

Article

The Defining Characteristics of Agroecosystem Living Labs

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Abstract: In response to environmental, economic, and social challenges, the living labs approach to innovation is receiving increasing attention within the agricultural sector. In this paper, we propose a set of defining characteristics for an emerging type of living lab intended to increase the sustainability and resilience of agriculture and agri-food systems: the “agroecosystem living lab”. Drawing on first-hand knowledge of case studies of large initiatives from Canada and France and supported by eight other cases from the literature, we highlight the unique nature of agroecosystem living labs and their distinct challenges with respect to their aims, activities, participants, and context. In particular, these living labs are characterized by exceptionally high levels of scientific research; long innovation cycles with high uncertainty due to external factors; and the high number and diversity of stakeholders involved. Both procedurally and conceptually, we link to earlier efforts undertaken by researchers seeking to identify urban living labs and rural living labs as distinct, new types of living labs. By highlighting what makes agroecosystem living labs unique and their commonalities with other types of living labs, we hope to encourage their further study and help practitioners better understand their implementation and operational challenges and opportunities.

Keywords: living lab; agroecosystem; agriculture; innovation; characteristics; sustainability; typologies; placed-based



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1. Introduction

Sustainability and resilience are becoming increasingly important outcomes in agricultural innovation in balance with the objectives of increasing productivity and efficiency. Sustainability means meeting current needs without compromising the ability to meet those needs in the future, whereas resilience refers to the ability to recover from negative impacts or unfavorable stresses. In particular, the effects of climate change—such as rising temperatures, shifting precipitation patterns, and increases in the frequency and intensity of extreme weather events—are having significant impacts on our environment as well as our agriculture and agri-food systems (an agriculture and agri-food system encompasses the social, political, economic, environmental, and ecological processes of producing food and agricultural products (including fibres, fuels, and raw materials such as animal feed) from production to waste. The agri-food system includes the actors, relationships, resources, and activities that go into producing, processing, distributing, and consuming food and agricultural products, as well as their outcomes [1–3]) [4,5]. Thus, there is a pressing need for innovation models and processes that will enable an accelerated response to climate change

through the rapid and widespread adoption of new practices and technologies throughout the value chain to support a systemic change toward sustainability and resilience.

This pressing need must be understood within the context that agricultural systems are socio-ecological systems [6] in which control is distributed between a network of farmers, advisors, agri-food industry actors, local and national authorities, and scientists, determining innovation [7–9]. Innovation thus develops within local socio-technical networks [10–12]. However, like in many other sectors, the innovation flows of the agriculture and agri-food sector follow their own rhythm and specificities, and this is due to four main factors [13]. First, there is the connection with nature and the living system, which is at the heart of the sector and acts as common context and opportunity for change. The need for “real-life” experimentation is crucial. Second, innovation is rooted (in the soil) and in a space, territory, or place. Third, the final output (food or energy supplies) generally has high social value and is therefore of high political concern. Fourth, the unique and integrated constellation of institutions, actors, and knowledge in the agri-food sector must be considered, because changes affect the entire system, as well as the sectorial and national specificities.

Innovation in the agriculture and agri-food sector generally involves multi-actor approaches. But with the transition toward greater sustainability and resilience comes the need for redesign, with path-breaking innovations in practices as well as in organizations [14], which may extend their co-creation potential. In such a context, living labs appear to have the potential to accelerate co-creation and adoption throughout the value chain, because of their user-centric approach used to develop and co-create innovative solutions in partnership with stakeholders and tested in the users’ real-life context.

With the benefits of this approach in mind, the Canadian government proposed at the G20 Meeting of Chief Agricultural Scientists (G20 MACS) in 2018 to evaluate the potential of “agroecosystem living labs” (An *agroecosystem* is defined by the OECD [15] as an ecosystem which encompasses the organisms living in an environment (i.e., biota) that is managed agriculturally; an agroecosystem is itself part of a broader agriculture and agri-food system) to tackle agri-environmental issues. It prompted the development of an international working group of representatives of national agricultural research institutes from 10 countries and the European Commission. The working group documented the application of similar approaches among G20 member countries and highlighted the approach’s potential impact on the improvement and protection of agroecosystems. Despite the increased complexity and the possibility of increased risk using this approach, the working group found that agroecosystem living labs can “increase the relevance and impact of scientific activities; accelerate innovation and adoption; and empower participants to tackle more complex challenges facing agroecosystems” [16] (p. 4).

In its executive report, the working group defines agroecosystem living labs as:

Transdisciplinary approaches involving farmers, scientists, and other interested partners in the co-design, monitoring, and evaluation of new and existing agricultural practices and technologies on working landscapes to improve their effectiveness and early adoption.

[16] (p. 4)

This definition outlines three general components: (1) transdisciplinary approaches, (2) co-design and co-development with participants, and (3) monitoring, evaluation, and research on working landscapes. The working group emphasized that the transformative power of the agroecosystem living lab approach “can best be captured when an initiative implements the three components here simultaneously and comprehensively” [16] (p. 10). To varying degrees, the working group found that most of the 10 countries represented in the working group were implementing at least some components of this definition through non-living-lab activities, but it highlighted the national agroecosystem living lab initiatives being rolled out in Canada and France as comprehensive examples of all three components being integrated.

Although the debate about various living lab definitions and conceptualizations is still on-going, these three components are recognizable within the now well-established living

labs literature. Indeed, since the mid-2000s, a rich body of scholarly literature has been developed (e.g., [17–19]) and has been complemented by various handbooks to assist in the study and practical implementation of living labs (e.g., [20,21]). Any prospective living lab now has much general information to draw upon in setting up a living lab and customizing its implementation to suit its objectives. Similarly, researchers can also build upon a body of literature that seeks to understand and explore the living labs approach. For example, the literature offers insights on the way living labs function and foster innovation in terms of living labs as open innovation networks (e.g., [22,23]); the roles of users, stakeholders, and other actors (e.g., [24–26]); innovation methodologies and tools (e.g., [27–29]); business model innovation [30,31], and many other topics. However the evaluation of the actual impact of a living lab in terms of innovation process, effective adoption, and sustainable changes is still a notable gap [32,33].

There are also studies targeting specific application contexts. For example, researchers and practitioners alike have identified the “urban living lab” (ULL) as a particular type of living lab that is distinct from more general applications [18,34], as will be discussed in this paper as an analogous effort. The persistence of the ULL concept in the literature suggests it does have some scholarly and practical value in identifying and understanding it as a distinct type, and making the link between the innovations expected from a living and the way it is run.

If we look at agriculture as an application context, the living lab approach is not new. European projects aiming to use living labs as instruments for rural development were launched in the early 2000s [35]. However, they focused on economic and social development in communities rather than in agriculture or food production. More recently, the term living lab has been used to identify innovation initiatives in the agriculture and agri-food sector, such as the “Agro Living Lab” for agri-machinery in Finland, the “Homokháti Living Lab” for agriculture and tourism in Hungary, and the “PA4ALL” for precision agriculture in Serbia, among others. However, using the living lab approach at an agroecosystem scale is new and presents unique challenges that make it both challenging to implement and interesting to study.

Living labs means different things to different stakeholders [36], but it may be inferred that in agroecosystems, living labs encourage the involvement of multiple stakeholders (farmers, food industry companies, retailers, researchers, students, non-governmental organizations, Indigenous communities, governmental institutions, financial institutions, small and medium-sized enterprises, consumers, advisory services and other members of the national Agriculture Knowledge and Information System) [37], and with end users playing a central role. Together, they co-create, explore, and evaluate innovations within the users’ real-life context, meaning this is an extension of the “usual” agriculture system innovation processes and promotes “on-field” experimentation.

For agroecosystem living labs, the three general components outlined in the international working group’s definition form a high-level framework that helps differentiate the living labs approach from other innovation processes in agriculture. But the definition’s value in guiding the implementation of the agroecosystem living lab concept may be limited because it is not yet anchored in the literature and is not sufficiently differentiated from the general principles common to all living labs. Because the concept has been implemented only recently, there is a lack of documented experiences or studies for those seeking practical implementation insights. Identifying and describing what makes agroecosystem living labs unique, including their distinctive challenges and opportunities, would not only provide a much-needed next step for future researchers, it would have immediate practical value for living lab managers and those seeking to start a living lab for improving the sustainability and resilience of an agriculture and agri-food system.

