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Posted Date: 6 May 2024

doi: 10.20944/preprints202405.0259.v1

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Article

Uncovering the Challenges and Cornerstones for the Governance of an Innovation Ecosystem in Organic and Agroecological Agriculture

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Abstract: The concept of innovation ecosystems brings to light a whole set of stakeholders that face the entire set of barriers to making new technologies change people's lives. This research aimed to understand and analyze the innovation ecosystem in organic and agroecological production in the Federal District, Brazil, and its directly influenced area. A questionnaire was applied to 27 institutions identified as the backbone of the innovation ecosystem. The Gephi 0.10.1 software and the Force Atlas 2 network algorithm set up the relationship network. We verified a certain misalignment between expected roles and functions performed by 66% of the stakeholders. Low integration and dispersed relationships in the network were observed with a misalignment around the innovation concept in organic food production. This arrangement of the ecosystem is compatible with the initial stage, in which stakeholders and resources would be spread out and demobilized. Although shared governance is the most effective for an innovation ecosystem, the analyzed ecosystem demands centralized governance with a leading organization. Strengthening strategies were proposed to (i) define leadership, (ii) define roles or competencies, and (iii) strengthen community attributes.

Keywords: stakeholders; social network analysis; trust relationships.

1. Introduction

Humanity is heading towards the milestone of 10 billion people by the year 2050 [1]. As a result, demands for water, energy, and food, among other resources essential to life, tend to grow substantially [2]. The global climate crisis further intensifies food, water, and energy security risks, making the population and natural resources even more vulnerable.

At the link of all these issues, agriculture is the activity that most affects global systems and their resilience [3]. However, projections about this resource demand compromise the perpetuity of intensive agriculture, operated mainly by the agribusiness sector for producing commodities, under a strong dependence on cheap energy, abundant water, chemical technology, and other inputs [4].

As an alternative to intensive farming, organic and agroecological agriculture can produce food in an efficient, sustainable, socially fair, and less resource-intensive [5,6]. Valuing self-sufficiency, diversification, responsible governance, and resilience, among other values, agroecology presents a strong alignment with global agendas, such as the Paris Agreement, the United Nations (UN) 2030 Agenda, the Convention on Biological Diversity (CBD); the United Nations Decade of Ecosystem Restoration (2021-2030); and the Agenda for Humanity, resulting from the World Humanitarian Summit in 2016, among others [7]. Allied with these contexts, the production and consumption of organic products have grown significantly worldwide, reaching an increase of 365% between 2000 and 2017 (IPEA, 2020).

However, organic production and the agroecological transition are ambitious challenges that depend on systemic changes, including politics, culture, market, and innovation systems. Practices, technologies, and equipment play a fundamental role in this transition. Still, beyond that, sharing

data and knowledge through exchanging experiences and new solidarities is the biggest promoter of change [8].

In addition to technological development, co-design, and co-creation methodologies, low-cost technologies, direct promotion of innovation in family farming, and other strategies aimed at this transition, the ability to organize in networks that exchange resources and knowledge guarantee new levels of cognition that, according to [9], “join and complement each other, promoting greater levels of knowledge with each step taken in the network”. On top of these, networks play a substantial role in creating new business. They also can create new consumption frameworks, production paths beyond the commercial value chains, and new knowledge-based relations in search of innovations [10]

This is the foundation of innovation ecosystems, a proposal considering different ways of increasing efforts to create intersectoral and multi-actor innovation niches to support systemic transitions at various scales, notably in community-based environments [11,12]. The ecosystem encompasses a set of interdependent actors organized in different networks or subsystems, which have different interests but converge as holders of resources, knowledge, techniques, and technologies intended to promote innovation [13].

The concept of an “innovation ecosystem” gained prominence with the work of American professor and researcher Ron Adner in 2006, who realized that this characterization of the ecosystem is essential for dealing with uncertain scenarios. This type of system captures the complex synergies between various collective efforts in bringing innovation to market [14].

Evidence in the literature shows that the innovation ecosystem, co-creation, and co-production of value can improve the ability to innovate, achieve solutions, increase resilience, and recover from crises [11–13]. Fostering innovation ecosystems is a promising strategy to enhance agroecological transition and socioeconomic development, aligned with several global commitments. Agroecological and organic practices can create circular ecosystems involving producers, consumers, financial and technical supporters, and the government in a complex actor network [14]. In this kind of experience, we must uncover the challenges and cornerstones related to its governance to leverage its socio-economic results. To do this, we built a diagnosis framework combining quantitative network analysis with qualitative gathering on innovation backgrounds and perceived roles the actors view themselves. This is the first step in a project to dynamize the innovation ecosystem for organic production and consumption in the Federal District area, Brazil.

The organic and agroecological transition production system in the Brazilian Federal District (FD) presents great potential for developing new ventures and businesses [15]. With diversified stakeholders, a growing interest in innovation, and one of the highest Brazilian GDPs, the FD is a territory with great potential for strengthening that articulation for innovation. To this end, the first step focuses on uncovering its governance – its stakeholders, resources, and form of relationship [11]; to identify its stage of development, trying to understand the specific strategies for their evolving and coordination [17].

This research, therefore, proposes to diagnose and analyze the innovation ecosystem of organic and agroecological agriculture in the Brazilian FD based on the actors and their relationships. It will wonder about its evolving stage so that appropriate governance strategies can be outlined to strengthen it. After this introduction, a theoretical framework is presented, followed by our research methodology. Then, we present our results, discussions, and conclusions.

2. Theory

In the context of local agricultural systems, innovation processes are essential to the agroecological transition and organic production, whether in the business model or family farming. Some studies show how innovation has emerged in these contexts [11,12]. Despite these experiences, the success of innovation ecosystems is very context-sensitive, so experiences cannot be generalized.

One of the main challenges of ecosystems is related to the actors' roles. [11] highlights that innovation may be compromised when key roles are not filled or performed and when actors are disconnected, whether due to distrust, lack of information or sharing of resources, or difficulty

coordinating actions. Another fundamental aspect is the existence of backbone organizations, which focus on coordinating the ecosystem.

Still related to the roles and functions of the actors, the triple and quadruple helix theories are frameworks already known in entrepreneurship. They guide the necessary composition of actors who must work together to favor the innovation environment, which comprises civil society, companies, institutions, research, and government [31]. These frameworks include several initiatives to classify the organizations and actors that should make up the ecosystem [31]. [35] suggest the Quintuple Helix Model, which adds the helix from the natural environments of society [19]. In this direction,[34] suggests the Sextuple Helix Model with the perspective of the entrepreneurial actors propelling innovation ecosystems.

