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Rethinking Innovation in Agroecosystem Living Labs: Insights from a Biocultural Perspective and Participatory Action Research in Agroecology

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Abstract

This study explores agroecological innovation in Agroecosystem Living Labs (ALL) from a biocultural perspective and through the Participatory Action Research (PAR) approach. The research focuses on two cases of Voisin Rational Grazing (VRG) implementation in Boyacá, Colombia, analyzing how the co-creation of knowledge in ALL is enriched by the interaction between human and non-human actors. The biocultural perspective is used to broaden the understanding of the actors involved, revealing that non-human components are not merely passive resources but active participants in the innovation processes. Additionally, the relevance of PAR as a methodological approach that must go hand in hand with the biocultural perspective is highlighted, allowing for an adaptive and context-specific innovation process that reinforces the sustainability and autonomy of agroecological communities. The findings suggest that expanding the understanding of ALL through the integration of the biocultural perspective and PAR not only enhances the characterization of these labs but also offers a more holistic and robust framework for agroecological transition in the Global South.

Keywords: living lab, agroecology transition, innovation, non-human, global south.

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1 Introduction

According to McPhee et al. (2021), Berberi et al. (2023) and Zavratnik et al. (2019), agroecosystems as living laboratories (ALL) can be defined as co-creation scenarios where processes of social and open innovation take place through experimentation in real-world settings, with the collaboration of multiple stakeholders. Moreover, ALL involve sustainability criteria, which, in the case of agriculture, can be analyzed through agroecology as it is a sustainable alternative (Anderson et al., 2021; Gliessman, 2016; González De Molina & Lopez-Garcia, 2021; Tomich et al., 2011).

Agroecology is an interdisciplinary field of knowledge that studies the interactions between soils, plants, animals, humans, and their environment at various scales (plot, agroecosystem, farm, agrifood system) and converges with sustainability sciences (Dalgaard et al., 2003; León Sicard, 2009; León-Sicard, 2014; Tomich et al., 2011). Agroecology is understood not only as a field of study but also as a practice and a social movement (Wezel et al., n.d., 2009).

Agroecology expanded between 1970 and 2000, being recognized as a scientific discipline covering scales from agroecosystems to the agrifood system (Wezel et al., 2009). During this period, multiple agroecological practices emerged, and the relevance of indigenous and peasant knowledge and practices was acknowledged as valid and important (Anderson et al., 2021; Giraldo & McCune, 2019; López-García et al., 2021; Salavisa & De Fátima Ferreiro, 2019; Wezel et al., 2009).

Unlike other forms of sustainable agriculture such as regenerative agriculture, agroecology incorporates political aspects that define a particular subject: the peasantry and indigenous peoples. These groups practice and advocate for agroecology because this way of thinking and practicing agriculture aligns with the defense of their territory and its ecological and cultural foundations (Giraldo & Rosset, 2021; Rosset et al., 2019; van der Ploeg, 2012, 2019, 2021).

Furthermore, agroecology is considered an alternative to address the negative impacts of conventional agricultural practices, requiring a process of change known as agroecological transition. This transformation involves modifying the socio-technical regime, encompassing the rules, norms, knowledge, technologies, and predominant practices within agriculture. This shift is driven by innovation processes that emerge within socio-technical niches (El Bilali, 2020; Ingram, 2018; Ollivier et al., 2018; Tittonell, 2020). From this perspective, agroecology is understood as niche innovations, and agroecological transition is defined as a succession of these emerging innovations (Tittonell, 2020). Recognizing and supporting living laboratories within the framework of agroecology not only enhances research and innovation in sustainable agricultural practices but also accelerates and ensures an effective transition towards more resilient and equitable food systems globally.

Different peasant, indigenous, and rural initiatives have undertaken agroecological transition processes in their territories. These processes have been accompanied by innovation, co-creation, and knowledge dialogue processes and have been articulated in multi-stakeholder networks (Levidow et al., 2021). Mainly participatory approaches have been used, and the innovations are open-ended (González De Molina & Lopez-Garcia, 2021; López-García et al., 2021).

The dialogue of knowledges is an approach developed in Latin America that critiques the dominance of scientific knowledge as the only valid form of knowledge. It recognizes other forms of knowledge, such as traditional knowledge, and places them in dialogue with scientific knowledge without establishing hierarchies between them (Eschenhagen, 2021; Escobar, 2005, 2007; Leff, 2007). This approach has been particularly embraced by agroecology, as it values the ancestral knowledge of traditional farming practices—an ecological knowledge that is dynamic and constantly reconfigured through the multiple interactions between humans and non-humans (López-García & de Molina, 2021; Silva-Rivera et al., 2022; Toledo & Barrera-Bassols, 2014). Furthermore, peasant farming practices are based on traditional knowledge and engage in co-production of knowledge with nature, that is, with the non-human component (van der Ploeg, 2010, 2012).

Therefore, the dialogue of knowledges fosters an exchange of insights among peasants, indigenous peoples, scientists, extension workers, and agricultural professionals (González De Molina & Lopez-Garcia, 2021; Levidow et al., 2021; Mier y Terán Giménez Cacho et al., 2018; Val et al., 2019). Typically, the articulation between these forms of knowledge has been understood and promoted from the perspective of co-design/co-creation (Levidow et al., 2021; Warner, 2006, 2008). In fact, collaborations have emerged among academics, activists, and peasants (Giraldo & Rosset, 2018; Rosset et al., 2021).

Knowledge dialogue has enabled the construction of situated knowledge, which is knowledge relevant to the ecological and cultural conditions of each territory, driven by the dialogue between academic and traditional/local knowledge (Toledo & Barrera-Bassols, 2014). Therefore, it is possible to assert that the innovation generated by agroecology contributes to sustainability because it is tailored to the ecological and biocultural conditions of the territories where knowledge is produced. These are often open-ended innovation processes, approached from a bottom-up perspective (González De Molina & Lopez-Garcia, 2021; Guzmán et al., 2013; López-García, 2020; López-García & de Molina, 2021).

The objectives of ALL are the generation of knowledge and innovation in agricultural practices and technologies, and their evaluation, through experimentation in real-world settings with the participation of multiple stakeholders and diverse forms of knowledge, aiming to achieve the sustainability of agroecosystems (Berberi et al., 2023; McPhee et al., 2021; Peña-Torres & Reina-Rozo, 2022; Toffolini et al., 2023). In this regard, the goals of agroecological transition experiences and ALL coincide in generating knowledge and innovation in real contexts, relying on co-creation/dialogue of knowledges processes. Ultimately, they are interested in making transformations to promote sustainability, achieving integration between humans and non-humans with socio-cultural, economic, and ecological benefits. In summary, agroecological experiences carry out niche innovations for agroecological transition, which aligns with the purposes of ALL.

In the Global South, particularly in Latin America, the social base driving agroecology consists of peasants and indigenous peoples (Rosset et al., 2019; van der Ploeg, 2012, 2021), who have distinct ways of co-creating and disseminating knowledge, generating socially and culturally adapted innovation processes, and managing their resources (García López et al., 2019; López et al., 2021; Val et al., 2019).