Thus, our goal in this paper is to identify the defining characteristics of agroecosystem living labs. This is the gap we seek to address in the literature. To guide us, we take lessons from the earlier efforts of researchers who sought to identify the defining characteristics of another new and unique type: the ULL. Using a conceptual framework from the ULL

literature, we identify the defining characteristics of agroecosystem living labs based on in-depth analyses of two cases from Canada and France (in which we are active participants) supplemented by additional cases from the literature. This work provides both theoretical and practical contributions to advance our understanding of this new type of living lab and to support a growing international community in its real-world implementations.

2. Conceptual Framework

In this section, we briefly describe past efforts to define and categorize living labs, which have yielded various typologies and lists of characteristics of particular types of living labs. Drawing on the literature on ULLs, we then develop a conceptual framework to guide and structure our identification of the defining characteristics of agroecosystem living labs.

2.1. Defining Living Labs

The “living lab” concept has proven attractive to practitioners and researchers alike. Over the past two decades, the living labs approach has been applied in a variety of contexts and sectors, originally focused on technological innovation but later expanded to include broader social challenges in areas such as eHealth, smart cities, public sector innovation, university campuses, and rural development [17]. The term is in some cases considered an *approach* or *methodology* for collaborative innovation, an *arena* or *environment* in which the innovation activities take place, or a broader *ecosystem* or open innovation *network*, among other interpretations (e.g., [22,38–44]).

Various definitions have been proposed to give clarity to the concept, although the resulting definitions each emphasize certain aspects over others (see Steen and van Bueren for examples), and no single definition has become particularly dominant or gained widespread acceptance. However, the present paper uses the commonly cited definition from the European Network of Living Labs (ENoLL), which identifies living labs “as user-centered, open innovation ecosystems based on systematic user co-creation approach, integrating research and innovation processes in real life communities and settings” [45]. ENoLL also lists five elements that must be present in a living lab: (1) active user involvement, (2) real-life setting, (3) multi-stakeholder participation, (4) multi-method approach, and (5) co-creation. Indeed, others have also offered sets of elements or characteristics to help clarify exactly what a living lab is (and is not) (e.g., [17,46–48]) or to differentiate between particular “types” of living labs.

Thus, rather than trying to resolve the challenge of finding a unifying definition, researchers have sought to identify key principles or characteristics that are common to all living labs and therefore represent a general model of a living lab that may be elaborated upon or interpreted to suit the context of implementation, if required. The operationalization of the principles “in the field” can further inform our interpretations of these characteristics or principles and have led to the recognition of various “types” of living labs.

2.2. Living Lab Typologies

Partly driven by the need to build consensus, delineate concepts, and distinguish between different applications that carry a common label [49], researchers have developed various typologies of living labs. Typologies are artificial constructs that can help researchers and practitioners classify living labs. Generally, a typology proponent selects a particular dimension to categorize living labs. The choice of dimension depends on the proponent’s perspective and goals: it may reflect some practical reality or salient feature, it may seek to reveal an underlying phenomenon for academic study, or it may be used to identify a unique manifestation or differentiate it from a general model, which can be particularly useful if the goal is to understand a newly emerging form of living lab. Thus, typologies can have practical benefits in teasing out what might be unique about particular application contexts and why certain approaches may or may not work within them.

Examples of dimensions used to develop living lab typologies include:

1. Sector: The most common way to categorize different types of living labs is by sector, thematic domain, or area of application. For example, ENoLL uses sectors to categorize its membership: Health & Wellbeing, Smart Cities & Regions, Culture & Creativity, Energy, Mobility, Social Inclusion, Social Innovation, Government, Education, and Other. (Within this typology, certain living labs could be described as “agriculture living labs,” although we will show why this label fails to capture key challenges associated with a particular category of living lab in this sector: agroecosystem living labs.)
2. Purpose or function: Efforts to distinguish living labs by their purpose or function have been part of an overall effort to clarify the living lab concept and separate out distinct clusters of “living labs” that all use this common label to represent somewhat different applications (e.g., European vs. American approaches or ICT innovations vs. engineering testbeds [23,46,49,50]).
3. Driving actor: Actors can play varying roles within a living lab, and various coordination, management, and governance structures are possible within living labs. Leminen, Westerlund, and Nyström [22] propose a typology that differentiates living labs based on who drives the activities, resulting in four types of living labs: utilizer-driven, enabler-driven, provider-driven, and user-driven.
4. Processes and approaches: Researchers have also based typologies on their coordination approach and participation approach [51]. This approach has been combined with a platform of dimension to categorize living labs as different types of collaborative innovation networks [52]. Leminen and Westerlund [27] have further proposed a related typology based on the innovation processes and tools used in living labs.

Typologies are not mutually exclusive—a given living lab could be recognized in multiple typologies at the same time. For example, a living lab could be a “mobility living lab” according to ENoLL’s sectoral typology while at the same time being a “utilizer-driven living lab” according to Leminen et al.’s typology [22]. However, in some cases, labels have been applied to certain types of living labs that do not fit into any existing or explicit typology but rather serve to distinguish a particular “type” of living lab from the general model of living lab. Through our experience and knowledge of the living labs literature, we recognize two such “types without a typology” that are particularly relevant to better understand agroecosystem living labs: “ULLs” and “rural living labs.”

Compared to rural living labs, the literature on ULLs is more abundant. Moreover, our first author’s years of experience helping ULL researchers articulate the unique characteristics of this new type of living lab in contrast to the general model of living labs drew our attention to the similarities with the objectives of this study. Indeed, the efforts of ULL researchers to identify the defining characteristics of ULLs provide us with a body of literature from which to develop a conceptual framework to guide our own parallel efforts.

2.3. Efforts to Distinguish ULLs from General Living Labs

In the urban context, the living lab approach holds appeal because it provides a model for stakeholder involvement and the co-development of solutions in a complex real-world system. Efforts to distinguish ULLs from general living labs (and other forms of urban innovation) show that there is something unique about the urban context that raises certain challenges in applying and implementing the living lab approach (e.g., [43,53]).

Much like with the efforts to define living lab typologies, ULL researchers have sought to identify particular dimensions along which the unique characteristics of ULLs can be identified and examined. For example, Franz et al. [54] compared ULL projects along four dimensions that go beyond the testing and improvement of new products and to contextualize the broader outcomes that are co-created. Voytenko et al. [43] compared ULLs along dimensions that were refined in a later typology of “strategic,” “civic,” and “grassroot” ULLs. Furthermore, Chronéer et al. [34] identified seven key components of an ULL from the perspective of city representatives.

Steen and van Bueren [18,55] assessed 90 sustainable innovation projects in Amsterdam to distill the “true” living labs from those that were improperly labelling themselves as living labs. Furthermore, through a comprehensive review of more than 50 papers from the general living lab literature and the literature focused specifically on ULLs, they developed a framework of nine defining characteristics of ULLs across four dimensions: “aims,” “activities,” “participants,” and “context” (Table 1). Steen and van Bueren acknowledge that their set of defining characteristics largely overlaps with the general characteristics of living labs, with two key exceptions that apply to most ULLs: an explicit focus on sustainability and the connection to a physical place, which may be a neighborhood, a city, a territory, or some other space-bound place.

Table 1. Steen and van Bueren’s [18] nine defining characteristics of urban living labs.

Dimension	Characteristics
Aims	<ul style="list-style-type: none"> • Aimed at innovation • Aimed at formal learning for replication • For urban living labs: Aimed at increasing urban sustainability
Activities	<ul style="list-style-type: none"> • Development (all phases of the product development process) • Co-creation • Iteration (feedback, evaluation, and improvement)
Participants	<ul style="list-style-type: none"> • Public actors, private actors, users, and knowledge institutes participate in the living lab activities • All actors involved have decision-making power
Context	<ul style="list-style-type: none"> • The living lab activities take place in the real-life use context of the innovation. In many urban living labs, this is a territory or a space-bound place.

