally, the challenge is compounded by a development paradigm that continues to view rural areas primarily as sources of raw materials for industrial development and export. This extractivist logic, as Lander (2010) critiques, is at the root of the current civilizational crisis, as it fails to recognize the planetary limits and the social and ecological costs of a model of infinite growth. A genuine transition towards food sovereignty requires a paradigm shift away from this extractivist model towards one that values rural life, local economies, and the ecological integrity of territories.

4. DISCUSSION

The results convincingly illustrate the profound relationship between the governance of genetic resources and Colombia's capacity to achieve genuine food sovereignty. The central hypothesis—that a management system promoting conservation, local control, and the recognition of traditional knowledge strengthens food sovereignty—is strongly supported. The findings reaffirm that food sovereignty is not simply about producing enough food, a perspective that has evolved from earlier, more limited conceptions of food security (Maxwell, 1996; Gordillo, 2004), but about who controls production, what is produced, and how. In Colombia, the erosion of agrobiodiversity and its associated traditional knowledge represents a critical vulnerability.

This erosion, driven by industrial agriculture and weak governance, directly undermines the resilience of food systems, limits dietary diversity, and increases dependence on external inputs. This situation contrasts sharply with the principles of autonomy inherent in the concept of food sovereignty. A key insight from this study is the indispensable role of traditional knowledge systems. These are not relics of the past but living bodies of knowledge for local adaptation and sustainable resource mana-

gement. The documented threats of biopiracy are not just ethical or legal infractions; they are direct assaults on the food sovereignty of communities.

The research highlights a significant disconnect between Colombia's international commitments (e.g., the Nagoya Protocol) and the on-the-ground realities faced by local farming communities. As Gómez Lee (2017; 2023) points out, Colombia has faced challenges in establishing effective governance for access to genetic resources, lagging behind other Andean nations. While legal frameworks exist, their enforcement appears insufficient to protect agrobiodiversity from the pressures of dominant agricultural models or to fully empower communities as stewards of these resources, a situation that also raises questions about the environmental impacts of transgenesis (León, 2004).

The proposed "ecology of knowledge" offers a constructive path forward. It suggests moving beyond a hierarchical view of knowledge towards a more pluralistic approach that seeks synergies. Such an approach is vital for developing solutions that are locally relevant and sustainable, integrating the deep ecological understanding of communities with scientific advancements where appropriate. This aligns with Escobar's (2014) broader critiques of dominant Western paradigms and with Gutiérrez Escobar's (2019) work on the importance of biocultural diversity.

Overcoming these challenges requires a political commitment to reorient food and agricultural policies towards the principles of food sovereignty. This includes strengthening legal protections for farmers' rights over their seeds and knowledge, as laid out in the UN Declaration on the Rights of Peasants (United Nations, 2018), and fostering genuinely participatory governance mechanisms that give local communities a decisive voice in the management of their resources (Alzate-Mora et al., 2018). The implications of inaction are severe: continued loss of irreplaceable genetic heritage, increased food insecurity, and the erosion of cultural identities.

This analysis aligns with the broader field of agrarian political economy, which, as Bernstein (2016) explains, examines the class dynamics and power relations that shape agrarian change in modern world capitalism. The struggles over genetic resources and traditional knowledge in Colombia are a clear manifestation of these dynamics, pitting the interests of peasant and indigenous communities against those of national elites and transnational corporations within the global food regime. The expansion of biofuel crops, for instance, has been shown to be linked to forced displacement and food insecurity (Gómez Chaparro, 2013), while processes of rural gentrification further squeeze peasant livelihoods (Corts, 2024).

The governance of these resources is further complicated by the complexities of the global political landscape. Margulis and Porter (2013) analyze the governance of the global land grab, highlighting the role of multiple actors and ideas in a complex, multipolar world. Similarly, the governance of genetic resources in Colombia is not a purely domestic issue but is shaped by international trade agreements, intellectual property regimes, and the influence of international financial institutions, all of which tend to favor a neoliberal, market-based approach to resource management (Thorsen, 2009).