[24] identified six key roles in an innovation ecosystem: a) community, formal and informal civil organizations that share knowledge, collaborate and support each other based on common interests and bring dynamism to the ecosystem; b) articulators, provide coherence and stability to the ecosystem, creating an appropriate environment for innovation, ensuring the creation of spaces, policies and/or platforms for actors to actively dialogue and collaborate; c) promoters, disseminate and promote innovation (practices, techniques and technologies) supporting the stability of ecosystems and fostering a culture of innovation; d) knowledge generators, any organization focused on creating scientific-technological or scientific-social knowledge, which generates new projects and/or technologies; e) enablers, all those who provide tools, training, consultancy, financial resources, infrastructure or shared spaces, provide resources to the ecosystem; and f) linkers, connect and articulate actors within the ecosystem, creating new relationships [24].

These roles are dynamic, overlapping, and changing according to the ecosystem's evolution. [11] defined eight complementary roles (functions) for local innovation ecosystems in developing countries: innovate, connect, celebrate, train, share knowledge, facilitate, advocate, and sponsor. According to the author, in addition to the key roles, another important component in establishing a more mobilized network is the actors' trust in each other. A strategy must be devised to build, guarantee, and reinforce trust. Effective participatory construction is one way to achieve this trust. [17] highlighted that the functioning of the ecosystem can be compromised when actors are disconnected, whether due to distrust, lack of information, sharing of resources, or difficulty coordinating actions. Moreover, the literature added attributes of generally analyzed communities in frameworks such as the Institutional Analysis and Development (IAD) model [26].

Different approaches based on network governance seek to understand how ecosystems can be managed according to their degree of maturity, relationships' complexity, and management's centrality [16] (Error! Reference source not found.).

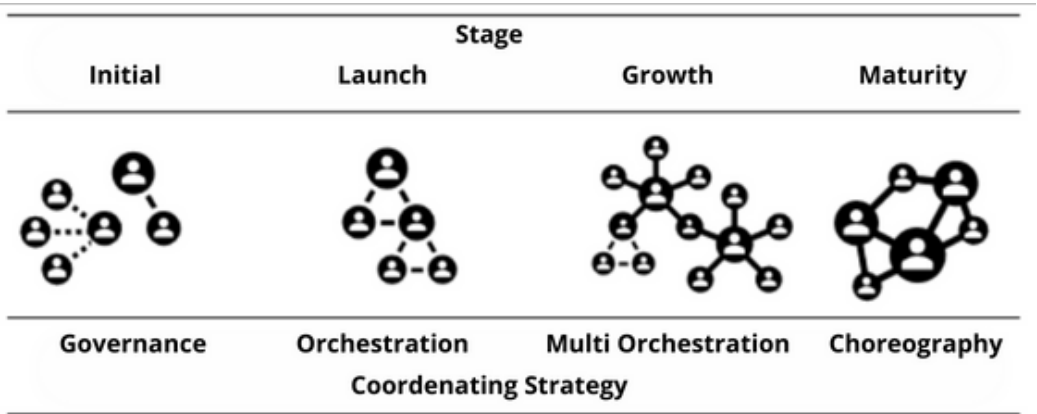


Figure 1. Coordination strategies for innovation ecosystems according to life cycle stage. Source: adapted from [16].

Ecosystems require coordination strategies to strengthen them. These strategies must build trust and collaboration through formal rules (contracts, regulations) or informal rules (reciprocity and

trust). Trust is initially scarce in this environment, and resources are underutilized [16]. The transition to a mature system results in decentralized coordination that shares leadership in a self-organized choreography [16] (**Error! Reference source not found.**).

Sultana and collaborators (2023) indicated, for their case study in Montreal, Canada, that the main mechanism underlying the emergence of innovation ecosystems is the coordination between actors. According to [22], in addition to trust, other predictor variables can influence the effectiveness of ecosystem governance: the number of participants, the level of consensus, and the demand for skills in the network. In high trust systems, with few participants, high consensus, and low need for new skills, the authors recommend shared governance [22], in which networks (ecosystems) can be governed by the actors that make up the network, where each would interact with everyone else to govern the network. This results in a dense and decentralized network.

On the other hand, in systems with little established trust, more participants, low consensus, and high demand for new skills, governance must be directed by a central organization with a formal, well-defined leadership role as a dedicated entity for this purpose. This form of governance may be desirable in the genesis of ecosystems when relationships and consensus are still under construction [22].

For their part, [38] proposes the development of appropriate water governance frameworks that promote the development of integrated water management plans while allowing flexibility to consider local differentiations in socio-economic factors. This is urgently necessary to achieve efficient water management and improve adaptations to local climatic conditions.

The authors [39] researched the power of ecosystems to adapt to climate change. Using the French Alps as a case study, the actor outlined a participatory framework for adaptation and governance to provide social innovation and adaptation solutions based on mountain ecosystems. He concluded that there is a need to increase the capacity of stakeholders to mobilize adaptation services and that capacity building and the implementation of adaptations related to global change are fundamental.

An example of previous experiences regarding ecosystem stakeholders in various regions of the planet is taken in [41]. A group of researchers from Indonesia and Malaysia [41] assert that business entities, through corporate social responsibility (CSR) or other activities, can balance negative impacts and strengthen sustainable development that can increase the resilience and welfare of the surrounding community. They developed a local farming community resilience (FCR) model, which supports the sustainability of agricultural development and measures farming community resilience across five dimensions (e.g., economic, social capital, environmental, community competence, and information and communication) to measure the FCR. Thus, full-scale development and policy provision for governments was achieved. Additionally, the FCR scale can be utilized by different entities (e.g., NGOs, open experts, and social group media) to determine the view of genuine customers regarding the association's CSR execution.

As an example of a less economically developed region, there is Liberia, which, according to [42], at a global level, many policymakers and extension professionals have advocated for the privatization of extension services to reduce the burden of funding faced by the state as well as to adequately respond to the low productivity problem of farmers as they endeavor to tackle productivity problems. These authors assessed farmers' willingness to pay (WTP) for private extension services. The findings revealed that 78.7% of rice farmers were willing to pay for privatized extension services. The results from the model showed that WTP was significantly positively influenced by the household head's age, years of schooling, household size, annual income, and distance to the extension service provider. The study recommends that the Liberian government and its development partners encourage the private sector to invest more in extension services to take advantage of the relatively high farmers' WTP and effective demand. In addition, the government should design and implement programs that reduce transaction costs and increase farmers' income to enhance their capacity to pay for privatized extension services.

In a developed country case, a study in Canada by [43] provided a model that supports systematic stakeholder inclusion in agricultural technology. The study developed a framework for

determining which stakeholder groups to engage in Responsible Research and Innovation (RRI) processes. This was done by identifying relevant stakeholders in the Canadian digital agricultural ecosystem, and they propose a systematic framework that categorizes stakeholders into individuals, industrial, and societal groups with both direct engagement and supportive roles in digital agriculture. These groups are then plotted against three levels of impact or power in the agri-food system: micro, meso, and macro.