Source: Steen and van Bueren [18].

Many living labs emphasize sustainability among their aims, and bibliographic studies reveal “sustainability” as a key term in the overall living lab literature [19,56]. This emphasis reflects not only the increasing emphasis on sustainability in living labs generally, but also the increasing focus on sustainability in ULLs specifically, particularly through “smart city” projects [19]. However, above and beyond this overall trend, sustainability seems to be a particularly important driver in ULLs [18,19,42]. In part, this is because of their potential for enabling sustainable transitions or new forms of urban governance [57–59].

In ULLs, the concept of “place” is also prominent—and distinct from the concept of testing and experimenting in the user’s real-life context, which itself is a fundamental feature of all living labs. As asserted by Voytenko et al. [43], “A first, fundamental feature of ULLs is that they are geographically embedded in real places, territorializing urban innovation at a more manageable scale. (p. 47).” Frantzeskaki et al. [57] emphasize that ULLs must be understood in light of their embeddedness in place as a socio-spatial context and link this aspect to their role in enabling sustainability transitions. Indeed, other researchers reflect on the foundational role of place in ULLs by describing a “place-based focus” [53] or emphasizing the role of “place-based innovation” in this type of living lab [60].

Finally, a high degree of complexity is another characteristic of ULLs that differentiates them from the general model of characteristics common to all living labs. As highlighted by Steen and van Bueren, this increased complexity is not only a challenge that needs to be overcome in ULLs, it is also a feature that makes this type of approach to urban innovation so appealing:

The intricate number of variables and relationships influencing the process and outcome of urban living labs compared to “normal” [general] living labs is exactly the learning environment that urban stakeholders tend to look for and appreciate. It helps them to develop real-world solutions to real-world problems while emphasizing the need for these solutions to work.

[18] (p. 26)

These efforts to identify the unique characteristics of ULLs reveal the importance of articulating what makes this type of living lab *different* from the general model. These efforts also highlight the importance of showing what clusters of living labs may have *in common* with each other, which enables further study into these challenges and improves the sharing of practical insights. In this way, the ULL literature holds valuable lessons for other types of living labs where the literature is not as developed, as is the case for agroecosystem living labs. For this reason, we draw on the lessons from ULLs in developing a conceptual framework to help identify the defining characteristics of agroecosystem living labs.

Specifically, we adopt Steen and van Bueren’s [18] four dimensions (aims, activities, participants, and context) (see Table 1), which they used to identify the defining characteristics of ULLs. We selected this as the basis of our conceptual framework because of its grounding in a comprehensive review of general living labs literature and the literature on ULLs specifically, and because of its intuitive structure and ease of application. Although Steen and van Bueren frame their list of nine characteristics as being specific to ULLs, they also acknowledge the similarities between the general and urban model. Indeed, it appears that only two of their characteristics are specific to ULLs: “aimed at urban sustainability” and “real-life use context . . . is [an urban] territory or a space-bound place” [18]. The remainder are the general characteristics of living labs; our task here is to identify and elaborate on the characteristics that are specific to agroecosystem living labs.

3. Methodology

To the best of our knowledge, there is no scholarly literature that conceptualizes agroecosystem living labs. Although our preliminary understanding of agroecosystem living labs is grounded in the International Agroecosystem Living Lab Working Group’s definition, we further developed it using two sources of evidence: case studies from our respective countries and case studies from literature on living lab approaches similar to agroecosystem living labs.

Case studies are essential to learning and to the production of knowledge from practice [61,62]. In 2019, the G20 MACS International Agroecosystem Living Lab Working Group noted that “Canada and France are rolling out comprehensive initiatives that aim to apply the agroecosystem living lab approach as a whole, giving significant consideration to the three components of the agroecosystem living lab definition.” [16] (p. 13), showing that both Canada’s and France’s agroecosystem living lab cases are representative of the working group’s agroecosystem living lab definition. Canada’s Living Laboratories Initiative and France’s Territoires d’Innovation are considered as “revelatory cases” [63]. They allow researchers to investigate undescribed phenomena, which in this case is the new concept of agroecosystem living labs. All the authors of this paper are involved in agroecosystem living labs initiatives in their respective countries, and three authors were members of the international working group. We used our experiences with these initiatives and relevant documents to do an in-depth analysis of the cases in each of the two countries. The same conceptual framework (Table 1) adopted from Steen and van Bueren’s [18] framework was used to code common aims, activities, participants, and contexts from case studies. The complementary disciplinary backgrounds and experiences of the authors (agroecosystem dynamics, innovation in the agriculture and agri-food sector, living lab approach, science policy) facilitated collective deliberation to achieve investigator triangulation [66] of the data used to identify the unique characteristics of agroecosystem living labs.

Our second source of evidence was based on living lab cases from a systematic review of both academic and grey literature. The systematic literature review was also a creative inquiry to engage in dialogue with the community of scholars and practitioners who are working in similar areas of research [65]. We did this to triangulate the data [66] gathered from case studies to minimize biases in the conceptions of agroecosystem living labs developed from the case studies from Canada and France. Nonetheless, the case studies from Canada and France were viewed as *guiding* revelatory case studies because of the scope and scale of their implementations. Subsequent cases from the literature were selected using the following criteria, which were based on the definition from the G20 MACS International Agroecosystem Living Lab Working Group: (1) The case must be aligned with ENoLL's definition of living labs as applied in this paper; (2) the case must include sustainability among its aims, with relevance to agriculture and/or food production; and (3) the case must be embedded within and examined at the scale of agroecosystems.

We systematically searched for relevant cases in the literature using Boolean search methods and specific keywords related to the criteria above (living lab* AND agr*; living lab* AND food; living lab* AND environment; living lab* AND landscape; living lab* AND ecosystem; living lab* AND rural). We used Scopus and Google Scholar for scholarly works, as well as Google for grey literature. We collected a total of 51 academic articles and 31 living lab initiatives. Out of these, we deemed eight sources as relevant to agroecosystem living labs after a more precise application of the three criteria above. Many case studies were eliminated because they did not meet the selection criteria. For example, cases that were not focused on innovation or co-creation or did not appear to test in the user's real-life use context were not selected. Cases that focused on agricultural and/or food innovation for reasons other than sustainability were also not selected. Other case studies were not included simply because they did not have enough information to determine whether they aligned with our selection criteria. There may also be other cases that could have been included but were not because, at the time, they were not recorded in academic literature, online, or did not appear in our structured searches. However, although the selected cases may not represent an exhaustive list of all agroecosystem living labs, we found that they were sufficient in number and detail to complement the primary cases from Canada and France for the purposes of proposing a set of defining characteristics of agroecosystem living labs.

Similar to the *guiding* case studies, the case studies from the literature were coded according to our conceptual framework adopted from Steen and van Bueren [18] using four dimensions. The findings from all case studies (i.e., from Canada, France, and supporting cases from the literature) were considered together when developing our proposed set of characteristics.

4. Case Studies

This section presents case studies from our own respective countries as well as from the academic and grey literature. We first present Canada's Living Laboratories Initiative, followed by France's Programme national d'investissements d'avenir, Territoires d'Innovation. Findings from these two primary set of cases are then supported with insights from additional relevant cases found in the academic and grey literature. These case studies are first introduced and then analyzed according to the four dimensions of our conceptual framework: aims, activities, participants, and context.

4.1. Canada: The Living Laboratories Initiative

Canada's Living Laboratories Initiative is a nationwide network of agroecosystem living labs that are coordinated and funded by Agriculture and Agri-Food Canada (AAFC), which is the Government of Canada department responsible for supporting the agriculture and agri-food sector in Canada, including through research and innovation. AAFC launched the Living Laboratories Initiative in 2018, with five living lab sites phased in over

three years. The first two living labs, in Canada's Atlantic and Eastern Prairies regions, were launched in 2019. In 2020, two more living labs are being launched in the provinces of Ontario and Quebec, and a site in the province of British Columbia will be launched at a later date (Figure 1). AAFC developed the Living Laboratories Initiative as a response to the urgent need for sustainable and resilient solutions to mitigate and adapt to the effects of climate change. The living labs approach also served as a model for greater collaboration with stakeholders toward system-wide innovation.