Although analyses of Agroecosystem Living Labs (ALL) often reference co-creation, they typically focus on the human dimension while overlooking the co-production processes involving the non-human component. This oversight is significant because understanding innovation in agroecological experiences requires recognizing the traditional knowledge co-produced through interactions between human and non-human elements. Therefore, a biocultural perspective that encompasses this relationship is essential.

The initial premise is that a biocultural analysis of agroecological experiences can offer a more profound understanding of innovation in ALL. Therefore, this paper asks: How does the biocultural perspective reshape our understanding of innovation in Agroecosystem Living Labs (ALL) through the lens of agroecological transition? Additionally, how is innovation linked to Participatory Action Research (PAR) as a co-creation approach in ALL? In this context, the objective of this work is to analyze the contributions of PAR and the biocultural perspective to understanding innovation in ALL through two cases of agroecological transition in Boyacá, Colombia.

This article is divided into four sections: literature review, methodology, results, and discussion. The literature review identifies contributions to a better understanding of agroecosystem living labs (ALL) and highlights a gap due to the absence of a biocultural perspective, which is crucial for recognizing ALL that have emerged in the Global South. Additionally, the concept of co-creation often overlooks the co-production of knowledge through human and non-human interactions, which is essential in Global South contexts because of the prevalence of traditional knowledge in the agroecological transition. The methodology is primarily qualitative, employing a participatory action research (PAR) approach and various methods. To characterize the innovation process of agroecological transition in Colombia, through two cases in the department of Boyacá.

The final section presents the research findings in two parts. First, it analyzes the network of human and non-human actors involved in the innovation and collaboration processes of the agroecological transition. In this regard, it identifies three kind of relationships as collaboration, cooperation and intra-act between human actors and highlights the need for future research to deeply understand the nature of relationships with non-human actors. Second, it offers a descriptive analysis of the innovation process base on PAR in the cases studied, as well as the transformations generated at the farm level. In the commitment to agroecological transition in the analyzed cases, the innovation process is anchored to a long-term project that gives agency to non-human actors and defines management strategies that go beyond productivity, shaping styles of agroecological life in a constant construction process.

Finally, this study discusses how the recognition of non-human actor should be considered as part of the multi-actor network within ALL, and the importance of PAR as a co-creation approach for developing innovation processes that address the cultural and ecological needs of peasant communities in the Global South. This leads to the suggestion that the features of ALL, at least in the Global South, should be expanded to incorporate the biocultural perspective and Participatory Action Research (PAR).

2 Literature review

In the literature on ALL, efforts have been made to distinguish this typology of living labs from other types, such as Urban Living Labs (ULL). In this way, we can speak of a broad family of LLs, but those that develop around agroecosystems have their particularities.

In the literature on Agroecosystem Living Labs (ALL), efforts have been made to distinguish this typology of living labs from other types, such as Urban Living Labs (ULL). While we can speak of a broad family of LLs, those that develop around agroecosystems have their particularities. ALLs, for instance, often emphasize the integration of agricultural practices with environmental sustainability, requiring a unique focus on the interaction between human and non-human components. They tend to involve stakeholders such as farmers, researchers, policymakers, and local communities, fostering collaboration to address specific agricultural and ecological challenges. Furthermore, ALLs typically operate in rural or peri-urban settings, where the dynamics of land use, biodiversity, and ecosystem services are central concerns. These characteristics set ALLs apart from other living labs, highlighting their specialized role in promoting sustainable agricultural innovations and practices.

A common aspect between ULL and ALL is the concept of "place-based innovation" proposed by McPhee et al. (2021). ALLs have unique characteristics due to the nature of agriculture, which has its own rhythms and specificities and requires physical space for real experimentation (Dumont et al., n.d.; Toffolini et al., 2023). Innovation is often rooted in a specific territory, and its products frequently carry significant social value (McPhee et al., 2021; Ortiz et al., 2018; Reina & Ortíz, 2019). Therefore, there is a recognition of the particularities of agriculture, given its close relationship with the non-human component, meaning the physical space and the entire ecological foundation on which this activity depends.

To demonstrate that ALLs have specificities and therefore need to be distinguished from the common principles of living labs, McPhee et al. (2021) identify four dimensions (aims, activities, participants, and context) and eleven characteristics of ALLs by analyzing a set of cases in France and Canada, as well as a literature review of cases in the Global North. Furthermore, the study found that sustainability, complexity, and place were common features shared by urban living labs and ALLs. Although the study acknowledges the unique aspects of interacting with various actors through networks and ecological factors such as resilience, it does not consider the non-human components as active participants in the production of knowledge.

One key attribute of Living Labs (LLs) is that their users experiment in real-world settings. In this context, Toffolini et al. (2023) have identified three ideal types of experimentation in agroecosystem living labs, highlighting the diverse ways people engage in experimentation. These ideal types are: experimenting as a game of creativity within a predefined space, as a progressive contextual adaptation for innovation adoption, and as a catalyst for long-term local collective action. This classification aims to enhance understanding of trust generation, social learning, adaptation possibilities, and emerging issues. Although experimentation in agroecosystems requires interaction with non-human components, these categories of experimentation do not address this relationship, which involves interventions that use, appropriate, and transform the non-human elements.

Schuurman & Leminen (2021) conducted a systematic literature review to ascertain the scope of ALL and identified three levels: organizational level, project level, and user activity level. The project level is situated at an intermediate point between user innovation and open innovation, and between entrepreneurial innovation and societal innovation. The categorization of the analyzed papers showed that the majority are oriented towards societal innovation.

While it is widely accepted that ALLs contribute to sustainability, only a few articles focus on analyzing agroecological experiences. Agroecology extensively references traditional knowledge in moving towards a bottom-up approach to sustainability, facilitating the dialogue of knowledge and recognizing the importance of local and traditional knowledge. However, in the case of the literature on ALLs, there are few references to the bottom-up approach. Peña-Torres & Reina-Rozo (2022) mention it as a different view for the co-creation of knowledge from community innovation, while Zavratnik et al. (2019) identify it as an efficient way for local development. For Toffolini et al. (2023) this approach is an intrinsic element of governance and decision-making power of the participants.

Although studies have characterized living labs, research on co-creation in rural contexts in the Global South is scarce (Peña-Torres & Reina-Rozo, 2022). The literature review by Berberi et al., (2023) shows that most living labs studied are from Europe, with no specific participation from Latin America. The emblematic LL networks mentioned in the literature are from the Global North (Berberi et al., 2023; Leminen & Westerlund, 2019; McPhee et al., 2021).

Several authors have analyzed cases in Latin America and Africa, covering various concepts. From the perspective of community innovation, Reina-Rozo (2020) provides a conceptualization of innovation ecosystems in Colombia and Uganda, analyzing the collective processes where collaboration is key for socio-technical change. In the same framework, Reina-Rozo & Ortiz (2019) revisit this conceptualization to analyze the case of Tierra Libre, focusing on the use of digital technologies to promote an agroecological-based farmers' laboratory in Colombia. Additionally, Calzada (2023) proposes the concept of Smart Rural Communities (SRC) as an experimental policy intervention model in the Global South, utilizing action research rural living labs. This postcolonial concept recognizes the potential for social innovation on the path toward the emancipation of rural communities.