In another example of developed countries in the European region, researchers from Germany, Spain, and Italy [44] analyzed the potential that CAP 2014-2020 (Common Agricultural Policy 2014–2020)-related instruments have on supporting agroecological transitions in Europe, focusing on the strengths and weaknesses of key instruments. Through a stepwise participatory research methodology, 105 key stakeholders (farmers, advisors, academics, environment experts, administration representatives, and professionals from food chains) in 15 European countries were engaged in the discussion of the potential of current CAP instruments to solve the barriers that constrain agroecological farming systems in their regions. The results of this comparative study show that CAP instruments are valued and have a high potential to support transitions to agroecology.

3. Methods

The first step in meeting our objectives was obtaining data from previous research on the context of organic food production in the Federal District. It would allow us to identify the main actors and their connections, which was necessary to tailor our approach to them. A more focused look aimed to identify the actors that made up the ecosystem's backbone [11].

A questionnaire was developed to collect data based on research developed on innovation ecosystems [24]. The questionnaire was applied between June 14 and September 25, 2022, and it focused on mapping the network of stakeholders participating in the innovation ecosystem in family farming in the Federal District, Brazil. In this survey, it was also possible to analyze perceptions about innovation and the degree of relationship between these stakeholders and obtain an indication of other stakeholders beyond the backbone that would compound the innovation ecosystem.

As central stakeholders (backbone) that bring together the entire set of interests regarding organic and agroecological production in the Federal District, we selected the components of the Sectoral Chamber of Agroecology and Organic Production of the Federal District – CAO/DF. The CAO aims to debate and monitor actions and present agroecology and organic production development propositions in the Federal District. It was established by Regulatory Decree No. 38,618 of November 16, 2017, and updated by Ordinance No. 32 of June 2, 2021, consisting of the following members: 1) State Secretariat for Agriculture, Supply and Rural Development - SEAGRI; 2) State Secretariat for the Environment - SEMA; 3) State Secretariat for Social Development - SEDES; 4) Technical Assistance and Rural Extension Company - EMATER; 5) Supply Center of the Federal District - CEASA; 6) Brazilian Agricultural Research Company - EMBRAPA; 7) Brazilian Support Service for Micro and Small Businesses in the Federal District - SEBRAE/DF; 8) Union of Producers of the Organic Market of the Federal District - SINDORGÂNICO; 9) Federation of Workers in Family Agriculture of the Federal District and Surroundings - FETRAF; 10) Federal Institute of Education, Science and Technology of Brasília - IFB; 11) Ecological Agriculture Association - AGE; 12) The Cooperative for Work and Development of Peasant Agriculture – CODESTAC; 13) Local Food and Nutritional Security Council, Consea; and 14) Federal University of Brasília (UnB).

In addition to these CAO stakeholders, other actors participated in the discussion and construction initiatives of the project “Strengthening the Entrepreneurial Capacity and Innovation of the Ecosystem of Organic and Agroecological-Based Products and Services of the Federal District (FD) and Surroundings”, which boosts the ecosystem, the following institutions [18]: 1. Bonança Small Farm. 2. Landless Rural Workers Movement – MST, 3. COGU - Brasiliense Mushrooms, 4. World Wide Fund for Nature – WWF, 5. Cerrado Research and Conservation – Pequi, 6. Invento Institute, 7. Malunga Farm, 8. Organic Brazilian Institute, 9. Federal University of Brasília (other departments) – UnB, 10. International Center for Water and Transdisciplinarity – CIRAT, 11. Brazilian Cáritas, 12. Association of Agroecological Producers of Alto São Bartolomeu – APROSPERA, 13.

Agroecological Association of Rural Women of the Canaã Settlement, and 14. Association of Rural Workers of Family Farming at Chapadinha Settlement (ASTRAF).

Therefore, the research of the 27 backbone institutions focuses on understanding FD's Innovation Ecosystem for Organic and Agroecological Agriculture from the perspective of their perceived interactions.

Furthermore, the respondents were asked to identify their represented organization and their institutional segment, which could be the private sector, public sector, civil society, research institution, or the term "other" if none of the above options were applied. The subsequent question delved into the understanding of innovation in family farming, which was analyzed through the interpretation of the contents and their meanings, as well as a word cloud generated using the "word cloud generator" web application (<https://www.freewordcloudgenerator.com/generatewordcloud>). This analysis excluded expressions and connecting words, prepositions, and articles, among others, to focus on the core concepts.

Next, the responding stakeholders or organizations were asked how they perceived their contribution or potential contribution within the scope of innovation in family farming. This question aimed to analyze the roles played by stakeholders in the ecosystem. The response options were: does not contribute; dissemination of good practices in the area of innovation; subsidize or contribute to public policies in the area of innovation and family farming; improving access to markets, from the perspective of innovation; interinstitutional articulation with a focus on innovation; promotion of rural development and innovation projects; execution of projects committed to rural development and innovation; rural technical consultancy, in the area of innovation; technical advice for processing, with aspects of innovation; research linked to innovation; extension actions linked to innovation; development and application of technologies; creation or adaptation of equipment and machines; software development; creation, appropriation or commercialization of bio-inputs; and others. It is worth noting that this question allowed several functions/contributions to be highlighted, with no limit on answers.

The last question, focused on data for generating the network of relationships, dealt with the level of relationship the home institution maintained with the others in the backbone. It presented three objective options: the first given by no contact or relationship, the second by some contact or partner in construction, and the last by joining projects executed or in progress.

In addition, open questions were also asked so that the respondent could mention other institutions that were not on the list. Thus, other institutions or actors and their respective levels of relationship could be mentioned.

The relationship levels were transformed into quantitative values, which in the first alternative, given by "no relationship or contact", would be assigned the value 0. The second value would be assigned by "some contact, partnership under construction", value 1, and the Last, "projects executed or in progress", value 2.

The Gephi 0.10.1 software was used to set up the network, in which the actors were placed as nodes, and their relationships as edges, and the relationships were obtained by adding the responses from both institutions. For example, if A reported that he has a level 1 relationship with B, and B responded that he has a level 2 relationship with A, the relationship between these two institutions was equal to 3. That's the algorithm used in the Force Atlas 2 network to distribute nodes.

Then, the nodes (actors) were colored according to the following legend (**Error! Reference source not found.**), adapted from the quintuple helix of innovation [19]. According to [40], the resulting network measured density, centrality, and dispersion parameters.



Figure 2. Colors for fourth Helix actors.

Information about the ecosystem, its actors, and expectations was complemented by a workshop on the project “Strengthening the Entrepreneurial Capacity and Innovation of the Ecosystem of Organic and Agroecological-Based Products and Services of the Federal District (DF), and RIDE”, held on November 10, 2022, at the Center for Sustainable Development, University of Brasília.