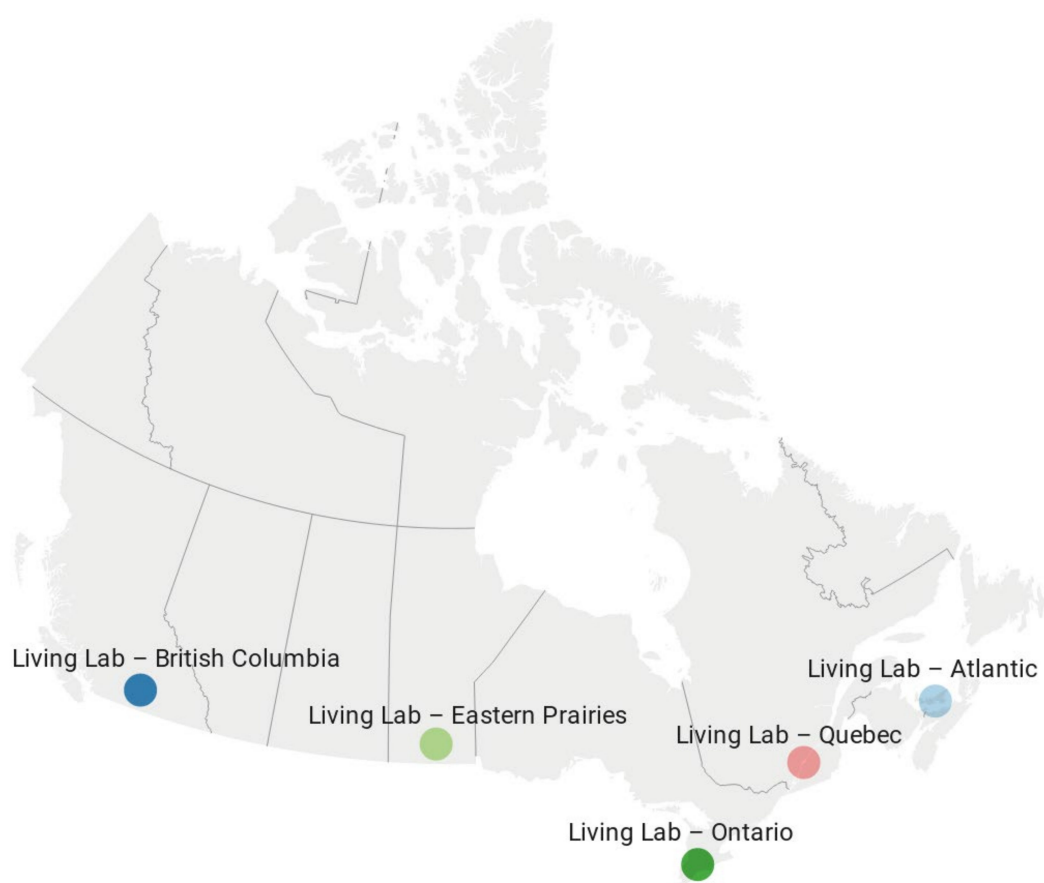


Figure 1. Map of Canada showing the five initial sites of the Living Laboratories Initiative. Individual locations are approximate and represent a wider geographical area than indicated. Map created with Datawrapper.

Below, and summarized in Table 2, we describe the aims, activities, participants, and context of the Living Laboratories Initiative.

4.1.1. Aims: Canada

The overall goal of Canada's Living Laboratories Initiative is to create innovative solutions to help the sector become more sustainable and resilient. The initiative has four priority areas: (1) mitigating and adapting to climate change; (2) reducing water contamination; (3) improving soil and water conservation; (4) maximizing habitat capacity and biodiversity on agricultural landscapes. As part of its innovative approach, the initiative takes a system-level view of these four priority areas and considers potential interactions between them, and each living lab site focuses on local agri-environmental issues at an agroecosystem scale.

The current focus is on the co-development, implementation, and testing of beneficial management practices (e.g., cover crop systems, water retention and drainage techniques, reduced tillage methods, and pollinator habitat plantings), with each living lab site developing and testing 10–15 innovative practices in total. Knowledge development and

dissemination are critical elements, with formal learning and information sharing occurring within each living lab site, across the national network, out to potential users not involved in the network, and with international partners and collaborators.

4.1.2. Activities: Canada

Encouraging widespread adoption of beneficial management practices is a key aim of the initiative, so the emphasis of activities is not only on the development and testing of the practices themselves but also a deeper exploration of the socio-economic, social, and knowledge-related factors that will influence the adoption of the new practices by other farmers. The co-development of practices occurs through both informal and formal activities, including regular co-creation workshops with all partners in addition to numerous ongoing scientific and educational activities that complement the innovation-specific activities. The iterative process follows a yearly cycle, corresponding to the growing seasons and seasonal activities and availability of users and partners. Results and activities can be greatly affected by weather and other events, such as Hurricane Dorian impacting activities in the Atlantic region in 2019 and COVID-19 impacting all sites in 2020, including delaying the launch of the living lab in British Columbia.

4.1.3. Participants: Canada

In total, each living lab site involves 50–100 participants representing diverse interests and values across a range of users (i.e., farmers) and external partners (e.g., conservation authorities, farmer organizations, Indigenous groups, NGOs, universities) collaborating with AAFC and science-based departments and agencies, such as Environment and Climate Change Canada. Most of the federal participants are scientists, which account for about 20–35 of participants and represent a broad spectrum of natural and social scientists working with transdisciplinary approaches in collaboration with external partners and farmers. Compared to general/typical living labs where the number of partner organizations is low and the number of users is high, each site in the Living Laboratories Initiative is characterized by a high number of external partner organizations (about 7–15 per living lab site) and a low number of individual users (about 10–30 per living lab site), although the involvement and commitment level required from these users is very high relative to what is usually required from users in a living lab. In addition to participating as equal partners in the co-design of new practices, the users also implement the practices on their working farms, dedicating a portion of their fields to experimentation, participating in the intensive scientific activity that takes place on their farms, and sharing data to allow for farm-level economic analyses of the practices. As farmers, the users are individuals as well as businesses; the private sector is otherwise not currently prominent in the living labs as they are in typical living labs, where the private sector often plays the role of developer or technology provider. AAFC is the primary funder of the living lab, and it plays a coordination and management role within and across the sites through its Living Laboratories Division. Therefore, according to Leminen et al.'s [22] typology, this case can be described as an enabler-driven living lab.

4.1.4. Context: Canada

The innovative practices developed in each living lab site are tested on the real working farms of users. However, the analyses extend beyond a given field or farm to the entire agroecosystem, showing an interconnection between ecological systems. Typically, activities are clustered within particular watersheds that share similar or contrasting features. Partners ensure that the living labs take into account the context and issues of the local communities. The context, therefore, also does not stop at the agroecosystem level but extends beyond it into other social and economic areas of agriculture and agri-food systems in general.

Table 2. Case summary: The Living Laboratories Initiative (Canada).

Dimension	Description
Aims	<ul style="list-style-type: none"> • Increase the adoption of beneficial management practices and technologies that will increase the sustainability and resilience of agriculture and agri-food systems to mitigate and adapt to climate change • Knowledge production and dissemination across and beyond the network
Activities	<ul style="list-style-type: none"> • Co-creation and testing of beneficial management practices • Iteration on a yearly, seasonal cycle subject to environmental and social disruptors
Participants	<ul style="list-style-type: none"> • High diversity of partners ranging from different levels of government, academia, farmers, Indigenous communities, and a range of non-governmental organizations • High participation of public sector scientists • Driven by government • Researchers from different fields develop interdisciplinary understandings of issues
Context	<ul style="list-style-type: none"> • Real working farms within interconnected agroecosystems • Embedded in the larger social and economic context of an agriculture and agri-food system

4.2. France: Living Labs under the “Territoires d’Innovation” Scheme

In 2010, France initiated the “Investissements d’Avenir” program, through which the French government invested in science, education, and public–private partnerships to: (1) accelerate a transition to sustainability and resilience through ecological principles, (2) base competitiveness on innovation, (3) build a state for the digital age, and (4) create foundations for a knowledge based society. The latest call for projects, “Territoires d’Innovation,” was launched in 2019 and devotes €450 million to large regional innovation projects for six different “transitions”: digital, sustainable energy, clean mobility, skill adaptation in an evolving labor market, the evolution of health systems, and the transformation of agricultural systems through agroecological practices. Among the 24 projects selected, 10 are oriented toward agroecological transitions (Figure 2) and are expected to benefit more than 12 million people.