In both LL and ALL, co-design and co-creation are considered relevant approaches. According to Toffolini et al. (2023), "the notions of co-producing innovations by involving local actors upstream in design processes, and of co-designing innovations to better respond to concerns, are explicity associated with these forms of research in the agricultural sector" (Toffolini et al., 2023, p. 3).

Regarding the implications of co-design and co-creation, cases of living labs in the global south have been analyzed. Reina-Rozo et al. (2018) documented the co-design process and its implications in a post-conflict and peacebuilding context in Colombia. Through Participatory Action Research-PAR processes (Peña-Torres & Reina-Rozo, 2022) and action research (Calzada, 2023), they present a systematization of living lab experiences around the development of technologies in Global South contexts. These works show that the participatory approach provides relevant solutions to the needs and challenges of rural communities. Peña-Torres & Reina-Rozo (2022) demonstrated that young people have the capacity to disseminate innovations, considering plural visions that include new epistemes and the vision of the academy. This dialogue of knowledge allows for the transformation of education and rural extension practices.

Progress has been made in documenting and analyzing ALLs in the Global South, identifying characteristics such as the application of PAR methods for postcolonial purposes and the use of co-design processes to develop situated solutions. However, these analyses have not addressed the role of the non-human component in the process of innovation and social learning in self-managed cases with low institutional support. ALLs are important for considering sustainability. In agroecological experiences that involve traditional knowledge, ALLs should consider the role of the non-human component, as it plays a crucial part in generating relevant and sustainable knowledge.

3 Methodology

The methodological design was based on the participatory action research (PAR) approach, characterized by cycles of reflection-action-reflection. PAR considers individuals experiencing the reality under study as active participants who contribute to the research process. This method involves iterative cycles of reflecting on their own realities and taking action to enact changes (Adams & Moore, 2007; Ernesto Méndez et al., 2013; Hall et al., 2017; Warner, 2006). Often, these participants are central to driving the research process concerning their own reality. PAR generates reflections that aid in transforming reality towards more just and beneficial circumstances for those involved, making it an appropriate approach for analyzing transitions.

In the analysis of the agroecological transition, the research was based on two case studies to examine agroecological transition processes and understand the interactions between humans and non-humans in real-world contexts. The cases studied between 2015 and 2022 reveal that reflection is manifested in the motivations and beliefs driving changes towards the implementation of agroecology, while actions are evident in the transformations made by families as a result of these cycles of reflection. This approach is crucial because it allows those involved to transform their reality through cycles of reflection-action-reflection (Guzmán et al., 2013; Hall et al., 2017; Jiménez, 2020), as follows:

- *Reflection:* Reasons and purposes for implementing the agroecological transition and the broader agroecological system.
- *Action:* Process of agroecological design and implementation on each farm and changes in lifestyle. The livelihoods of families, encompassing their beliefs, knowledge, habits, customs, and ways of living.
- *Reflection:* Transformations and challenges generated in the transition to agroecological farms.

This research employed qualitative methods including dialogues, semi-structured interviews, social cartography, and participant observation. Dialogues and participant observation were conducted during multiple visits from 2015 to 2022, with visits occurring at least once a month. Participatory action research (PAR) involved five individuals from the Florida case, each interviewed two or three times, totaling 13 interviews, and one individual from the Pacha case, interviewed three times. Additionally, social cartography was conducted in 2018, focusing on land use design.

The interviews and observations conducted on the farms regarding the implementation of agroecological practices aimed to identify both human and non-human actors involved. The process also documented actions to identify phases and steps in the innovation process toward agroecological transition. Social mapping commenced in 2019 with the design and implementation of agroecological practices on each farm, involving discussions among family members. By 2020, a redesign process occurred, resulting in the creation of the 'dream farm', which included additional production lines and enhanced multifunctionality compared to the initial map.

The interviews and observations conducted on the farm regarding the implementation of the agroecological practices aimed to identify both human and non-human actors involved, as well as to document the phases of reflection-action-reflection of the innovation process towards agroecology. Social cartography began in 2019 with the design and implementation of agroecology on each farm, involving discussions among family members. By 2020, a farm redesign process occurred, resulting in the creation of the 'dream farm,' which included additional production lines that enhanced the farm's multifunctionality compared to the initial map.

Figure 1. Social cartography of Florida Family.

Constant dialogues were held to reflect on the progress of the implementation of the project defined in the cartography, on the limitations and mistakes made during the process, and on the achievements made. These dialogues took place during visits to the farms and in spontaneous conversations.

3.1 Study cases of agroecological transition in Boyacá, Colombia

One of the proposals for the transition to agroecology is Voisin Rational Grazing (VRG) (Pinheiro Machado Filho et al., 2021; Pinheiro Machado, 2011), defined as a technology capable of addressing the impacts of conventional agriculture. VRG creates conditions for natural cycles to restore soils, increase CO2 capture, enhance productivity in the soil-plant-animal relationship, and produce high-quality food (Pinheiro Machado Filho et al., 2021). VRG is an agroecological-based technology that seeks to restore biological cycles and the soil-plant-animal-human relationship through practices that allow for adequate soil rest periods, optimal grass growth, quality feeding, and animal welfare, ultimately enhancing human quality of life. These practices are carried out respecting and restoring natural cycles and protecting the ecological base, making it a sustainable practice (Pinheiro Machado Filho et al., 2021; Pinheiro Machado & Pinheiro Machado Filho, 2016).

This technology has been implemented by various initiatives in Latin America, led by engineer Luis Carlos Pinheiro Machado and his team. In Boyacá, Colombia, two families became interested in VRG and began the agroecological transition process through a self-managed innovation approach. The VRG implementation process involved understanding the foundations of this technology to reinterpret and adapt it appropriately, considering the cultural, economic, and ecosystem conditions of the two cases analyzed in this work. These cases, located in Boyacá, Colombia, have become living laboratories worth analyzing to understand the characteristics of spaces of innovation, co-creation, and transition to agroecology that emerge in contexts of autonomy and low institutional support. A multiple case analysis was conducted on two agroecological experiences based on VRG implementation in Boyacá, Colombia. These experiences are named Florida, located in the municipality of Miraflores, and Pacha, situated in the municipality of Pachavita, both within the department of Boyacá. The main characteristics of these experiences are as follows:

Table 1. Characteristics of cases

Experience	Farm Area	Members
A Florida Family	21 ha	6 adults (2 since 2015, 3 since 2020, and 1 floating who is a researcher) 3 children
B Pacha Family	3 ha	3 adults (two owners, once of whom is a researcher and a permanent worker)

The two cases began their agroecological transition processes in 2015 and 2013, respectively, and have collaborated in parallel on implementing VRG since 2018. Both farms share a location in the Andean Region at 1800 meters above sea level, with similar rainfall and ecological conditions. This similarity has motivated them to exchange seeds and animal breeds such as sheep and chickens. Another shared aspect is the diversity of plant and animal species for self-consumption, as well as a variety of land uses that include residential areas with surrounding gardens, rotational grazing areas with crops, permanent crop zones, forest and water source protection areas, and protein banks for animal feed. Based on these factors, the distribution of land uses in both experiences is shown in the following table:

Table 2. Distribution of soil uses

Uses on soil	PACHA	FLORIDA
Forest	49,7%	40,0%
Pastures and forajes	39,7%	51,4%
Garden and polyculture	7,5%	7,3%
Buildings	3,1%	1,3%

This land use distribution aligns with the ideal farm map, demonstrating the multifunctionality implemented in the analyzed cases. Recognizing this multifunctionality served as a basis to explore the actors and knowledge used in the innovation process, guiding the formulation of questions in interviews and farm observations.