Members of the networks that initially formed the structure of the ecosystem project were invited to the workshop. The invitations were published on the project's social networks and sometimes reinforced individually. The workshop collected information about the ecosystem's actors' composition, roles, expectations, and current and future projects.

To analyze the roles played by actors and institutions, information was extracted from the workshop's questionnaire (Appendix 1) and triangulated with literature data [20]. Such a methodology was used to analyze the governance structure, as suggested by [21], which refers to mapping the ecosystem structure and designing appropriate governance instruments to impact the ecosystem functions and tensions.

The proposal by [16] was used to analyze the ecosystem's life cycle stages. We made adaptations based on [22] regarding the forms of governance analyzed. In the end, brainstorming and discussion with a set of backbone actors allow us to propose strategies for strengthening the ecosystem's governance.

4. Results

4.1. Study Area

Organic production in Brazil follows the global growth trend. The National Register of Organic Producers (CNPO) registered 22 thousand organic production units in 2018 [20]. Likewise, Brasília stands out, along with other Brazilian municipalities, due to its high concentration of organic production units.

Organic production initiatives in the Federal District started with the creation of the Ecological Agriculture Association (AGE) in 1988. In 2005, with the support of the DF government, organic production was leveraged to 161 production units, which became 220 in 2013 [20]. Currently, the Federal District has 255 active organic certification records. Despite these active certifications, the universe of organic production exceeds 1,700 farmers in almost 1,200 rural properties (data from 2017 – [37]).

Agrarian reform settlements and small rural producers form the main actors in the Federal District's universe of organic and agroforestry producers. The FD Government assists them through the Public Technical Assistance Company, EMATER. There are public policies for the use of family farming products in school meals at primary, elementary, and secondary schools in the FD, and there are also policies for the flow of production through the supply company, with a large regular fair held every Saturday. Some of these producers are organized in participative organic certification boards, and recently, small fairs have been organized by ecosystem actors, such as the landless movement, with the support of universities and non-governmental organizations.

Another highlight in the DF's organic innovation ecosystem is Fazenda Malunga, a pioneering initiative from the 1980s that covers 220 hectares of organic vegetable production today. Installed in the region of the FD Managed Settlement Program (PAD-DF), it is the largest organic production unit in the region. It also has its markets spread across the district and delivers to large local retail chains.

4.2. Actors and Roles for the Innovation Ecosystem

The questionnaire to the 27 institutions or stakeholders in the ecosystem's actors obtained twenty-three responses. After learning the whole context of organic and agroforestry production in the territory, we understood these organizations as the ecosystem's backbone, as already mentioned. In this structure, civil society stakeholders, associations, or other civil organizations predominate (43,5%), followed by “public sector/government” (21,7%) and “research institutions” (8,7%). This is a positive scenario in the sense of integrating non-governmental actors, accommodating more diverse

perspectives in ecosystem governance, and favoring hybrid governance networks, as suggested by [23].

However, the lack of participation from private sector actors, companies, or industries is a notable gap in the ecosystem. According to the helixes of innovation, their involvement is crucial. This insight was also echoed in the innovation ecosystem project workshop, where the perception of producer associations as part of this sector was raised. Curiously, the family agriculture organizations do not understand themselves as companies for the third helix but as civil society organizations on the fourth. It opens roads for discussing and preparing these organizations to enter the market as a commercial force.

Most of the stakeholders (81.8%) indicated that they contribute to the “execution of projects committed to rural development and innovation”, followed by “dissemination of good practices in the area of innovation” (promoter role) and “subsidizing or contribute to public policies in the area of innovation and family farming” (articulators), both with 68.2%. Also highlighted was the “interinstitutional coordination with a focus on innovation” (59.1%), which is the role of articulators and linkers. None of the interviewees answered the option that they “do not contribute” to the ecosystem.

The roles of the ecosystem’s backbone were analyzed in the matrix in **Error! Reference source not found.** according to their expected (○) and performed (●) contributions, or both (▲) in the innovation ecosystem of organic and agroecological agriculture in the DF.

Table 1. Roles of the central component institutions (backbone) of the Federal District's organic and agroecological agriculture innovation ecosystem.

Central Actors of the innovation ecosystem	Roles [29]						Expected Roles [16]	Role in quadruple helix
	Community	Articulators	Promoters	knowledge generators	Enablers	Attachers		
SEAGRI/DF		▲	▲	●	●	▲	Connect, Facilitate, Advocate, Finance	Government
SEMA/DF		▲		●	●		Advocate	Government
SEDES/DF		○	●	●			Advocate, Finance	Government
EMATER/DF		▲	▲	●	▲	▲	Connect, Train, Share Knowledge, Advocate	Government
CEASA/DF		○					Connect, Advocate	Business Sector
EMBRAPA		○	○	▲	▲	○	Celebrate, Train, Share Knowledge, Advocate, Finance	Government
SEBRAE/DF					○		Train	Business Sector
SINDORGÂNICO	○	▲			○	●	Connect, Facilitate	Civil Society
FETRAF/DFE	○	○	○		○		Advocate	Civil Society
IFB		▲		▲	○	●	Innovate, Train, Share Knowledge	Knowledge Sector
AGE	○	○			○		Advocate	Civil Society
CODESTAC	○	▲			▲	●	Advocate	Civil Society
Consea/DF		○					Advocate	Government
Chácara Bonança		○	●	○			Share Knowledge	Business Sector
MST	▲	▲		●		▲	Connect, Train	Civil Society
COGU		○	●	▲	●		Share Knowledge	Business Sector
WWF		●	○	▲	●	○	Connect, Celebrate, Facilitate, Finance	Third Sector
Pequi		●	○	●	●	▲	Share Knowledge, Facilitate, Finance	Third Sector

Invento Institute	●	○	▲	●	▲	Innovate, Celebrate, Train, Share Knowledge	Third Sector
Malunga Farm	○	●	▲	●		Connect, Share Knowledge, Facilitate	Business Sector
IBO	○	▲	▲	●	○	Connect, Share Knowledge, Advocate	Civil Society
University of Brasília (UnB)		▲	▲	▲	▲	Innovate, Connect, Celebrate, Train, Share Knowledge, Facilitate	Knowledge Sector
CIRAT		▲	●	▲	●	Train, Share Knowledge, Facilitate, Advocate	Knowledge Sector
Cáritas	○	○	●	●	●	Connect, Advocate	Civil Society
APROSPERA	▲		●	▲	●	Innovate, Train, Share Knowledge	Business Sector
Canaã	○			○		Innovate, Share Knowledge	Business Sector
ASTRAF	▲		●	▲		Innovate, Share Knowledge	Business Sector
Expected ○	70%	50%	29%	10%	30%	15%	32
Performed ●	0%	15%	47%	40%	50%	38%	34
Both ▲	30%	35%	24%	50%	20%	46%	34
Total (n)	10	20	17	20	20	13	100

* Empty circles (○) represent an expected or potential performance, while filled circles (●) represent the performance performed. The triangles (▲) are roles that are expected and, at the same time, played. The colors correspond to the roles in the quadruple helix and the legend of Figure 8 (grid). Source: workshop, questionnaire, and [18].