“Territoires d’Innovation” aligns with the principles of living labs and addresses the three types of values known to be delivered by living labs (knowledge, business, and social values). The activities are designed to: (1) engage the largest possible number and diversity of stakeholders, (2) test the efficient use of innovations, and (3) involve users in real-life experimentation. The projects are expected to: (1) generate social benefits, (2) involve academics, and (3) have a direct impact on industrialization and the daily lives of users. Each of the 10 projects implements the living lab approach in its own way, from the creation of a living lab as one of the arrangements for innovation to the design of the entire project as an archipelago of living labs.

Below, and summarized in Table 3, we describe the aims, activities, participants, and context of the 10 projects aiming at accelerating agroecological transitions:

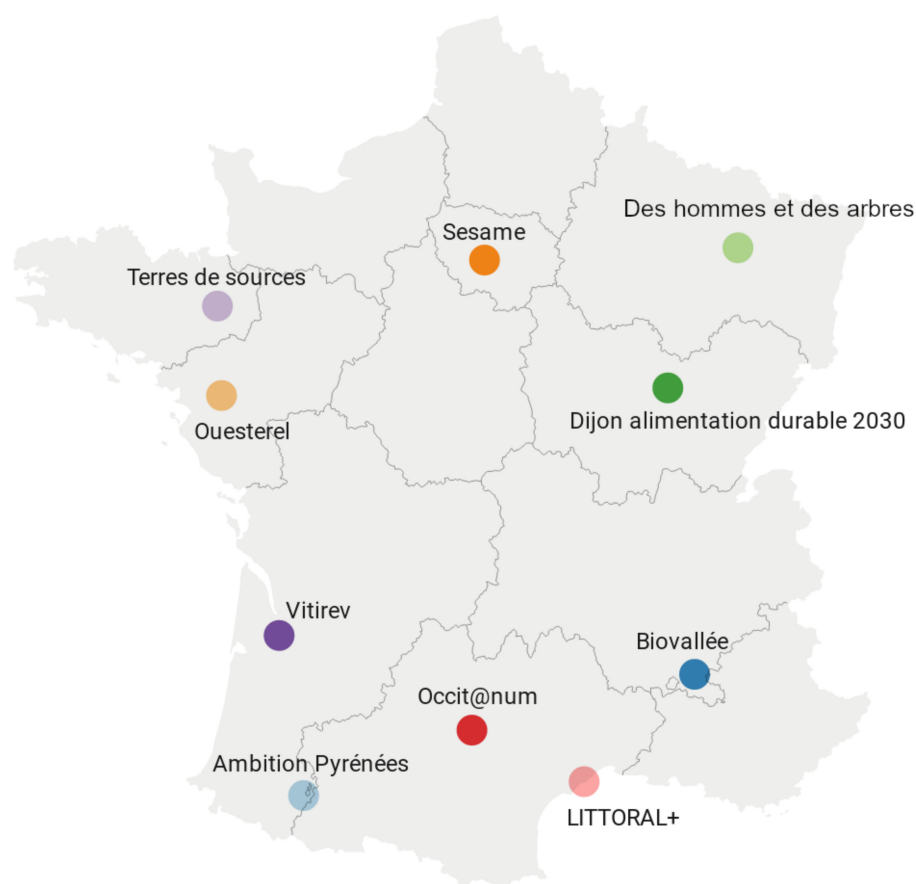


Figure 2. Map of France showing the locations of the 10 “Territoires d’innovation” projects using a living labs approach to accelerate agroecological transitions. Individual locations are approximate and represent a wider geographical area than indicated. Map created with Datawrapper.

4.2.1. Aims: France

The 10 projects aim to: (1) Foster resilience of economic activities at the territorial level; (2) develop agroecological practices along the agri-food value chain; and (3) reduce the dependence on inputs (e.g., fertilizer, pesticides) and protect soil and biodiversity. For example, the “Occit@num” project mobilizes digital technologies, and the “Vitirev” project focuses on the reduction of inputs in wine production through practices to improve soil quality, support biodiversity, and provide public health benefits. The “Dijon alimentation durable 2030” project supports agroecological development “from farm to fork” and for the benefit of all citizens of the City of Dijon. The “Sésame” project targets food sovereignty through the agroecological transition of peri-urban landscapes.

The projects also aim to reconcile ideas on agricultural development with citizens through genuine collaboration with a large number of stakeholders as well as data and knowledge sharing along the agri-food value chain. For example, the “Ouesterel” project aims to reconcile livestock production with citizens and support employment while preserving the rural-urban relationship. The “Des hommes et des arbres” project aims to implement different models of forest stewardship and governance, while the “Terre de sources” project implements new farming practices and reconfiguring agri-food value chains to manage water resources more efficiently.

4.2.2. Activities: France

Three categories of activity are featured in these living labs: (1) co-creation, (2) iteration, and (3) experimentation, exemplification, and scaling-up. Co-creation in these living labs happens not just in agricultural and food innovation, but also for funding, regulation, and

insurance schemes. Iteration is facilitated through regular self-evaluation and because financial support from the government is long term (10 years). Regarding experimentation, all projects include assessments in the user's real-life context. For example, the "Dijon alimentation durable 2030" project relies on citizens and start-ups to test solutions, and gather and exchange accurate information with local participants. The "Terres de sources" project tests innovations in regulation to raise awareness about water consumption. The "Des hommes et des arbres" project estimates the value of services of trees in the city, in the countryside, and in the forests. The "Cœur d'Essonne" project aims to empower 500 citizens per year through agroecological practices. The "Vitirev" project is developing a model for sustainable soil and biodiversity protection based on dialogue between producers, citizens, associations, trainers, industries, and investors. The "Occit@num" project develops training programs on digital technologies for producers to allow them to evaluate their value-added production of different crops and livestock as they undergo an agroecological transition. The "Ouesterel" project plans to reduce the use of antibiotics in livestock farming and to improve the traceability of livestock products in the agri-food value chain.

4.2.3. Participants: France

The projects bring together an unusually large and diverse number of actors (farmers, advisers, industrials, policy makers, NGOs, representatives of citizens, researchers, etc.) relative to typical living labs. The number of different representatives engaged in the projects are without precedent (Biovallée = 29; Des Hommes et des arbres = 39; Ouesterel = 41; Sésame = 51; Occit@num = 58; Terres de Sources = 107; Vitirev = 130). They form consortia composed of public and private actors, NGOs, academics, and scientists from government, R&I companies, and cooperatives. Their values and interests are more diverse than in any other known innovation platform. All actors engaged in the project have decision-making power through a unique governance structure in each project. In 8 out of 10 projects, the leaders are local administrations representing a city, metropolitan area, district, or region. The other two projects (Occit@num and Ouesterel) are coordinated by a governmental research organization (INRAE).

4.2.4. Context: France

Activities take place at a territorial level and engage real communities by building sustainable transitions through promoting dialogue along the agri-food value chain. For example "Des hommes et des arbres" mobilizes the public and the users to accelerate innovation. "Sésame" is developing tools to include citizens in its activities. "Occit@num" encourages the creation of new companies developing advanced technologies in the region. "Ouesterel" informs and involves citizens in the co-construction of the experimentations and prototyping activities.

Table 3. Case summary: Territoires d'Innovation (France).

Dimension	Description
Aims	<ul style="list-style-type: none"> • Innovation for sustainability and resilience of economic activities at the territorial level through the development of agroecological practices along the agri-food value chain • Innovative agriculture practices with a reduction of input-dependency (fertilizers, pesticides, increased soil protection, care for biodiversity, and empowerment of citizens) • Social innovation through the implementation of processes with large numbers of stakeholders for local social and economic development, sharing of data and knowledge, and the development of new value chains based on better resource management

Table 3. Cont.

