Environmental Challenges 7 (2022) 100505

Contents lists available at ScienceDirect

Environmental Challenges

journal homepage: www.elsevier.com/locate/envc

A research agenda for evaluating living labs as an open innovation model for environmental and agricultural sustainability

Christine Beaudoin[a,*], Steve Joncoux[b], Jean-François Jasmin[b], Albana Berberi[c], Chris McPhee[d], R. Sandra Schillo[e,f], Vivian M. Nguyen[c,g]

[a] School of Sociological and Anthropological Studies, University of Ottawa, 120 University Private, Ottawa, ON K1N 6N5, Canada
[b] Living Lab en innovation ouverte, Centre collégial de transfert du Cégep de Rivière-du-Loup, 78 rue Frontenac, Rivière-du-Loup, QC G5R 1R1, Canada
[c] Biology Department, Carleton University, 1125 Colonel By Drive, Ottawa, ON K1S 5B6, Canada
[d] Agriculture and Agri-Food Canada, Ottawa Research and Development Centre, 960 Carling Avenue, Ottawa, ON K1A 0C6, Canada
[e] Telfer School of Management, University of Ottawa, 55 Laurier E, Ottawa, ON K1N 6N5, Canada
[f] Institute for Science, Society and Policy, University of Ottawa, 120 University Private, Ottawa, ON K1N 6N5, Canada
[g] Institute of Environmental and Interdisciplinary Science, Carleton University, Ottawa, ON K1S5B6, Canada

ARTICLE INFO

Keywords:
Living labs
Environmental sustainability
Agricultural sustainability
Evaluation
Research agenda
Adapted Delphi method

ABSTRACT

The magnitude of environmental challenges we are facing today requires the involvement of a diversity of stakeholders and collaborators to develop socially, culturally, and economically robust sustainability practices. Living labs catalyse the development of user-centric solutions for complex environmental issues by exploring, co-creating, testing, and evaluating innovations within real-world contexts. The living lab approach is relatively new in the environmental and agricultural sectors but is quite well established in many areas such as information and communication technology. For living labs to play a greater role in environmental sustainability, we present a research agenda related to the evaluation and effectiveness of living labs in the context of environmental and agricultural sustainability. We refer to evaluation as the act of assessing the process and outcomes of a living lab, and effectiveness as the level to which a living lab is successful in achieving a certain desirable process or outcome. Our research agenda is based on empirical research using an adapted Delphi method – a process to iteratively gather input from a panel of experts – involving a total of 44 researchers and experts in the domains of living labs, evaluation methods, and agro-environmental issues. The resulting integrated research agenda identifies important gaps in both research and practice to improve the impact of living labs. Our findings highlight the need to better understand effective use of this collaborative, open innovation approach in research and management focused on environmental and agricultural sustainability. Future research should investigate the knowledge gaps for we have identified in terms of diversity of stakeholders, key dimensions of evaluation and how to enable effectiveness of living labs.

1. Introduction

While uncertainty can undermine our ability to identify and manage environmental risks (Stewart and Hursthouse, 2018), it can also open the door to freedom, creativity, broader participation, and engagement (Holtorf and May, 2020). It is increasingly recognized that collaborative approaches (i.e., research methods and programs that are inclusive of a diversity of actors) are effective for promoting uptake of knowledge, innovation, technology, and best practices for environmental solutions (Perz, 2019, Glaser et al., 2012; White et al., 2018; Sutherland et al., 2017). More specifically, in the context of environmental governance, "collaboration refers to actors (i.e., individuals or groups, such as organisations) that together, through various types of social interactions, aim to achieve different [natural resource management] goals" [(Adams et al., 2018), p. 755]. In this article, we consider collaborative approaches for addressing environmental and agricultural sustainability – the preservation of "natural capital, i.e. the range of functions provided by the natural environment." [(Franco, 2021), p. 2]. We address both environmental and agricultural sustainability because of the significant role agroecosystems and food production play in ensuring or degrading environmental sustainability. Collaborative approaches in these contexts include co-management (Berkes, 2017), boundary work (White et al., 2018), co-production (Lemos et al., 2018), action research (Mistry et al., 2021), and community science (Charles et al., 2020) among others. These are designed to include local knowledge, perspectives, priorities, needs, and skills in the development process while facilitating empowerment of communities (Guijt and Shah, 1999). Of particular interest is the living lab approach, a collaborative approach to solving complex environmental challenges through user-centred and user-