Triangles (▲), which are roles expected and, at the same time, performed, appear in a greater proportion (50%) among knowledge generators (organizations focused on creating scientific-technological or scientific-social knowledge, which generates new projects and technologies), followed by linkers (which connect and articulate actors within the ecosystem, creating new relationships). Furthermore, the scarcity of triangles (▲) in other functions (between 20% and 30%) highlights a certain misalignment between these functions in the ecosystem actors. Some institutions have not shown connection, clearly performed actions in the innovation ecosystem, or do not recognize themselves in the expected functions. These actors appear in **Error! Reference source not found.** without acting or performing roles that were not expected (especially as promoters or enablers). This reflects a certain misalignment in the functions performed, which can compromise the functioning or evolution of the ecosystem.

The “community” role (formal and informal civil organizations that share knowledge, collaborate, and support each other based on common interests and bring dynamism to the ecosystem) accumulates 70% of stakeholders who do not recognize themselves in this role. Consequently, this function is not well performed in the ecosystem. Another observation, in this sense, from **Error! Reference source not found.** is that “articulators” (they create an appropriate environment for innovation, ensuring the existence of spaces, policies, and platforms for actors to dialogue and collaborate actively) are essential to provide coherence and stability to the ecosystem, is expected – and not performed – by half (50%) of stakeholders from all sectors. Interestingly, some authors performed as articulators, especially non-governmental organizations, when it was not expected, such as WWF.

There is similar behavior among promoters (those who disseminate and promote innovation by supporting the stability of ecosystems and fostering a culture of innovation), where 47% play this role even if it is not expected – as is the example of Malunga Farm, Aprospira, Astraf, Bonança Small Farm, and Cogu. This scenario is very similar among enablers (which provide tools, training, consultancy, financial resources, infrastructure, or shared spaces and provide resources to the

Several actors, such as Seagri, Emater, UnB, Aprospira, and Cirat, stand out in the leadership role – actors who accumulate different functions, especially as linkers, building relationships; articulators, creating and ensuring spaces for innovation; and knowledge generators, focusing on the creation and execution of projects. An actor who assumes the role of leader usually constructs and defines the roles of other actors in addition to coordinating interactions between them. This function is considered essential in the genesis of the ecosystem [25]. It is important, however, to reinforce that surveys related to roles represent the actors' perception, individually or collectively, and must be complemented with network analysis to understand how connected and articulated these actors effectively are.

Regardless of the perception concerning roles, we can see that all interviewees see themselves as part of the innovation ecosystem in organic and agroecological agriculture in the FD, as all respondents indicated some form of contribution to the ecosystem. Based on this finding, we analyzed the perception of innovation presented next.

A question regarding innovation perception was strategically placed in the questionnaire to highlight the topic to be explored, which allowed a better diagnosis of the perspectives surrounding this concept in the ecosystem. **Error! Reference source not found.** presents the word cloud generated from the interviews.



Figure 3. Word cloud for **innovation** (Source: authors).

In addition to the words or expressions directly related to the issue (innovation, agriculture, family, etc.), the words “new”, “technologies”, “practices,” and “techniques” stood out, representing a commonsense view of innovation as technical elements with novelty.

Despite this, some points can be highlighted from the responses obtained. For example, the idea that innovation is not limited to just equipment but includes new policies, techniques, practices, and forms of organization appears in several responses, as illustrated in the following (transcriptions of the questionnaire, each sentence corresponding to a different respondent):

Any technologies or public policies that contribute to the sustainable development of agricultural production on small rural properties.

I understand it as new forms of action aimed at family farming, from new production and processing technologies to public policies through new forms of organization and sustainability.

Integration of innovative practices into content that facilitates, improves, and optimizes the efficiency of family production systems.

A set of new techniques, practices, and tools that can be included in family farming to improve it.

Using methods and techniques to make production more sustainable is associated with ethically producing healthy and quality food and other products.

As stated, some perceptions are like scientifically defined innovation types [45,46], but some actors in the researched ecosystem stated that socio-sustainability ethics are understood as drivers for innovative practices. Indeed, there is a general view that production equipment and technologies are the main results of innovation:

Innovation in family farming can be considered the update or adaptation of social technologies or peasant family farming.

Technologies that provide productive and economic sustainability for the producer and production unit.

In short, they are processes, products, and technologies that, through some adjustment or transformation, become attractive to women and family farmers who start to adopt them.

In general, the ecosystem actors think that innovation can be an effective way for organic producers to enter mainstream markets:

It means making family farming part of the formal market alongside large companies.

The combination of technology, knowledge, and innovation capacity was essential for developing Brazilian agriculture.

Other responses focused on the results or objectives of innovation, which are to improve life, relationships with nature, self-sufficiency, and independence, in addition to producing something that is accessible, cheaper, and more efficient, that is in line with the very purpose of innovation according to [45], and even coherent with disruptive innovation theory [47]:

The search for solutions to concrete problems that improve life in the countryside and relationships between human beings and between human beings and nature.

Everything that is done differently from everyday life and that improves people's lives.

Innovation is often not something complex and futuristic but rather the search to do something simpler, cheap, and efficient. This includes seeking out the ancestral roots of how it was done in the past and, with innovative science, improving it. This is one of the ways to innovate. Creole seed is innovation.

Measures that generate development culminating in self-sufficiency and financial independence.

Science and techniques can be understood as an evolution from the traditional way of doing things (Habermas, 2014), which is an in-depth analysis of innovation, such as the current effort to recover the tradition of using creole seeds for organic and biodiversity production. Moreover, for the researched actors, sustainability, health, and well-being appear as prerequisites for innovation:

Implementation of new sustainable production practices in family farming.

Use of practices and techniques that promote improvements but are sustainable.

We are united and present healthy food. Collaborative agriculture has challenges and opportunities, and it consequently generates income that improves the quality of life and provides the best use of natural resources.

The responses showed a mainstream vision for innovation as innovative tools, devices, and equipment. They also showed a variety of perspectives and understandings about innovation, which accommodate the diversity of views necessary for good governance [23] but, simultaneously, can

make it complex to create common goals. Anyway, it is important to realize that the researched ecosystem has a good basis for alignment around a common objective related to innovation and reinforces the broader concept, which includes and values transdisciplinary knowledge, forms of management, social organization, and innovation as a practice, in addition to equipment and technologies.

4.4. Reasoning for Ecosystem Participation

To investigate the ecosystem's community attributes, the IAD model [26] raised motivations for participating in the ecosystem from the ecosystem workshop. The categories, inspired by [24], show the trends illustrated in **Error! Reference source not found.**.