Dimension	Description
Activities	<ul style="list-style-type: none"> • Experimentation concerning the diversity of actors along the value chain • Co-creation with as many actors as possible to bring value at the territorial level through innovations in production, funding, regulation, insurance schemes, etc. • Iterations over a long-term process sufficient to develop a sustainable public–private–people partnership model; new knowledge and data evaluated to empower people at each iteration
Participants	<ul style="list-style-type: none"> • The largest possible set of stakeholders • Values and interests are more diverse than in any other innovation platform due to the high number and diversity of partners. Users are either the farmers, the economic actors, or the citizens. The consortia are composed of public actors, private actors, NGOs, academia—scientists from government and academia, and companies; the values and interests are more diverse than any other innovation platform • All actors have decision-making power; a local governance is built through a bottom-up governance approach • The leaders of the projects are either local administrations (city, region) or government research organizations
Context	<ul style="list-style-type: none"> • Real communities on a territory concerned with the development of agroecological practices • Diverse value chains embedded in agroecological transitions at a territorial level

4.3. Living Lab Cases from the Academic and Grey Literature

We found various examples of living labs relating to agriculture, food, and sustainability in our search of the academic and grey literature. Among these, eight cases had enough information to determine that they were living labs aimed at sustainability, were relevant for agriculture and/or food, and were embedded and examined at the agroecosystem scale.

1. Agro-Lab (Madrid, Spain)
2. L'Acadie Lab (Quebec, Canada)
3. Laboratoire d'Innovation Territoriale Grandes Cultures (Auvergne, France)
4. ILVO Living Lab Agrifood Technology (Belgium)
5. AU/LAB Centre de Cocréation et d'Innovation Ouverte pour l'Agriculture Urbaine à Montréal (Canada)
6. Ryerson Urban Farm Living Lab (Canada)
7. Agrilink's Dutch Belgian Living Lab (Netherlands and Belgium) (Although Agrilink has a broader network of six agriculture-related living labs, not all fall under all three parameters used to discern case studies for the purpose of this article)
8. Agrilink's Norway Living Lab (Norway)

Certain patterns were observed through the application of our conceptual framework. As with the above case studies, the eight living labs are analyzed below using the same four dimensions.

4.3.1. Aims: Cases from the Literature

The aims of each living lab centered on sustainability in an agriculture and agri-food system. All living labs focused on innovation (through technology, best management practices, or system processes), knowledge production, or knowledge network creation.

Some living labs, such as the Agro-Lab, AU/LAB Centre de Cocréation et d'Innovation, and Laboratoire d'Innovation Territoriale Grandes Cultures discussed all three forms of sustainability (i.e., environmental, social, and economic dimensions). The Agro-Lab identified agroecology as the “connector” that fused communities, food production, and environments creating a holistic vision of sustainability [67]. Similarly, the AU/LAB Centre de Cocréation et d'Innovation emphasized all three dimensions of sustainability through

urban agriculture [68], while the Laboratoire d'Innovation Territoriale Grandes Cultures emphasized a systems view of the three dimensions of sustainability [69].

The living labs from Agrilink aimed to tackle environmental and economic sustainability through sustainable maize production and grain crop rotations that would economically benefit producers, but also the environment [70,71]. L'Acadie Lab focused on agri-environmental issues embedded in the social and economic contexts of producers, emphasizing environmental sustainability [72]. While the Ryerson Urban Farm Living Lab did not have a transparent aim in its description, the development of rooftop farming in urban areas is most often associated with environmental benefits (i.e., climate change mitigation, stormwater management) and social benefits (i.e., access to local healthy food) as described by Ryerson University academics involved in the Ryerson Urban Farm Living Lab [75]. Lastly, the ILVO Agrifood Technology Living Lab mentioned sustainability as a goal emerging from more effective food supply chains, however, it did not elaborate on what this meant [74].

Overall, it was found that all living labs identified, mentioned, explained, or implied sustainability, with a common environmental sustainability dimension in all living labs. These aims are over and above the general goal of innovation as an aim of its own and as a means to achieve other aims.

4.3.2. Activities: Cases from the Literature

Activities were based on co-development and co-creation between the different actors involved in a given living lab. Six out of the eight living labs analyzed (Agrolab, ILVO Agrifood technology Living Lab, Agrilink's Dutch Belgian Living Lab, AU/LAB Centre de Cocréation et d'Innovation, l'Acadie Lab, Laboratoire d'Innovation Territoriale Grandes Cultures) discussed co-creation, co-design, or co-production [67–70,72,74]. Ryerson's Urban Farm Living Lab and Agrilink's Norway Living Lab mentioned “collaboration” in their descriptions. Iteration was identified and used by Agrolabs and L'Acadie Lab and discussed as crucial to the initiative's continuity [67,72].

Activities varied from living lab to living lab, though all involved agriculture and food production on a system-wide scale. Three main activities were identified: the development of technologies and best management practices, knowledge and knowledge network creation, and finally a mix of various activities encompassing the first two, but also spanning beyond them.

First, activities developing technologies and practices in the agriculture and agri-food system were identified in the ILVO Agrifood Technology Living Lab [74], and the Agrilink Dutch Belgian Living Lab [70]. Second, knowledge generation and knowledge networks appeared in the Ryerson Urban Farm Living Lab [73], contributing toward more research in technologies and practices on rooftop farms; Agrilink's Norway Living Lab [71], leading toward the development of complementing rotational crop systems between farmers; and in the AU/LAB Centre de Cocréation et d'Innovation, which aimed to develop a knowledge network that would then branch of into other activities promoting the development of urban agriculture [68]. Lastly, there were living labs that had multiple activities that spanned the development of a combination of technologies, practices, and knowledge networks. The Agro-Lab was one such example where it provided training programs, focused on social inclusion through strengthening of the rural–urban networks, and promoted agroecological practices [67]. L'Acadie Lab developed and adopted innovative sustainable agri-environmental practices, fostered long-term behavioral changes, and mobilized a long-term multi-stakeholder network [72]. These two living labs had activities that focused on education and bridging the divide between urban and rural or between agricultural producers and non-agricultural producers [67,72]. Laboratoire d'Innovation Territoriale Grandes Cultures also focused on several activities including the development of technologies and practices, educational programs and tools, knowledge and knowledge network production [76].

There were a range of different activities occurring across these living labs dependent on the needs and aims of the initiative. Given that all of these activities were grounded in differing dimensions of sustainability, both public and private goods were being produced when discussing climate change, cleaner water, healthier soil, and access to healthy foods. It was also clear that activities were not just limited to a particular geographic place, but bled into larger economic and social dimensions of the agriculture and agri-food system.

4.3.3. Participants: Cases from the Literature

Every living lab had more than one partner involved. Researchers/academics and farmers were involved in every living lab examined. However, the users were not the same across living labs and even differed within living labs.

Farmers were clear end users in L'Acadie Lab, Laboratoire d'Innovation Territoriale Grandes Cultures, Agrilink's Dutch Belgian Living Lab and Norway Living Lab [69–72,74]. User roles were shared with other industries in the agriculture and agri-food sector in the ILVO Agrifood Technology Living Lab [74]. The AU/LAB Centre de Cocréation et d'Innovation did not have very defined users, but it was obvious that the users included the community, as was also the case in the Ryerson Urban Farm Living Lab [73] and the Agro-Lab [67]. Some living labs, such as l'Acadie Lab, also mentioned the inclusion of natural and social scientists [72], while others implied this by stressing that their approach was multidisciplinary as in the case of the ILVO Agritech Living Lab and interdisciplinary as in the case of the Ryerson Urban Farm Living Lab. Overall, it was clear that users were not only farmers; given the system-wide implications of many of these activities in the living labs, they included a wider range of users involved in the agriculture and agri-food system depending on the context of the living lab. Lead partners ranged from governments (Agrolab, AU/LAB Centre de Cocréation et d'Innovation, and Agrilink's two living labs), to academia or research institutes (l'Acadie Lab, Ryerson Urban Farm Living Lab, and ILVO Agrifood technology Living Lab). The Laboratoire d'Innovation Territoriale Grandes Cultures was the only outlier in this case. While it was originally developed by a government institution, it continued to run as an association of different non-state actors.