4 Results

The results of the analysis of the characteristics of ALL in a particular type of experience are presented in two sections. The first section outlines the identification of the innovation process network in which human and non-human actors participate. The second section provides an analytical description of the innovation process and the resulting transformations at the farm level.

4.1 Human and non-human actors in the innovation to agroecological transition

From an ecological perspective on social worlds, or more-than-human participatory research, humans are constantly immersed in networks of non-human life. This perspective challenges the traditional view of non-human elements as passive in the construction of reality, instead recognizing their agency even in research processes (Noorani & Brigstocke, 2018). As a result, the conventional distinction between society and nature has been questioned, given that societies have actively transformed forests, rivers, and landscapes, thereby contributing to what we understand as nature (Haraway, 2006).

By embracing the concept of more-than-human, we can better understand the dynamic interplay between humans and non-humans in agroecological practices, acknowledging the active role of non-human entities in shaping and influencing social and ecological outcomes (Noorani & Brigstocke, 2018). Agriculture and agroecosystems, therefore, result from interactions between culture and ecosystems, or between the human and the non-human, making it essential to consider the roles of both in the generation of knowledge. The relationships with the non-human component facilitate mutual learning (Ulloa, 2022), which plays a significant role in agroecological innovation and the production of the social reality it supports.

In the context of agroecological experiences, analyzing the non-human within a network of actors is crucial, as non-human forces significantly impact social reality. Historical ecology, for instance, demonstrates how the Amazon rainforest has been shaped by human activities over centuries, underscoring that nature is partly a result of human action. The non-human encompasses everything from plants, animals, water, and forests to objects and technology (Noorani & Brigstocke, 2018). These entities occupy a specific place to exist and operate within a defined territory (Ulloa, 2022). For example, agriculture relies on water to establish crops, so understanding the dynamics of water sources like rivers and springs is essential for maintaining the conditions necessary for effective human-water relationships in agricultural practices.

This interaction between human and non-human components forms the basis of biocultural memory, which has enabled the reproduction of agriculture for thousands of years (Toledo & Barrera-Bassols, 2014).

Literature, mainly in Latin America, shows that agroecology has been disseminated through a dialogue of knowledge to foster innovation (Acevedo-Osorio & Álvaro Rivas, 2017; García López et al., 2019; Ortiz et al., 2018; van der Ploeg, 2012). The transition to agroecology relies on this knowledge dialogue to generate innovation through farmer-to-farmer methods, field schools (Acevedo-Osorio & Álvaro Rivas, 2017; ; Val et al., 2019; van der Ploeg, 2012), and collaborative dynamics (Peña-Torres & Reina-Rozo, 2022; Reina-Rozo, 2020). However, these approaches to innovation and knowledge generation often overlook the role of the non-human component, which is a crucial factor in the creation of agricultural knowledge.

According to van der Ploeg (2010), the peasantry engages in a process of co-production of knowledge with nature (the non-human component) through continuous observation and experimentation, enabling the maintenance and management of the resource base that supports agriculture and associated forms of life (van der Ploeg, 2010, 2012, 2019). These processes have been integral to experiences of agroecological transition (Acevedo-Osorio & Álvaro Rivas, 2017; Ortiz et al., 2018), and this co-production takes place in real-world contexts that could be understood as living labs.

Human actions are motivated by worldviews that shape particular ways of life. In agroecology, motivations such as confronting the impacts of conventional agriculture and fostering community autonomy have been documented (Giraldo & Rosset, 2018; Khadse & Rosset, 2019; Mier y Terán Giménez Cacho et al., 2018). In the analyzed experiences, two main motivations for implementing VRG are evident: the alignment between VRG's practices and traditional practices regarding soil protection, animal welfare, human labor, and lifestyle; and the level of autonomy and reduced market dependence allowed by VRG, generating high productivity.

The design and implementation of VRG in Experiences A and B began through knowledge exchange strategies, including: i) reflecting on the need to transition toward an agroecological approach; ii) a member of Experience A visiting several agroecological projects; iii) three members from Experiences A and B participating in the VRG workshop led by Luis Carlos Pinheiro Machado in 2017; iv) a member of Experience A exchanging knowledge with a VRG project in Argentina for three months in 2018; v) monthly meetings for dialogue and reflection between 2017 and 2022; vi) experience-sharing between Experiences A and B to observe the progress and results of implementation; vii) collaborating with a beekeeper to learn how to implement an apiary; and viii) frequent observation of changes in plant cover, soil compaction, presence of soil macrofauna, emergence of new grasses and native trees, pasture availability during rainy and dry seasons, animal behavior, and the physical characteristics of animals.

Regarding observation, it is acknowledged that there is a co-production process between the human and the non-human (van der Ploeg, 2012), resulting in the generation of knowledge about this interaction. Consequently, the source of knowledge is recognized as stemming from the observation process, establishing non-human components as actants in the agroecological transition process.

These strategies involve collaborative actions between actors, a dialogue of knowledge (traditional, academic, empirical) and co-production with the non-human component. To recognize this circulation of knowledge, a social network was created to identify human and non-human actors who contributed to the two experiences and influenced the agroecological project's implementation. Figure 2 is a network of actors representing this flow of information, from the source of information to the actor for whom it is intended (both human and non-human reactions). For example, Friend 1 provided information to the PACHA family and vice versa.

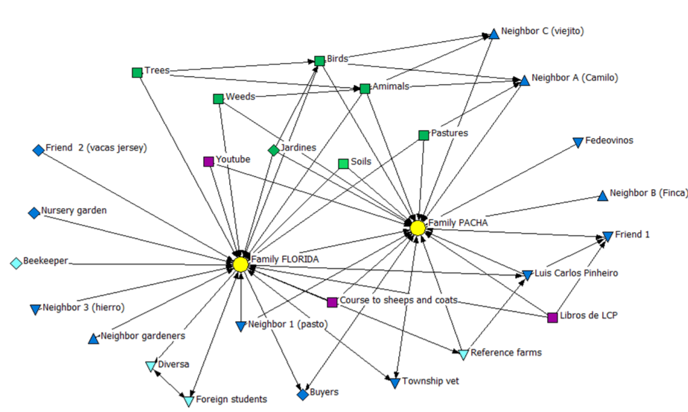

Figure 2. Actor network of knowledge flows between human and non-human actors.

The network nodes represent human (triangles) and non-human (squares), with traditional (up triangle), academic (down triangle), or mixed (diamond) knowledge. The purple squares are non-living devices, while the green ones are living components present on farms. The registry was created for actors who provided information used for some implementation action on the farms.

The network comprises 29 nodes, of which 19 are human and 10 are non-human. Among the human nodes, eight contributed academic knowledge, five provided traditional knowledge, and six offered both. The relationship with living non-human nodes is associated with traditional knowledge, while non-living nodes like YouTube deliver both academic and traditional knowledge. There are also two academic actors (a course and a VRG book).