* Corresponding author.
E-mail address: cbeau143@uottawa.ca (C. Beaudoin).

https://doi.org/10.1016/j.envc.2022.100505
Received 20 December 2021; Received in revised form 7 March 2022; Accepted 26 March 2022

driven open innovation. Living labs provide means to bring together actors through social interactions to achieve a particular goal. Living labs have been viewed as both research methodology and infrastructure that involves producers and users in co-creation and co-involved innovation processes which include testing, experimentation, and evaluation within real-world contexts (Schuurman et al., 2011; Leminen and Westerlund, 2019; Delina, 2020). Often, the objective of adopting a living lab approach is to ensure that an innovation (e.g., product, service, practice) has been adequately co-developed and iteratively improved to meet user preferences and needs and is therefore ready for wide and rapid adoption.

The living lab approach emerged in an information and communication technology context (Følstad, 2008; Schuurman et al., 2013), but has now become well-represented across a variety of sectors, such as health and well-being, smart cities and regions, culture and creativity, energy, mobility, social inclusion, social innovation, government, and education (European Network of Living Labs, 2020; McLoughlin et al., 2018; Westerlund et al., 2018). Agroecosystem living labs generally aim for sustainability and resilience, innovations and the production of knowledge and networks by including a high diversity and number of participants such as end-users, the public sector, and academic institutions (McPhee et al., 2021), however, a scoping review found that they are relatively underused in the environmental and agricultural sector (Bronson et al., 2021). Among the few studies found in environmental and agricultural contexts, even fewer measure the impacts or effectiveness of living labs (McPhee et al., 2021; Bronson et al., 2021), though the literature on urban living labs (ULLs) often addresses sustainability (McPhee et al., 2021; Greve et al., 2020; Ersoy and van Bueren, 2020). Living labs show great potential for bringing forward user-centric solutions and innovations for solving a diversity of complex environmental and agricultural issues. For example, living labs have been used to explore and test climate change adaptations, green infrastructure design, low-carbon technologies, and more sustainable natural resource management (Bronson et al., 2021; Hossain et al., 2019). More specifically, they have been used for home energy management and to test eco-feedback mechanisms (Cech and Wagner, 2019; Schwartz et al., 2014), for interactive value production targeting renewable energy (Kovács, 2016), for changing water consumption habits (Davies, 2022), and for improving environmental considerations in the housing industry (Moore et al., 2022; Hagy et al., 2017).

Living labs have recently gained traction in the field of agriculture because the approach holds great promise for accelerating the co-development and adoption of innovations, catalysing system-wide transitions for greater sustainability, encouraging knowledge exchange, and driving policy development (McPhee et al., 2021). Living labs can stimulate cooperation among end users on difficult-to-implement practices such as environmentally friendly processes to reduce social and economic impacts or collective governance and experimentation to address sustainability (McPhee et al., 2021; Hossain et al., 2019; Voytenko et al., 2016). By elucidating the connections between environmental and human systems, there exists great potential for all sectors to apply the living lab approach to environmental issues (Bronson et al., 2021; Hossain et al., 2019). The European Network of Living Labs (ENoLL, https://enoll.org/) shows that some living labs across Europe are working towards environmental and agricultural sustainability. Participants in our research had ties to various institutions and projects in France such as the National Research Institute for Agriculture, Food and Environment (https://www.inrae.fr/en), the Laboratoire d'Innovation Territoriale (https://www.lit-gca.com/), and VitiReV (https://innovin.fr/en/vitirev-project/). Other European examples include the Precision Agriculture Living Lab in Serbia (https://siscodeproject.eu/pa4al/), the ARCA Living Lab in Italy (http://www.consorzioarca.it/), Agrotopia in Belgium (https://inagro.be/agrotopia), and Green Point Living Lab in Slovenia (https://itc-cluster.com/green-point/), among many others (McPhee et al., 2021). Examples are also found in other parts of the world, such as the Solar Commons Project (https://solarcommonsproject.org/) and the Landscape Lab (http://cepd.cap.utah.edu/landscape-lab/) in the United Stated and the REFOOTURE project which hosts living labs in Kenya, Ethiopia, and Uganda (https://www.wur.nl/en/project/REFOOTURE-Food-Futures-Eastern-Africa.htm) [see also Ondiek and Moturi (2019), Cunningham and Cunningham (2016) for more examples in Africa].