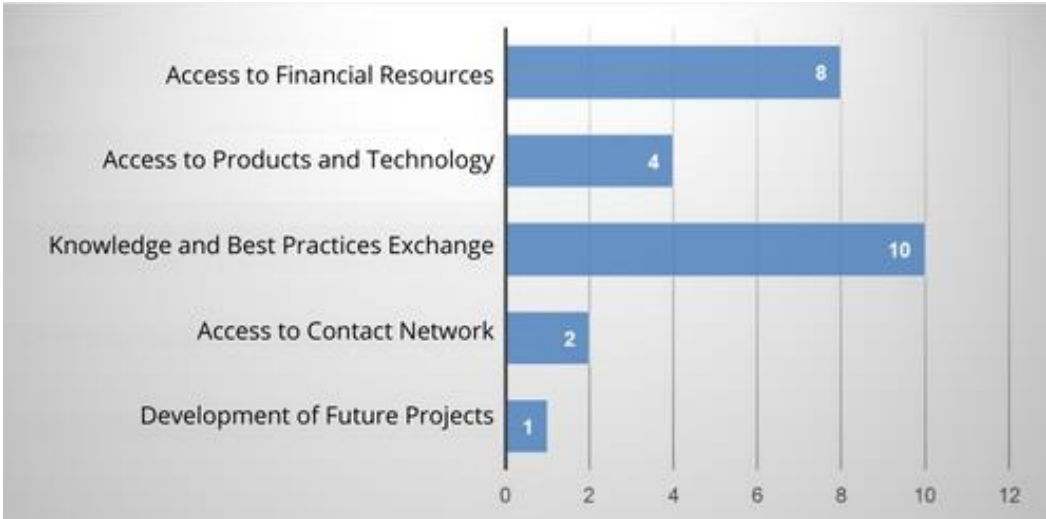


Figure 4. Motivations for participation in the organic and agroecological agriculture innovation ecosystem in the DF. Source: ecosystem workshop.

The main motivation that workshop participants selected was “exchange of knowledge and best practices” (n=10), followed by “access to financial resources” (n=8). This reflects the expectation of exchanging knowledge and experiences, which starts from observing the existence of different practices that are not very widespread and the challenges in organic and agroecological agriculture. Furthermore, expectations for access to financial resources also point to the actors’ demand, which can be better managed within a group like the researched ecosystem.

Similar results were obtained in the workshop [24] for an innovation ecosystem of entrepreneurs in São Paulo. The predominant motivation was developing projects together (38.4%), followed by exchanging knowledge and best practices (23.7%), obtaining resources (17%), and access to a network of contacts (15%). These results and those from the workshop related to this research reflected intrinsic motivations for collaboration when actors aligned their priorities to build an ecosystem's general demand.

4.4. Actor Network Analysis

From the 23 actors who responded to the questionnaire, 62 different nodes (actors) were obtained based on the indication of actors not mentioned in the questionnaire, which returned 344 edges relating to the degree of relationship between each one. It is important to highlight that the institutions mentioned by the respondents only showed some degree of relationship with them, not with other institutions mentioned in the form.

Error! Reference source not found. shows the network of relationships between organic producers and the other actors in their ecosystem.

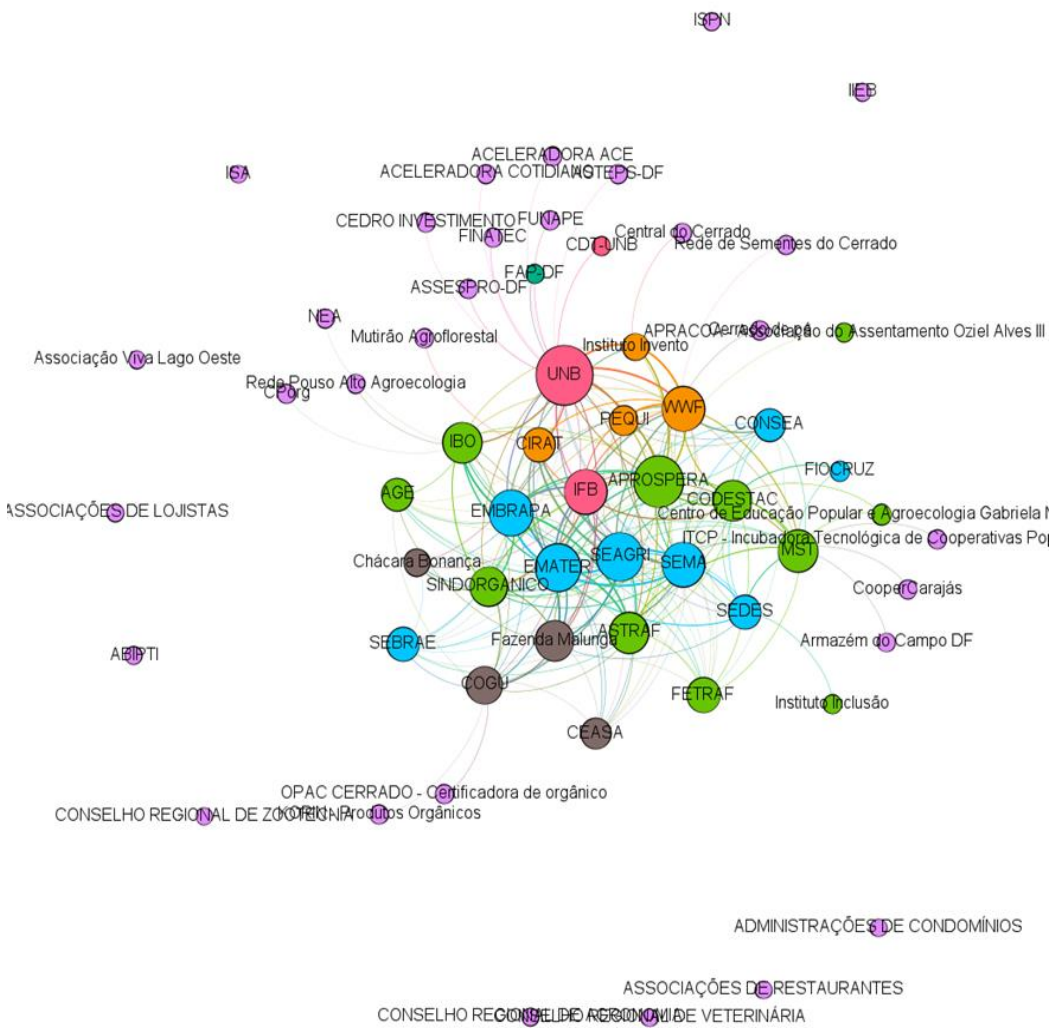


Figure 5. Organic and Agroecological Agriculture Innovation Ecosystem Network of the Federal District. Source: Prepared by the authors.