The actors forming the network in the analyzed cases are families with diverse experiences and an NGO that supported the co-creation processes. Unlike the definitions of living laboratories by Leminen & Westerlund (2019), McPhee et al. (2021), and Zavratnik et al. (2019), these cases do not involve public sector intervention, and the leadership of the transition has emerged autonomously from the community.

In Colombia, the actors that have supported the dynamics of the agroecological transition are the Church, national and international NGOs, and academia, with little support from the public sector (León-Sicard et al., 2017). Therefore, the experiences analyzed reflect what is happening in the national context. Thus, the analyzed experiences reflect broader national trends. Cases A and B are establishing themselves as laboratories that can serve as references for spreading the VRG approach. These laboratories, with limited public sector participation, have the potential to diffuse innovations and promote agroecology as a sustainable alternative.

Based on the above, it is clear that collaboration and cooperation are manifested in this network. Cooperation occurs when individuals work independently to achieve a goal, while collaboration occurs when people work together on shared interests (Reina-Rozo, 2020; Zamenopoulos & Alexiou, 2018). In these experiences, information is obtained from different actors who are not directly connected (12 human actors), but who contribute indirectly through spontaneous dialogues or recommendations without involvement in the project design. These relationships are cooperative. The relationship with Diversa (NGO) and foreign students is also cooperative, established to develop co-creation processes that have contributed to the project in specific areas (biodigester prototypes, a mesh machine, and a prototype of grazing houses for rabbits and chickens), enhancing innovation dynamics.

Cases A and B, in turn, foster continuous collaboration among themselves and with other human actors, maintaining medium-term relationships and exchanging information on agroecological initiatives. The deepest interactions occur between the families of the two cases, who frequently share information and results. This exchange happens through dialogues and farm visits, where the behavior and transformations of non-human components are observed. However, it is necessary to rethink the nature of relationships with non-human actors, as current definitions of collaboration and cooperation focus solely on human actors, leaving criteria for non-human participation undefined.

Recognizing the role of non-human components in knowledge generation and innovation is essential. In this context, living and non-living nodes have agency in co-producing knowledge, which emerges from interactions based on observation and reflection. For example, in Florida, a pile of dry grass and rabbit manure was set up for composting. Twenty days later, worms appeared naturally, prompting the construction of a structure to contain the humus they produced. This process exemplifies intra-action, as the presence of worms—a non-human actor—directly influenced human decisions and innovations, illustrating the co-constitutive relationship between human and non-human elements.

Knowledge is constructed through observation and interaction with the non-human. This process involves a dialogue in which humans recognize the unique language of plants and animals, expressed through signals like color, shine, behavior, sound, and the shapes of their parts. These signals are not merely measurable physical traits but expressions of the non-human world. From this dialogue, potential solutions to everyday challenges emerge. During observations, expressions such as 'the sheep are happy', 'this plant likes to be seen every day,' and 'this plant thrived with this substrate' were identified, reflecting a sensory understanding and the ongoing development of criteria regarding the behavior of plants, animals, and soils.

Given that human and non-human relationships are based on co-existence, where the life of one sustains the other, this relationship can be described as intra-action. (Barad, 2007) introduces the concept of intra-action, proposing that entities do not preexist independently but are mutually constituted through their relations. In this framework, humans and non-humans co-configure in a continuous process, where the life of each is inherently tied to the other.

Reflecting on the agroecological transition analysis, it becomes clear that considering both human and non-human actors in Agroecological Living Labs (ALL) is essential. The actor network reveals three types of relationships—collaboration, cooperation, and intra-action—each playing a crucial role in the biocultural analysis of ALL. These interactions highlight the intertwined agency of human and non-human entities, emphasizing the need for a more integrated approach that recognizes the collective contribution of all actors to the co-production of knowledge and innovation in agroecological systems.

4.2 Innovation process and transformations generated at the farm level in agroecological Lifestyles

It has been recognized that in Agroecosystem Living Labs (ALLs), innovation in real-world contexts allows for testing and adjustments, ensuring the applicability and practical effectiveness of innovations, as well as their long-term impact (Berberi et al., 2023; McPhee et al., 2021). Innovation processes in ALLs are based on co-creation and collaboration within multi-actor networks, which facilitate the creation and evaluation of new practices, technologies, and organizational forms aimed at the sustainability of agri-food systems (Berberi et al., 2023; Leminen & Westerlund, 2019; McPhee et al., 2021; Toffolini et al., 2021). Additionally, ALL focus on innovation in technology, practices, and knowledge, with an emphasis on creating knowledge networks both among those involved in the living lab and beyond.

Similarly, the agroecological transition is also grounded in innovation, but it encompasses both technological and social dimensions (Peña-Torres & Reina-Rozo, 2022; Reina & Ortíz, 2019; Reina-Rozo, 2020; Reina-Rozo & Ortiz, 2019; Camargo Calderón & Acevedo Osorio, 2023). Unlike the techno-diffusionist model of the Green Revolution, agroecology relies on a capacity-building model with small-scale family farmers for the development of social technology, "the latter denotes a design and use promoting social aims such as collective capabilities, inclusion and socio-economic equity" (Levidow et al., 2021, P. 8). This innovation is driven by the strengthening of peasant autonomy, the defense of territories, social justice, and the achievement of sustainability at various scales (González De Molina & Lopez-Garcia, 2021; Rosset et al., 2021; van den Berg et al., 2021; Camargo Calderón & Acevedo Osorio, 2023). Ultimately, innovation is meaningful if it contributes to the coexistence between humans and non-humans.

In this context, Participatory Action Research (PAR) aligns closely with the principles of co-creation central to agroecology, as it actively involves communities in the innovation process. This alignment makes PAR particularly valuable for agroecological transitions, where the participation of local communities is crucial for the co-creation of sustainable solutions. For this reason, the approach outlined by López-García et al. (2021) is essential for analyzing innovation processes in agroecology.

According to López-García et al (2021), innovation in agroecology is inherently open-ended, with uncertainty being considered an integral part of the innovation process. It is viewed "as a key element for integrating divergent profiles and positions into shared solutions, thus building collective action through creativity" (López-García et al., 2021, p. 9), where the potential for conflicts to generate change is recognized.

The open innovation process using PAR in agroecological transitions can be explained through key concepts such as "pain points" or "sensitive issues", "low-hanging fruit" and "comprehensive topics", which are concepts proposed by (López-García et al., 2021). PAR involves iterative cycles of reflection-action-reflection that shape the innovation process according to the needs of the involved participants and repeat as many times as necessary, continuously adapting to changes in reality. The initial reflection phase focuses on identifying sensitive issues or pain points, which represent the most urgent problems and contextual barriers hindering innovation. This phase is critical as it allows efforts to be directed toward the most pressing needs of the community. Once these sensitive issues are identified, strategic actions known as "low-hanging fruit" are designed and implemented. These are interventions that leverage available resources to generate tangible short-term results.