4.3.4. Context: Cases from the Literature

All of the cases selected were in agriculture and agri-food systems, but some sources did not clearly explain the contexts. For example, in the AU/LAB Centre de Cocréation et d'Innovation, it was not evident whether the activities of the living lab were happening strictly in a social innovation hub on a university campus, or whether some were also occurring on urban farms across Montreal [68]. Context was also unclear in both of Agrilink's living labs, although this may have been because such information was not accessible from the sources used. Given that farmers were primary users in both cases, it may be implied that the contexts occurred on farms.

In other living labs, such as the Agro-Lab, l'Acadie Lab, ILVO Agrifood Technology Living Lab, Ryerson Urban Farm Living Lab, and Laboratoire d'Innovation Territoriale Grandes Cultures, the context involved working farms and farming fields. However, it is noteworthy that the context of “the farm” was not limited to the traditional notion of a rural area. Agro-Lab, Ryerson's Urban Farm Living Lab, and AU/LAB Centre de Cocréation et d'Innovation discussed urban or peri-urban farming, showing that farming contexts can also differ.

5. Analysis and Discussion: The Defining Characteristics of Agroecosystem Living Labs

Below, we present our proposed defining characteristics of agroecosystem living labs grounded in the G20 MACS International Agroecosystem Living Lab Working Group's definition of agroecosystem living labs and based on the case studies from Canada and France and from the literature, as presented above. The characteristics (summarized in Table 4 and described in the text below) are organized in the same way as in the previous sections, drawing on the conceptual framework that has been used throughout the paper.

An agroecosystem living lab will possess these unique characteristics in addition to the general living lab characteristics summarized in Table 1.

Following our analysis and discussion of our proposed characteristics of agroecosystem living labs, we discuss their implications for researchers and practitioners and their broader implications for similar types of living labs, especially urban and rural living labs.

5.1. Aims: Agroecosystem Living Labs

Similar to general living labs, agroecosystem living labs focus on innovation in technology, practices, and knowledge. They also emphasize creating knowledge networks [77] among those involved in the living lab and beyond it. Agroecosystem living labs emphasize sustainability, but they also focus on resilience and do so at the scale of an agriculture and agri-food system (often referred to in the French case as “territory”). Several agriculture and agri-food systems exist simultaneously at different geographical scales, and they are each interconnected and embedded within each other.

It was found that, at a minimum, an agroecosystem living lab addresses the environmental sustainability of an agriculture and agri-food system, but it also may include the economic and social dimensions of the system’s sustainability. A sustainable agriculture and agri-food system according to the Food and Agriculture Organization’s understanding of sustainability means that the system is profitable, beneficial for society, and has a positive or net-zero impact on the environment [1]. Various agroecosystem living labs can emphasize different aspects of sustainability. Though some agroecosystem living labs among our cases emphasized the ecosystem within agriculture and agri-food systems (specifically soil/water management, and increasing biodiversity), the consequences and outcomes of these activities or actions would occur on a systemic level through the complex relationships with other elements in the agriculture and agri-food system. This was evident through discussions surrounding the need to contextualize innovations in social and economic realities, as well, the purpose behind the development of the living labs centered on environmental and social concerns in the agriculture and agri-food system on various geographic scales.

Resiliency was also discussed explicitly or implicitly in many living labs. A resilient agriculture and agri-food system can be seen as one that can ensure the capacity of the system to deliver its function during systemic traumas in the form of economic, social, environmental, and institutional pressures and shocks, while maintaining the ability to recover from them “through capacities of robustness, adaptability, and transformability” [78]. This was brought out by many living labs when focusing on technologies, beneficial management practices, or building processes and networks that aimed to create an agriculture and agri-food system that responded to many current and future social, environmental, and economic issues—especially those aimed at the complex agri-environmental issues involved with climate change.

5.2. Activities: Agroecosystem Living Labs

The agroecosystem living labs examined were grounded in the typical living lab activities of co-development, co-production, and co-creation. Iteration, an important part of the living lab process, although not explicitly identified by all our living lab cases, was a key feature in the cases from Canada and France and in several of the living labs from the literature. Activities were based in the agriculture and agri-food system and therefore involved additional layers of complexity.

All case studies were grounded in ecological processes upon which agriculture depends. This implies that the development of agroecosystem living lab activities and the subsequent iteration processes are embedded in and dependent on longer, unpredictable, and seasonal climatic conditions. A related finding is a greater need for qualitative and quantitative measurement, evaluation, and scientific activities in agroecosystem living labs than in other types of living labs. This is due to the embeddedness of the agroecosystem living lab within the agriculture and agri-food system. The result is a high degree of com-

plexity, which reflects the complexity of the agriculture and agri-food system, including its unique emphasis on the levels of social, environmental, and economic contexts. This complexity is also reflected in the high number and diversity of partners involved in the agroecosystem living lab itself.

Lastly, our cases revealed a characteristic scaling up and out of living lab activities, which were consistently mapped onto the agriculture and agri-food system level, rather than simply being used as examples of policy learning that could be transferred to different jurisdictions.

5.3. Participants: Agroecosystem Living Labs

There are many different stakeholders involved in agriculture and agri-food systems, ranging from producers to consumers and citizens, with many others in between. Each stakeholder participates in the agriculture and agri-food system differently and for diverse reasons. This is reflected in the agroecosystem living lab, where we found a large number of partners with diverse values and interests, to the point where end users varied across different agroecosystem living labs.

What was common with all agroecosystem living labs was the presence of academics and/or researchers and producers in differing capacities. Researchers working across academic fields was an activity that was implied or outright promoted in many living labs, all pointing toward forms of interdisciplinarity or even transdisciplinarity when tackling complex issues in the agriculture and agri-food system.

A living lab with such a diversity of partners, values, and interests requires a unique form of governance able to combine these complexities. For this reason, it may be why the public sector often took a leading role in governing agroecosystem living labs to act as a mediator between the diversity of partners, values, and interests. This is what Leminen, Westerlund, and Nyström [22] identify as an “enabler-driven” living lab, a public sector initiative with societal driven goals. In other living labs, academic institutions and institutes were involved in the governance of the living labs, which Leminen et al. [22] identify as “provider-driven,” taking on a metagoverning role in the network.

5.4. Context: Agroecosystem Living Labs

Similar to ULLs, agroecosystem living labs are situated within a territory or space-bound place. However, because the territory or place is an agroecosystem, the living lab’s borders are not as bounded as they would be in a city or rural region, but are more fluid and intersect with many other systems. While some places in the living labs we examined, such as watersheds, may be considered more geographically bounded places, it is important to note that watersheds intersect with many other landscapes and places that are not only part of the living lab, but also the broader agriculture and agri-food system. As above, we distinguish this broader context of “place” in which the living lab is embedded from the more specific real-life context where users test innovations. In agroecosystem living labs, the real-life use context is often working farms, perhaps on a specific field or as part of a specific farming activity, but the effects are examined across the broader context of the agroecosystem. Finally, we found that agroecosystem living labs are not only situated in rural areas, but our cases revealed that agroecosystem living labs could also be found in urban and peri-urban regions.

Table 4. Defining characteristics of agroecosystem living labs.

Dimension	Characteristics
Aims	<ul style="list-style-type: none"> • Aimed at sustainability and resilience of agriculture and agri-food systems • Innovation can be expressed through technology, best management practices, or processes • Knowledge production and knowledge network creation
Activities	<ul style="list-style-type: none"> • Exceptionally high level of evaluation and data management • Long/seasonal innovation cycles with high uncertainty due to external factors • Scaling up and out to outcomes at the level of agriculture and agri-food systems
Participants	<ul style="list-style-type: none"> • Emphasis on public sector researcher participation • User roles may be diverse and can evolve • Often driven by the public sector or academic institutions • High diversity and number of partners, interests, and values requiring complex governance schemes
Context	<ul style="list-style-type: none"> • The living lab is embedded within and examined at the scale of agroecosystems

5.5. Implications for Researchers and Practitioners in Agroecosystem Living Labs

Understanding agroecosystem living labs beyond their definition helps researchers and practitioners observe which fundamental characteristics are unique and require particular attention in agroecosystem living labs. This is important for two key reasons: it shapes the research agenda for similar types of living labs, and it identifies implications for the use and method of implementation of an agroecosystem living lab.