In the network generated, it is possible to observe that there was low integration, which returned a network of dispersed relationships based on the 62 institutions analyzed. The institutions mentioned by the respondents may have been the reason for the dispersion, considering that out of 23 responses, 39 institutions were individually mentioned. This could mean that these 39 institutions are dispersed across the network.

The clustering coefficient was 0.315, representing low integration, with a density of 0.114 (dispersed) and eigenvalue (eigenvector) of 3.677, representing low centrality [40]. The low centrality indicates that several institutions are equally connected regarding innovation in organic and agroecological agriculture, especially those that presented higher degrees of relationships, such as UnB, Embrapa, Emater, Seagri, Aprospira, and others at the center of the network. It represents a kind of a more compartmentalized collaborative network with subgroups not fully connected to the whole cluster [36].

The dispersion and low centrality of the network are interconnected [36]. When it was observed that the dispersion was generated by the 39 institutions mentioned by the individuals, the low centrality was generated by the 23 responding institutions, so one characteristic of the network ended up being a consequence of the other.

Regarding the degrees of relationship, the responses were not reciprocal between several institutions because while one responded that it had some contact or relationship with another, the

other, in turn, reported that it had no relationship, which resulted in grades 1 and 0, respectively. In this way, the edges with stronger and more vibrant colors in the generated network represent the strongest relationships, which happened when there was reciprocity between the responding parties.

5. Discussion

The researched ecosystem's layout is compatible with the initial stage in Santos et al. (2021), in which actors and resources would be spread out and demobilized [16]. This scenario can be corroborated by other initiatives and projects that are still struggling to mobilize the actors. The next stage, launch, foresees a common strategy, the beginning of the mobilization of actors and resources, accompanied by a developing specialization not yet verified in the case studied. In the initial stage, actors usually keep underused resources, and a strategy for mobilizing, aligning, and defining common objectives is necessary.

Following [22] criteria for effective governance, we found that in the case study, around 23 stakeholders participated more actively, corresponding to those responding to the questionnaires and attending the research workshop. We identified these actors as the backbone stated by [12]. No specific number in the literature indicates an ideal size for a backbone, but the literature states that small groups can maintain greater trust and better governance [11].

According to [22], consensus is desirable because it allows better performance among actors even when there are conflicts in the network. Regarding the level of consensus, we see a diversity of views concerning innovation, although they are convergent or complementary. Considering the ecosystem's lack of maturity, this consensus can still be built or strengthened, especially around a common purpose for the ecosystem.

Concerning the demands for skills, it is assumed that ecosystem actors seek results they would not achieve independently. However, depending on the demands or costs of their contributions to the network (participation costs), different forms of governance will impose different burdens on actors [22]. If these participation requirements are high, the ecosystem's governance tends to fail if the actors choose to have more shared or hybrid systems in a course. Our data suggest that more centralized forms will be necessary.

In the analyzed ecosystem, we did not find significant gaps in the skill demands. Although the roles of linkers and communities have not stood out, they do not constitute gaps. They are competencies that can be built or only recognized by some actors. In this sense, it is understood that the cost of participating in the ecosystem is low without the need to develop new skills or abilities.

The predictor variables of effective governance (trust, degree of consensus, demand for skills) lead, according to [22], to a paradox where the shared governance model is the choice, in principle, because of the whole set of roles performed by various actors (**Error! Reference source not found.**), and the low centrality data (**Error! Reference source not found.**). On the other side, the same lack of centrality and the initial stage, according to [16] (**Error! Reference source not found.**), can demand a centralized approach to reach the orchestration stage (also **Error! Reference source not found.**). Most mature levels of innovation ecosystems demand full connectivity and a greater level of specialized roles. In this way, the flatness of decentralized governance can overcome the necessary full articulation and goal-sharing.

Shared network governance will be most effective in achieving network-level results when trust is widely shared among network participants (high density, decentralized trust), when there are relatively few participants in the network, when a consensus of goals at the network level is high and when the need for network-level skills is low [22]. These conditions are not present in the researched case, and according to [16], an early ecosystem's most effective coordination mechanism will be a more centralized control mechanism as governance.

In general, the results lead us to the need for governance with a leading organization - unnecessary in shared governance but essential in forming the ecosystem. This governance makes the network more centralized and intermediated. With power asymmetries, a leading organization manages the network and facilitates the activities of actors in their efforts to achieve the network's objectives, which can happen in alignment with their own goals, a possible threat to a non-

entrepreneurial ecosystem [34]. What is desirable is that, after the consolidation of the ecosystem, governance gains contours of greater sharing to evolve for the choreography stage [16].

The analysis of the roles and functions of the actors highlighted the absence of clear leadership – something necessary in the genesis of the ecosystem to coordinate actions and initiatives and articulate and create links. The literature states that actors who assume ecosystem leadership during this initial phase will first engage in actions related to projecting the role of other actors and coordinating interactions between them [25]. The leading organization or actor must have sufficient resources and legitimacy to fulfill this role. Analyzing a similar ecosystem, [14] identified a non-governmental organization as the orchestrator for an organic food ecosystem in Southwest Brazil. This organization has technical expertise that orchestrates producers, consumers, and even agricultural financing agencies.

In our case study, organizations such as Seagri, Emater, UnB, Aprospira, and Cirat accumulate skills. Linkers and articulators stood out in these aspects especially. These are also the institutions with the most relationships in network analysis. However, this decision must be made collectively and participatory to guarantee this leadership's legitimacy and acceptance. Furthermore, formal instruments, such as contracts, projects, or agreements, are essential [16]. A case like ours reveals the complexity of ecosystem evolution once actors without prominence over the others need centralized governance to evolve, but only to mature the organization so that other less centralized forms of governance can emerge [28].

It was possible to verify that the actors are not completely clear about their roles in the ecosystem in its current format. There are also overlapping roles, concentration of roles, and gaps that are not filled regarding necessary functions [11,12]. Therefore, it is important to define roles or competencies with ecosystem actors. It is worth highlighting that informal functions must be negotiated and defined between leadership and the network of ecosystem actors in addition to the roles and functions mapped out in the ecosystem. In addition to leadership, a group of actors must deal with the direct creation of value [25]. These are suppliers, who offer materials, technologies, and services to be used or replicated by others in the ecosystem; transformers, who assemble, modify, or adapt the components produced (Aprospira, Astraf); and users, who define a problem or need, develop ideas, and use innovations. Actors in this direct value chain role are usually the main candidates for leading this kind of innovation ecosystem, but others have prominence over the entire network, such as in [14], which stresses the definition of leadership.

[25] also indicate the need for a support group for value creation, in which the following participate: knowledge generators, enablers, and linkers who encourage the transfer and commercialization of innovations, build connections, and provide access to markets. This would include research institutions such as universities, third-sector institutions such as WWF and Invento Institute, and private companies such as Fazenda Malunga, a player with entire value channels for organic commercialization.