Despite these formidable structural challenges, the emergence of local resistance and alternative governance models, as documented in this research, offers a source of hope. These grassroots initiatives demonstrate the agency of rural communities in defending their territories, knowledge, and ways of life. As Boyer (2010) shows in the case of Honduras, transnational agrarian movements can play a

key role in supporting these local struggles and articulating a collective vision for a more just and sustainable food system.

Ultimately, strengthening food sovereignty in Colombia requires a multi-scalar approach that combines grassroots mobilization with policy advocacy at the national and international levels. A narrative analysis of public policy reveals the need for more coherent frameworks (Ramírez & Rojas, 2018), and case studies show the importance of designing local strategies that are context-specific (Reyes Benavides & Sánchez Castillo, 2024). It demands the construction of broad alliances between peasant organizations, indigenous movements, environmental groups, and critical academics. Only through such a collective effort can the dominant agro-industrial model be challenged and a new paradigm based on agroecology and social justice be built.

5. CONCLUSION

This research has analyzed the intricate relationship between the governance of genetic resources and the pursuit of food sovereignty in Colombia, confirming that the two are inextricably linked. The findings strongly support the hypothesis that a governance framework prioritizing conservation, local control, and the recognition of traditional knowledge is fundamental to strengthening food sovereignty. Such an approach enhances the resilience of productive systems, diversifies food sources, and reduces detrimental dependencies on external inputs and technologies.

The analysis revealed that Colombia's rich agrobiodiversity and the ancestral knowledge associated with its management are invaluable assets currently under threat. The pressures of industrial agriculture, coupled with regulatory frameworks that fail to adequately protect these resources, significantly impede the nation's ability to achieve food sovereignty. The study highlighted the critical contributions of traditional knowledge systems to local adaptation, productive diversity, in-situ conservation, and community empowerment, underscoring that their erosion is a direct loss to national food security and cultural heritage.

Furthermore, the research pointed to the urgent need for greater policy coherence and more effective implementation of legal instruments pertaining to genetic resources. Addressing bioprospecting, preventing biopiracy, and ensuring that local communities are the primary beneficiaries of their own biological and intellectual heritage are paramount. The "ecology of knowledge" emerged as a vital perspective, advocating for a constructive dialogue between scientific and traditional knowledge systems. This approach is essential for developing innovative and sustainable solutions for Colombia's food future.

In response to the research question, the current management of genetic resources in Colombia presents significant challenges to achieving comprehensive food sovereignty, though it also offers profound opportunities for policy reorientation. However, it is important to acknowledge the limitations of this study. As a qualitative documentary review, the analysis is intrinsically constrained by the scope of the available published literature and primarily focuses on the formal national regulatory framework. Furthermore, the specific socio-political complexities of Colombia—such as historical agrarian conflicts, land concentration, and regional disparities—mean that these empirical findings are deeply rooted in a unique national context. Consequently, the direct legal and structural outcomes described can-

not be perfectly generalized to other countries without considering their own specific historical and regulatory nuances.

Nevertheless, the theoretical and systemic implications of this research offer valuable insights that transcend the Colombian borders. The underlying dynamics identified—particularly the critical need for an "ecology of knowledge," the defense of farmers' rights against corporate seed enclosure, and the tension between industrial agriculture and traditional knowledge—are highly relevant to other realities. These patterns can be cautiously generalized to other megadiverse nations in the Global South facing similar globalized pressures from agribusiness and neoliberal trade policies. Ultimately, the formulation of specific, context-sensitive policy recommendations is the critical next step to translating these analytical insights into tangible actions, ensuring the right to adequate food and autonomy for communities facing these shared global challenges.

Conflicts of interest

The authors declare that there are no conflicts of interest that arise in relation to the article submitted for publication and that may involve third parties.

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