While there are many examples around the world of living labs looking at environmental and agricultural sustainability, Canada has been a leader in applying the living lab approach in the domains of agriculture and regional innovation. Notable examples include AcadieLab (https://www.rang3.org/lelabo) and Living Lab in open innovation (LLio) (http://llio.quebec/) in Quebec. The approach is now applied at a nationwide scale through Agriculture and Agri-Food Canada's (AAFC) Living Laboratories Initiative (www.agr.gc.ca/livinglab), which formed a nationwide network of agroecosystem living labs (McPhee et al., 2021; International Agroecosystem Living Laboratories Working Group, 2019) that is now expanding through AAFC's new Agricultural Climate Solutions program (https://www.agr.gc.ca/agriculturalclimatesolutions). Four agroecosystem living labs (McPhee et al., 2021) were initially launched as part of the Government of Canada's $70 million commitment to support agricultural discovery science and innovation. A further investment of $185 million led to the launch of the living labs stream of the 10-year Agricultural Climate Solutions program in 2021 (https://www.agr.gc.ca/agriculturalclimatesolutions), which will expand the network to at least 10 living labs to accelerate co-development, testing, adoption, dissemination, and monitoring of technologies and practices, including beneficial management practices, that sequester carbon and/or mitigate greenhouse gas emissions. The AAFC initiative demonstrates the relevant context in which our work is emerging, and is an example of the growing interest in environmental and agricultural living labs.

Despite extensive scientific coverage and capacity for technical indicators focused on the performance of the innovations examined in living labs, evaluating the effectiveness and assessing impacts of the living labs themselves are difficult tasks. While research has given a "strong indication that living lab projects can have an important added value" (Ballon et al., 2018, p. 1212), the pragmatic, complex, and unstandardised nature of living labs requires multiple instances of evaluation. Overall, there is a need to continue developing and implementing standard methods for evaluating the effectiveness, impacts, and performance of living labs (Bronson et al., 2021; Ballon et al., 2018). The environmental and agricultural sector also requires a better understanding of the social and environmental impacts of this approach. Therefore, this paper highlights living labs as a research topic that is highly relevant to environmental and agricultural management and solutions, both in terms of collaborative process and potential outcomes.

Through eliciting expertise using an adapted Delphi approach, we put forth a co-produced research agenda identifying key research questions in this field to improve our understanding and evaluation of the impacts of living labs within an environmental and agricultural sustainability context – a gap identified by Bronson et al. (2021). More specifically, our work aims to fill the gap between the growing application of living labs to the environmental and agricultural sectors and the significant lack of references in the literature regarding the evaluation, effectiveness, and social-ecological impacts of these living labs. Do living labs actually have the impact that we anticipate they can have? What are efficient practices for living labs to successfully reach desirable goals (i.e., collaborative process, sustainability outcomes)? Our research agenda presents future research directions for researchers, particularly in the social sciences, to pursue in relation to the evaluation and effectiveness of environmental and agriculturally focused living labs. This is relevant for researchers and practitioners working in Canadian and European contexts where most of these living labs are present, but also for the global community as effective living lab processes and evalu-