Identifying characteristics of agroecosystem living labs enabled us to draw similarities between other living labs that also did not have a “typological home.” As we began deliberating the characteristics emerging from the cases, we found that the key themes of sustainability, complexity, and place that emerged from the ULL literature (as discussed above) were mirrored in our findings about agroecosystem living labs. Despite obvious contextual differences, it was clear that agroecosystem living labs shared certain features with ULLs. In our view, several of the characteristics we found in our cases could be attributed to or were influenced by the place-based nature of agroecosystem living labs, and therefore were not unique to agroecosystem living labs specifically. We also suggest that the increased complexity seen in agroecosystem living labs, and perhaps ULLs, too, may largely be a result of their place-based nature than a characteristic unto itself.

We also considered other apparent similarities between agroecosystem living labs (as found in our analysis) and ULLs (as discussed earlier), which may warrant further study. For example, the embeddedness of a living lab in a particular place appears to increase complexity through its influence on the make-up, number, and diversity of stakeholders. In these types of living labs, we see an increased prominence of government, community, and citizen roles relative to more general implementations of the living lab approach. Also, living labs with strong embeddedness in a particular place may be more likely to be aimed at developing public goods and/or facilitating economic, environmental, and social transitions, which adds complexity to the articulation of aims and efficient progress toward reaching them.

While the literature on rural living labs is not as abundant as that on ULLs, it is apparent that they also share features related to sustainability, complexity, and place. Zavrtnik, Superina, and Duh [79] emphasize economic, social, and environmental sustainability as a key purpose in living labs in the rural context. This implies a wider systems perspective of rural living labs as opposed to general living labs. Those authors also highlight the complexities that must be taken into consideration in rural living labs relative to what they call “ordinary” living labs (i.e., general living labs that do not require specialization of

the approach beyond its basic characteristics), which often comes from a larger number of stakeholders, including whole communities. Similar to Zavrtnik et al. [79], Garcia Guzman, Schaffers, Bilicki, Merz, and Valenzuela [81] identify users as communities and important partners in the rural living lab. When describing cases of rural living labs, authors illustrated that each case was embedded in a rural region or a rural community [77,78]; in other words, the rural living lab was place-based. Along the same lines, others have highlighted the challenges and implications of embedding living labs within territories to encourage rural development [64,82,83].

Thus, we suggest that our findings may have broader implications for ULLs, rural living labs, and other types of living labs where embeddedness in a particular place is a key feature. Specifically, the recognition of the importance of place in certain living labs leads us to propose a typology of “place-based living labs.” This concept recognizes that there is a “family” of related living labs, and it reveals the practical and scholarly value of revealing similarities between its siblings. Members of this family already share common characteristics by virtue of all being living labs, but they may also share a set of common characteristics that reflect their place-based embeddedness in addition to the set of characteristics that makes them unique. Although we propose this place-based typology, we do not see it as a profoundly new idea given that the concept of “place-based innovation” is familiar within the living labs community (e.g., [57,64,84–86]). However, formally recognizing this typology may reveal similarities between different implementations of living labs, and therefore it gives both practitioners and researchers a framework to find and share insights about common challenges, and a different lens through which to study and interpret them. During our analysis, the awareness of the importance of these living labs being embedded in a place helped us to separate out a level of complexity and search for the specific characteristics that were unique agroecosystem living labs. In effect, this multi-level typology assumes that there are sets of characteristics representing each level—those common to all living labs, those associated only with place-based living labs, and those unique to a particular type of living lab (i.e., agroecosystem living labs) in the lowest level.

For researchers and practitioners alike, recognition of the place-based aspect suggests that someone studying or working within an agroecosystem living lab may, in some cases, be better off looking for insights from urban or rural living labs than other (non-place-based) living labs within the agriculture sector. Similarly, the challenges facing ULLs may be more similar to those facing agroecosystem living labs than the typical technology-focused living labs that may be based in a city but are not anchored within it and do not face the same challenges with respect to complexity, stakeholders, etc. A fuller investigation into the dimensions and characteristics of place-based living labs is outside the scope of this study. However, given that this proposed “family tree” of place-based living labs would be relevant to other types of living lab, such as ULLs, rural living labs, and others, we believe that proposing the place-based typology is a useful contribution to the living labs literature and as a topic for future study.

Another reason why it is important to identify and differentiate agroecosystem living labs from other living labs is to better navigate certain characteristics of the agroecosystem living lab. While agroecosystem living labs may hold similarities to urban and rural living labs, the embeddedness and functioning of agroecosystem living labs within the agriculture and agri-food system bring a unique perspective to effectively implementing and managing them. The sustainability and resilience of agriculture and agri-food systems is based on interconnected social, economic, and environmental systems, and these relationships are contextualized within cultural and political imaginaries. When working with users and other partners to tackle agroecosystem issues, these additional systems and contexts must also be considered which demand interdisciplinary or even transdisciplinary skills within the living lab’s science activities and innovation processes. Agroecosystem living labs will therefore have to be designed in such a way to accommodate these complex relationships and function within seasonal cycles that may have some unpredictability and seasonal vari-

ations. This means that agroecosystem living labs may be very difficult to predict, and will take more time to establish and to see potential results. If including agroecosystem living labs in broader policy tool inventory of governments to tackle increasingly challenging and wicked policy issues within the agricultural and agri-food systems, public sector actors will therefore need to accept that these types of living labs may require more flexibility and intentional governance structures to balance complexities and number of changing users and partners involved.

6. Conclusions

Environmental pressures are threatening our current agriculture and agri-food systems, and solutions must cater to the challenges and realities of these threats. Agroecosystem living labs were introduced as a way to stimulate faster adoption of innovation aimed at the sustainability and resiliency of agriculture and agri-food systems [16]. Grounded in the international working group's definition and general conceptualization of agroecosystem living labs, we identified the defining characteristics of agroecosystem living labs. Agroecosystem living labs were then positioned in relation to similar living labs so that researchers and practitioners alike would be able to investigate and manage their unique challenges and opportunities of agroecosystem living labs to increase their effectiveness in developing sustainable and resilient agriculture and agri-food systems.

We drew on the efforts on ULL scholars who had been able to show how ULLs differed from other types of living labs. For this reason, we adopted Steen and van Bueren's [18] framework to use as a coding guide when looking at case studies. We examined case studies of agroecosystem living labs from Canada and France, as well as case studies found in the academic and grey literature to build a preliminary conceptualization of agroecosystem living lab characteristics. We found that these characteristics portrayed two things: a similarity to urban and rural living labs, as well as implications for living lab management and implementation. Agroecosystem living lab characteristics were shown to mirror urban and rural living labs through three characteristics: sustainability, complexity, and place-based context. The place-based context was identified as being particularly relevant, suggesting a mid-level typology within living labs that was not previously explored. Implications for management and implementation of agroecosystem living labs stemmed from the embeddedness and functioning of the agroecosystem living lab in the agriculture and agri-food systems which brought to the table a multiplicity of complexities unseen in other living labs because of the interconnectedness of systems and contexts.

Future research is needed to replicate and evaluate our conceptualization of agroecosystem living labs as well as what unique characteristics may present to both management and implementation of such labs in practice. Furthermore, the idea of place-based living labs may serve as a useful way to group and better refine our current understandings of similarities and differences between living labs and their implications. We hope that others, through analyses and refinements of this proposed typology will promote future study and sharing of practical insights on development and implementation of both place-based and agroecosystem living labs.

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Conflicts of Interest: As discussed in the Methodology section, all authors of this manuscript are involved in their respective countries' agroecosystem living lab initiatives upon which the case studies were based, and three of the authors were members of the G20 MACS International Working Group on Agroecosystem Living Labs.

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