These "low-hanging fruit" not only address immediate problems but also enhance the legitimacy of the innovation process and boost participant motivation. From this action phase, the agency of the participants emerges, leading to a renewed reflection phase that delves into the root causes of the problems. This deeper reflection identifies comprehensive topics—broader and more complex issues that require greater collaboration and creativity to address—and precedes a new action cycle where both technological and social innovation occur. These reflection-action-reflection cycles repeat, activating creative processes and enabling participants to overcome initial barriers while developing new strategies and knowledge adapted to the ecological and cultural conditions of the territory. Thus, the innovation process becomes an adaptive and non-linear pathway, strengthening the resilience and sustainability of the agri-food system.

Figure 3 summarizes the innovation and experimentation process of the agroecological transition of A and B. Five stages are identified, and in each of them the actions carried out, the prototypes generated in the innovation process, and the direct effects that refer both to agronomic practices and to environmental and social effects.

According to López-García et al. (2021), innovation processes begin by identifying the most pressing needs as problems through reflection on one's own reality. This ongoing reflection gradually leads to a more complex understanding of the issues, ultimately allowing the identification and addressing of their root causes. The following is a description of the innovation process base on PAR, the reflection-action-reflection cycle in the analyzed cases, which is summarized in Table 3.

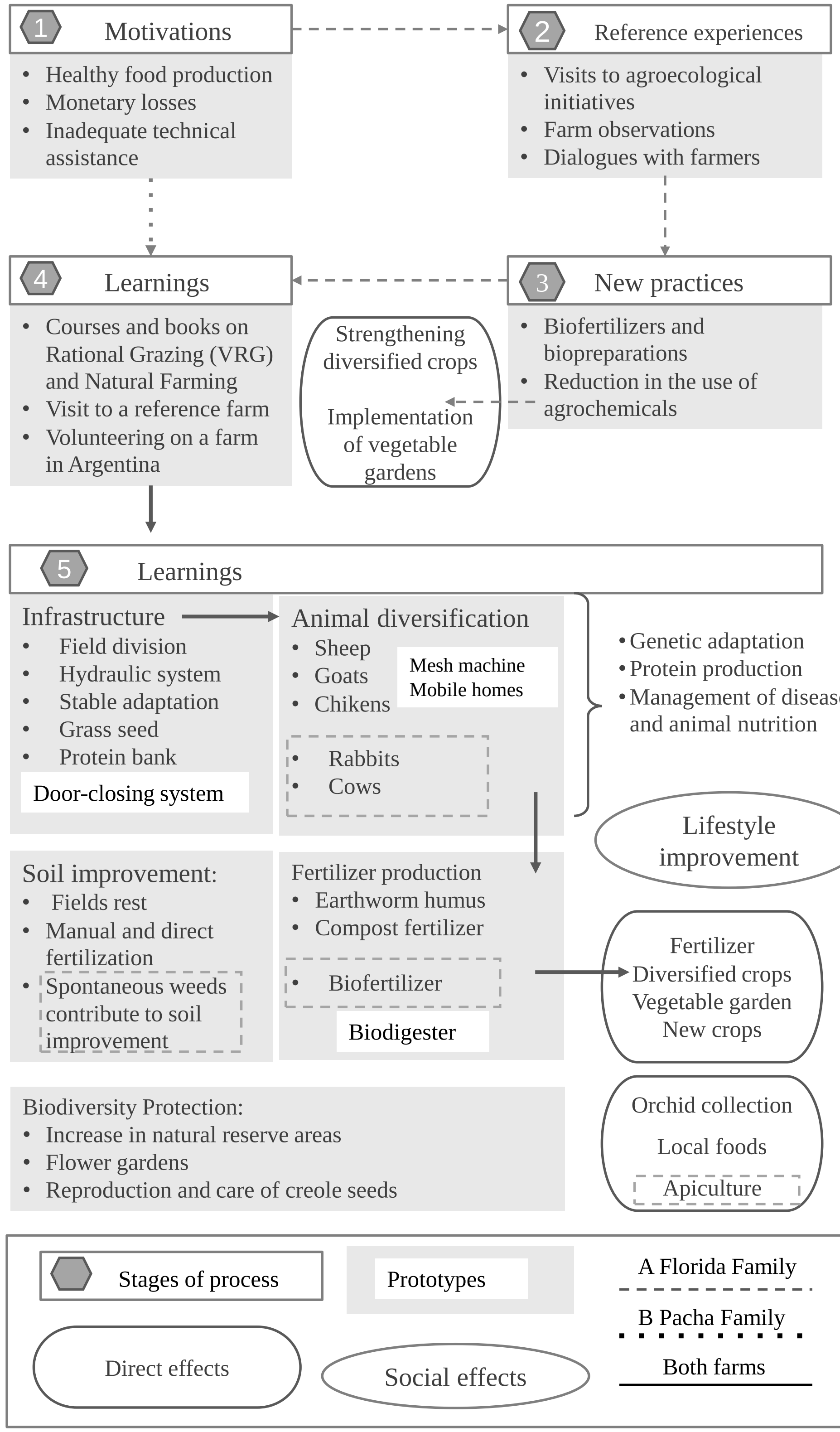

Figure 3. The agroecological transition phases.

Table 3. Innovation Process Based on PAR

PAR phase	Key concepts	Estudios de caso
Reflection	What are the "pain points" or "sensitive issues" that require short-term solutions? The most urgent problems and contextual barriers hindering innovation.	Problems and barriers Economic losses due to low product prices, low productivity, theft, crop unsustainability, and high demotivation. Unfair market access conditions resulting in a forced dependency on exploitative intermediaries. (Step 1 and 2)
Action	What can be done in the short term with "low-hanging fruit" solutions?	Deactivation of the market-oriented peasant economy to reduce losses. Initiating learning on agroecology.
Reflection	What are the comprehensive topics?	Definir motivaciones y objetivos para orientar la transición agroecológica
Action	Social and technological innovation	Redesign of farms (practices, resource management, and processes) Dialogue of knowledge and experimentation Development of prototypes Establishment of partnerships (Steps 3, 4 y 5)
Reflection	Reflecting on the changes brought by social and technological innovation	Support for diverse actors. Increase and reproduction of agrobiodiversity Internal production of inputs (fertilizers, materials, food)
Action	Social and technological innovation	Reconfiguration of the actor network Reorganization of tasks within the family.
Reflection	Reflecting on the changes brought by social and technological innovation	Participation in new fair trade markets Strengthening internal production of inputs. Increasing the diversity of food available for human consumption.

In the innovation process of farms A and B, the starting point was problematization, where pain points and motivations were identified to support the development of strategies and actions for agroecological transition. The first cycle of reflection revealed these pain points: economic losses due to low product prices, low productivity, theft, crop unsustainability, and high demotivation, as well as unfavorable market access conditions. This situation, where farmers are forced to sell their produce to intermediaries at unfair prices below production costs due to limited market access, poor infrastructure, and lack of transportation options, highlights the challenges they face.

In response, the families made decisions such as reducing commercial crops, cutting ties with intermediaries, decreasing the purchase of external inputs, and rejecting municipal technical assistance projects. These decisions align with the concept of "deactivation" (van der Ploeg, 2010) and represent the "low-hanging fruit" that helped reduce economic losses and outline new motivations toward a greater purpose: the agroecological transition (the first cycle of action). The objectives defined for this broader purpose include pursuing food autonomy, reducing dependence on intermediaries, planning actions based on diverse knowledge, and improving family lifestyle.