According to [25], the group of entrepreneurs brings together the roles of entrepreneurs, sponsors, and regulators. These establish networks, coordinate collaboration, support or start new ventures, finance projects, expand the ecosystem, or promote regulatory or policy changes. The researched ecosystem has the local government as the main regulator but lacks entrepreneurs as funding organizations and actors specialized in creating new business models for organic and agroforestry products.

Community attributes refer to any relevant aspect of the social and cultural context that can influence a situation [29] — the innovation ecosystem. The following stand out. Trust needs to be guaranteed between members of the ecosystem so that it is perceived that their participation in the ecosystem will not generate vulnerabilities. In the initial stage of the ecosystem, for relationships in which there is still no trust, it is also recommended to use formal instruments to define individual roles and collective commitments [16], and it was not identified in our case study. In a complementary way, creating discussion forums and updating or formalizing proposals, workshops, fairs, or events strengthens relationships.

Reciprocity refers to a feeling of sharing common expectations, so there is greater certainty that acts of cooperation will be reciprocal [26]. It is present in the ecosystem since the motivations reflect the inherent needs of the ecosystem to the detriment of individual priorities. Once again, trust-building strategies reinforce reciprocity actions. Our case study demonstrated a set of non-reciprocal relations where one actor stated that there was a relationship, and its counterpart didn't state the same. This lack of reciprocity can explain the low centrality and higher dispersion presented in **Error! Reference source not found.** A question for a specific research protocol in the future.

6. Conclusions

When analyzing the organic and agroecological agriculture innovation ecosystem in the Brazilian Federal District based on the attributes of the community and the network of actors, we found a poorly integrated, dispersed network with low centrality. However, all the actors interviewed recognized themselves as ecosystem contributors, but various ecosystem roles were not perceived. This is also reinforced by the accumulation of roles for some actors, especially third-sector agents.

We found a certain misalignment between expected roles and functions performed by 66% of the actors. Despite this, there are no significant gaps in the execution of fundamental roles in the ecosystem. All of them are being implemented, although the roles of linkers and community require greater occurrence or perception by ecosystem actors.

Unlike traditional ecosystem analysis, our study is settled on an unclear leading-based network with various actors performing a set of ecosystem roles but lacking other fundamental elements for a value chain, such as producing, commercializing, and funding. Some actors based on producing and commercializing organic food do not identify as these roles, suggesting a misunderstanding of the whole value chain or its importance. This profile can explain the low centrality of the resulting network once economic issues tend to be the central point for value networks and, consequently, sectorized ecosystems.

In our case study, the actors' main motivations for participating in the ecosystem were the "exchange of knowledge and best practices" and "access to financial resources". This result suggests that ecosystem actors can find it easier to access funds working together than isolated. It also can be explained by the complexity of working on organic food and agroforestry, which are disruptive innovations with the challenges of building non-existent value networks [47] wherever they apply. Crossing these results with the misunderstanding and misalignment of ecosystem roles identified, it can be suggested that all actors find that group-based activities allowed by the ecosystem meetings make it easier to access funding agencies. To do so, more than value chain activities, such as supplying, producing, and commercializing, roles related to articulating, linking, enabling, knowledge-creating, or promoting are considered to be important for training and performing.

It can be suggested that reciprocity and trust are far more complex in this kind of ecosystem than in other circular economy ecosystems or traditional innovation ecosystems for well-known products with stronger company-based actors.

Regarding the views surrounding the concept of innovation, we realized various perspectives and backgrounds that accommodate the diversity of views necessary for good, shared understanding and governance. Despite the general issue that these perspectives complement each other and are good for the value networks, some actors stand that innovation has intrinsic relations to ethics and sustainability. This meaning can be followed once organic production results in healthy and sustaining products, but this relation is not commonly associated in the innovation literature.

This study also analyzed the life cycle stage in which the innovation ecosystem is located, noting that, due to the characteristics of the network, it is still in its initial stage, in which resources and actors would be little mobilized. This scenario indicates the need for more centralized governance with a leading organization. A lack of leading organizations can jeopardize the entire ecosystem's construction. As no economic agent depends on this ecosystem for short-term business, nor does a civil society organization work to coordinate the other nodes for a common view, this lack can

prevent the ecosystem from taking hold. This is the major identified challenge to overcome to boost the ecosystem.

Although the predictor variables of shared and effective governance (trust, degree of consensus, demand for skills) are present in the ecosystem, it is in their initial stage, suggesting that these predictors are weaker than the presence of a strong actor working and depending on ecosystem actors to realize their intended results. Governance has the role of providing the necessary environment for the genesis of the innovation ecosystem. This governance is expected to stimulate cooperation for a common purpose [17,27]. Therefore, based on the challenges and cornerstones identified, beyond the leadership issue mentioned, the case study suggests other elements as critical as that for the construction of an effective ecosystem in organic production: (i) multiple actors with the same roles in the ecosystem, and (ii) lack of trustiness and reciprocity among ecosystems' actors. These elements reinforce previous analysis, but the specificity of organic and agroforestry-based food brings additional complexities once the actual stage of organic food consumption, with short markets, can impel the actors directly linked to the value-chain to competition-based reasoning, making trustiness and reciprocity larger challenges.

The main theoretical contribution of our work at this stage was the framework used to uncover the actors, relationships, and backgrounds in innovation ecosystems. It combines the identification of perceived roles, their understanding regarding innovation, a largely discussed theme with technical, economic, social, and political standpoints, and a quantitative analysis of their relations, which allows visualizing the whole set of actors' connections with network measurements. The results presented here can validate this way of uncovering fundamental governance issues for the ecosystem's design and management.

As practical contributions, this research can help policymakers design organic production or family farm boards where a balanced set of actors can work together and complementarily perform the whole set of roles demanded for building new value chains compared to traditional agribusiness networks. It can also help the fifth helix actors to organize themselves with their counterparts to avoid shadowing actions and contribute more specifically with their strengths to building effective ecosystems that deliver value to society.

As a limitation, the study is focused on representative organizations, so a more accurate view can be gathered if organic producers are included as respondents. Specific research protocols can achieve this, with focus groups or semi-structured interviews with strategically chosen producers. Another limitation is that the analytical step could have been done using a participatory methodology where ecosystem actors could provide insights for data interpretation. An ecosystem like this is very complex with different social, background, and value chain positions, and looking from the outside is very difficult for any actor, even university researchers.

Future studies can characterize different ecosystems using the same frameworks used in this research and build their networks using the methodology here employed to compare ecosystem elements such as trustiness, reciprocity, attributes, and innovation standpoints to network parameters such as centrality, dispersion, and density, as a way to contribute to network analysis theory.

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