These objectives express the comprehensive topics aimed at strengthening family autonomy in managing their own agroecological transition (the second cycle of reflection).

Following the identification of these comprehensive topics, the next phase is action, where technological and social innovation emerge (the second cycle of action). In iterative and overlapping cycles, action arises from reflection, expressed in the two cases through the redesign of farms. The redesign involved significant changes, including:

- Changes in land use (increased conservation of native forests, delimitation of pastures for livestock, and crop rotation).
- Increased agrobiodiversity through the association of different livestock species and multi-crops.
- Self-production of fertilizers and establishment of biofactory areas.
- Creation of garden and orchard spaces.
- Introduction of honey bees.
- Increased domestic food production.
- Enhanced energy autonomy through biodigesters and solar panels.
- Development of prototypes adapted to co-creation processes (e.g., gate mechanisms, netting machines, mobile houses for poultry).
- Selection of adapted genetics (native breeds and seeds) more resistant to climate and disease, with space adaptation for free-range grazing.

Innovation actions were implemented through strategies that include giving agency to non-human elements, respecting their rhythms and dynamics, and leveraging signals from nature for long-term sustainability. The ultimate goal is sustainability, projected through food autonomy and the transformation of unequal market relations.

The two families agreed to respect the rhythms of nature, allowing it to act and prioritizing a sustainable future. Non-human actors are crucial in recognizing the agroecological transition process. This perspective is inspired by the principles of VRG from Pinheiro's perspective and Fukuoka's natural agriculture, as well as observations of non-human responses and the need to establish lifestyles based on mutual care.

These changes have transformed farm operations, achieved set objectives, and altered lifestyles. Agroecological innovations have been shown to generate unforeseen chain effects. For examples, in the case of Farm A, a positive relationship was observed between rabbits and chickens: the rabbits produced organic matter that increased insect availability for the chickens. The expansion of reserve areas, gardens, and rested pastures motivated the implementation of an apiary for honey production. For Farm B, the ease of managing the flock increased the motivation of the worker caring for sheep and goats. Increased fodder and fertilizer availability encouraged the establishment of cereal and tuber crops.

Therefore, the redesign of ways of life has allowed for the expression of multifunctionality (Acevedo-Osorio & Álvaro Rivas, 2017; León-Duran & Acevedo-Osorio, 2021). In both experiences, intertwined production lines were generated, reinforcing each other. For instance, animals produce organic matter to create fertilizer and nourish plants that produce food, biomass, and flowers, pollinated by hummingbirds, bees, and other insects. Among the spontaneously grown weeds are medicinal plants used to treat some human and animal diseases, increasing biodiversity with important uses for health autonomy and self-sustainability.

Multifunctionality has led to increased food autonomy, with more family members involved in the development of integrated production lines. These designs have created leisurely, less monetized lifestyles with higher levels of tranquility and improved nutrition. This shift has resulted in a wide variety of food for self-consumption (80%) and exchange (20%), increased food availability for animals, self-production of fertilizers, and enjoyment of landscapes in gardens and reserve areas.

One common limitation in implementing VRG agricultural projects is labor scarcity. However, VRG technology allows non-human nature to act, reducing the need for human labor. For example, reforestation has occurred spontaneously through the spread of seeds by wind or animals, mitigating the labor shortage.

Observing and interpreting non-human behavior has been crucial for knowledge generation. According to Pinheiro Machado Filho et al. (2021) and Pinheiro Machado (2011) weeds serve as indicators signaling soil deficiencies and contribute to soil improvement. This knowledge was reinforced by observing that certain weeds disappear as organic matter incorporation increases. These weeds reduce labor costs and provide medium-term benefits (6 to 7 years), such as improved soil fertility.

Consequently, autonomy has increased by strengthening the internal resources of the productive units, which are reinforced as the conditions of the agroecosystem improve. Thus, it is true that peasant agriculture is based on a flow of non-commodified resources, so that internally produced and contracted resources are more important than external ones (van der Ploeg, 2012).

The agroecological way of life requires a new vision for farm management with a long-term perspective. On one hand, a controlled base of locally available resources is created, where most benefits flow internally, ensuring long-term continuity (van der Ploeg, 2012). Most resource flows occur through non-monetized relationships between humans and non-humans. As shown by the arrows in stage 5 (Fig. 3), integration of animals, soil (fertilizer), plants (nutrients), and humans (food) has been achieved.

Table 4. Strategies of agroecology transition

Aspect	Strategy
Soils	Delimitation of fields Allowing non-human elements to act Observing changes and being patient
Manures	Creating conditions to allow non-human elements to act Co-creation processes (biodigesters)
Crops	Spontaneous and induced organic fertilization Use and care of Creole seeds
Animal husbandry	Exchange and selection of adapted breeds Exchange of information with other actors Co-creation processes (mesh weaving machine, mobile houses for chicken grazing, biodigester) Observation of animal behavior
Protection zones and forests	Delimitation and closure of areas for forest and water sources Allowing non-human elements to act Planting native species

These experiences underscore the importance of considering the role of non-human nature from a PAR perspective to support autonomy and agroecological ways of life—two aspects often overlooked in the framework of ALLs. This approach requires recognizing the complex interactions between human and non-human actors and the feedback processes that enable the emergence and development of innovation. The innovation process intricately weaves together actions aimed at regenerating ecological conditions, co-creating purpose-specific devices, and designing a sustainable lifestyle.

5 Discussion and conclusions

Considering the biocultural perspective—and thus the relationships between humans and non-humans—along with applying a PAR approach, prompts reflections on the characteristics of ALL. These reflections relate to the co-creation of knowledge, the types of actors involved, the forms of experimentation, and the innovation process from a PAR standpoint. Consequently, they lead to an expanded understanding of the features of ALL.

Co-creation of Knowledge

The literature on Agroecosystem Living Labs (ALL) emphasizes the use of a co-creation approach due to its ability to involve local actors in the design of innovations, leading to better outcomes (Toffolini et al., 2023) and even transforming rural extension practices (Peña-Torres & Reina-Rozo, 2022). Similarly, one of the defining features of ALL is that knowledge creation and innovation are based on co-creation through multi-actor collaboration (Berberi et al., 2023; McPhee et al., 2021).

From an agroecological perspective, co-production not only involves the human dimension but also requires the integration of non-human elements, such as agrobiodiversity. This approach builds a social order through identities, institutions, and discourses, while simultaneously creating a natural order through the reproduction of agrobiodiversity. The knowledge produced within this framework fosters a solidarity-based technoscience (Levidow et al., 2021). The cases analyzed reinforce these ideas, demonstrating that transformative actions and innovations arise from the interplay between human and non-human components. This interaction generates a continuously evolving biocultural diversity, making the innovation process inherently open-ended.

Building on this understanding, ALL have three core components: a transdisciplinary approach, co-design processes with participants, and ongoing monitoring and evaluation. These elements are essential to the transformative potential of ALL (McPhee et al., 2021). However, for the innovation process in agroecology to be truly holistic, it must embrace a more situated and participatory approach. PAR plays a key role here, as it not only enhances innovation through a deeper understanding of local realities but also empowers farmers to take informed actions within their own contexts. Consequently, incorporating PAR could significantly amplify the impact of ALL on the agroecological transition.

Finally, the co-production of knowledge occurs in the daily observation of the responses of the non-human component. This knowledge is often referred to as ecological knowledge. The dependence of agriculture on the ecological component provides levels of uncertainty typical of ALL (McPhee et al., 2021), so this is a feature that is maintained and fed back into innovation cycles in the long term.

Network of Human and Non-Human Actors in Innovation within ALL

Innovation within Agroecosystem Living Labs (ALL) and the agroecological transition is crucial for driving changes toward sustainability. In both cases, the innovation process is supported by multi-actor networks and requires participatory or co-creation approaches that empower farmers within their real-life contexts (López-García et al., 2021; McPhee et al., 2021).

From a co-creation perspective, innovation extends beyond the development of technologies or processes; it also involves recognizing the social processes that are essential to making innovation possible. Beginning with an acknowledgment of sensitive issues situates innovation within the realities of life in these territories, recognizing that the diffusion and scaling of innovation require actors with agency who can share experienced, adapted knowledge with the potential for broader application. The continuation of the action-reflection cycle implies an open-ended process, positioning innovation to serve goals defined within a context of effective participation.

Building on this, the biocultural perspective suggests that multi-actor networks in both agroecology and ALL should consider the role of non-human actors and their interactions with human counterparts to achieve a deeper understanding of the innovation process. If ALLs recognize that experimentation and knowledge generation occur in real-world spaces, then in agriculture, this experimentation necessarily involves continuous interaction with non-human elements, refined through constant observation. This more-than-human perspective decouples humans from the center of the design process, acknowledging that innovation arises from co-existence. This approach has fundamental implications for sustainability, offering a stark contrast to the use of agrochemicals in a battle against non-human entities deemed pests or weeds.

Observing the behavior of animals, plants, wind, frost, and rain, detailing their actions, associations, and discovering relationships—such as who can feed whom (e.g., rabbits-worms-chickens)—illustrates the interconnectedness of these systems. Even artificial tools like YouTube can become allies, offering new ideas that are experimented with on the farm and adapted to its specific realities. For example, in Florida, a fertilizer for orchids was developed after watching over 30 YouTube videos from experts in Japan, Peru, Mexico, Colombia, and other countries. This process allowed a deeper understanding of orchids' nutritional needs and helped identify local sources for each component. As a result, kitchen waste is now separated and processed differently to create a highly effective orchid fertilization formula, leading to increased blooming and a significant reduction in orchid mortality.

At least in the Global South, where peasant movements demand autonomy, the use of Participatory Action Research (PAR) is fundamental for initiating innovation processes in real agroecological transition spaces and ensuring their timely and effective use. In these contexts, iterative cycles of reflection have progressed from simple goals, such as reducing losses in agricultural projects, to more complex objectives, such as designing agroecological ways of life.

Generally, ALL are recognized as emerging and supported at the institutional and political levels, with the public sector playing a leading role (Leminen & Westerlund, 2019; McPhee et al., 2021; Toffolini et al., 2023; Zavratnik et al., 2019). However, in the cases analyzed, the need to undertake an innovation process, mobilize actions, implement these actions, and evaluate them arises within families, even though they are connected to a network of actors who provide knowledge and useful information for the experimentation process. Unlike the scaling up of ALL with public sector participation, a deep scaling is evident in the analyzed cases through the continuous strengthening of agroecological values and practices. For example, the implementation of regenerative practices for soil, the production of healthy food, forest conservation, and the equitable distribution of benefits among all family members. Thus, the values and practices guiding decision-making are deeply integrated into the innovation process and become embedded in the cultural matrix of the agroecological lifestyle.

In Latin America and the Global South, it is essential to recognize that some ALL result from self-managed community initiatives supported by a network of actors, often with little public sector involvement. Therefore, further research is needed to analyze a broader range of cases to establish a specific typology that can characterize ALL in the Global South context.

Additionally, this research identified a network of actors focused on recognizing knowledge flows that generated design interventions at the farm level. However, it did not explore knowledge flows related to the diffusion of innovations to other farms. Therefore, future research should expand on the impact of knowledge flows towards network actors who have implemented innovations. The diffusion of these innovations may spread spontaneously through word of mouth, contributing to the agroecological transition, either as a productive system or as a way of life.

Innovation process embedded in ways of life

The farmer's natural space for experimentation and innovation is the farm and its surrounding territory, where they observe, experiment, and generate new knowledge to sustain their livelihood. The analyzed farms have integrated various production lines that create multifunctionality, leading to diverse compositions within their agroecosystems. Thus, the innovation process is approached from a holistic perspective, viewing the farm as a complex system that integrates multiple activities across different spaces, managed not only to develop new methods but also to create sustainable ways of life.

In the cases studied, the innovation process has occurred at the farm system level, where deliberate experimentation takes place. However, this experimentation is closely tied to the production and reproduction of family life, as is typical in family and community-based farming, which serves both productive and non-productive functions. In this context, innovations arise as part of the adaptation process to local conditions (Ortiz et al., 2018; Reina & Ortíz, 2019).

The forms of experimentation involve a constant transformation not only of cultivation practices but also of the ways of life of those transitioning to agroecology. Experimentation in agroecological transitions results from the ongoing feedback between human and non-human elements, leading to innovations that impact social order, the construction of nature, and the production of knowledge. When agroecology is viewed as a way of life rather than merely a method of production, experimentation becomes a catalyst for long-term collective local action (Toffolini et al., 2023).

Another characteristic of this experimentation is that it does not end with the generation or testing of innovations but extends into their use for continuous improvement. This open-ended innovation process does not produce finished products, processes, or relationships; instead, they evolve over time. These continuous improvements are inspired by the ongoing dialogue between humans and non-humans, where the latter communicate through their own signals, prompting responsive actions. Therefore, innovation emerges from biocultural relationships between humans and non-humans, not solely from human ingenuity.

One of the purposes of agroecology is to confront the negative impacts of conventional agriculture, which has led farmers to a high level of dependence on the market (García López et al., 2019; Pinheiro Machado & Pinheiro Machado Filho, 2016). In this sense, one of the objectives of the ALL on agroecological way is to increase the autonomy of access to the resources of the productive process, achieving the reduction of the dependence on inputs from the market and reducing the amount of labor required. Like the ALL of the Global North, one of the goals is to achieve sustainability, which is understood as a consequence of achieving agroecological ways of life. This means creating dignified livelihoods in rural areas, including opportunities for young people, increasing diversification of food production on the farm, and strengthening conservation actions on the farm.

In conclusion, the analyzed experiences provide key elements for a better understanding of innovation processes in Agroecosystem Living Labs (ALL), especially those involving non-human actors, as is natural in agriculture. This study demonstrates that a biocultural perspective, which recognizes the agency of non-human actors, is essential for advancing the sustainability of agroecological systems in the Global South. The integration of a biocultural perspective in these experiences reconfigures the innovation process, articulating it not only around technological innovations but also social ones, highlighting the importance of PAR as a co-creation approach. The combination of these approaches allows for the development of sustainable agroecological practices that promote not only sustainable practices but also ways of life based on co-existence, ultimately ensuring sustainability.

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