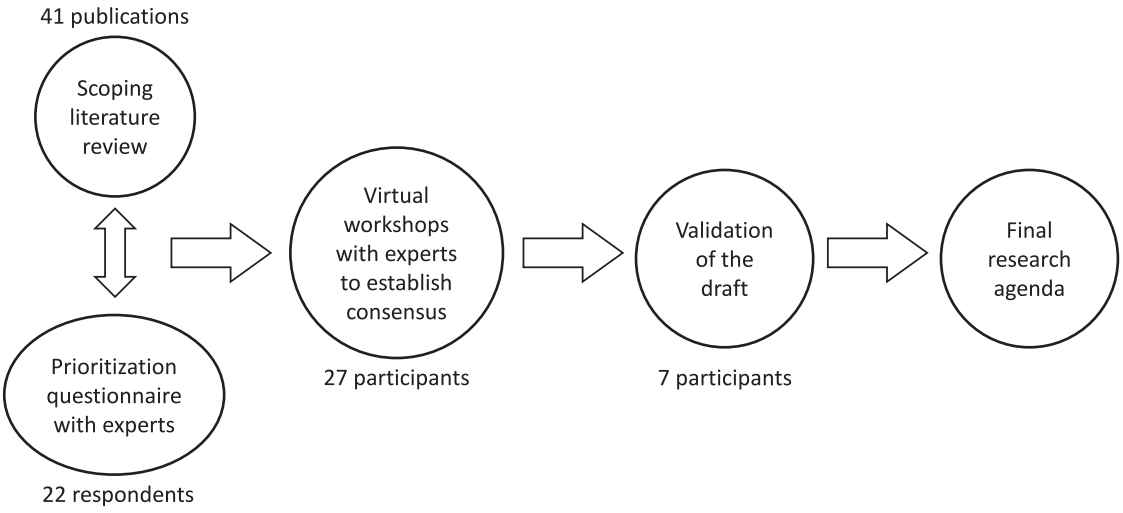

Fig. 1. Adapted Delphi method used, which iteratively builds on previous steps to generate a co-produced research agenda.

ation frameworks could be expanded to other parts of the world and contribute to global sustainability transitions.

2. Methods

2.1. Eliciting expertise

This work is part of a larger project on the potential of living labs for environmental and agricultural research and practice. We build on a scoping review which identified gaps in the literature about the evaluation of living labs focused on environmental or agricultural sustainability (Bronson et al., 2021). We adapted a Delphi methodology built from similar approaches for setting research agendas in other fields (Fazey et al., 2012; Hoffman, 1998; Steffen et al., 2004). We used this method to reach consensus through multiple rounds of input from experts (Barrett and Heale, 2020; Vogel et al., 2019), a valuable approach to prioritize research questions. Delphi methods are also useful to identify future trends in a specified field of interest (Veal, 2006). While Delphi methods are generally anonymous, adapted Delphi methods at times forgo anonymity to include face-to-face dialogue (e.g., workshops) that facilitates in depth exploration of a given topic (Fazey et al., 2012).

Participants were sent a preparatory questionnaire prior to a virtual workshop (due to the COVID-19 pandemic) with the aim of helping them reflect on and articulate their implicit knowledge and expertise. The combination of a questionnaire and workshop offered opportunities for participants to reflect individually and collectively. The research team then synthesised the themes and questions identified during the workshop into a draft research agenda, which was circulated to the participants for further input and validation of the co-produced agenda (Fig. 1). In the following sections, we first describe the participant recruitment and selection process, then we describe each step of our adapted Delphi method (see Table 1 for key stages of the research and analyses).

2.2. Participant selection and recruitment

We focused on eliciting expert knowledge from practitioners and researchers of living labs to gain greater understanding of the complexities in the field, including expertise in the approach itself and in-depth knowledge of the academic literature. Given the novelty of living labs in this space, we expected relatively few experts. Thus, we recruited participants with expertise in living labs focused on environmental or agricultural sustainability, and in related fields (to broaden perspective on spectrums of concepts, methods, and tools for evaluating living labs), to identify gaps for evaluating and understanding the effectiveness of living labs for environmental and agricultural sustainability. This selection aimed to provide a balance of breadth and diversity of perspectives. It was beyond the scope of our study and method to include end-users (e.g., farmers, citizens), although we recognize the importance and value of their perspectives. While this means that end-users were not heard in our research, our results represent the views of experts in living labs and related fields. Participants were also required to have fluency in either English or French. We had a total of 44 participants across research activities.

2.2.1. Questionnaire recruitment

Questionnaire participants were identified via authors' collective networks including the European Network of Living Labs (ENoLL), the International Society for Professional Innovation Management (ISPIM), Francophonie Living Labs, France's National Research Institute for Agriculture, Food and Environment (INRAE), Agriculture and Agri-Food Canada (AAFC), the Living Lab in open innovation (Llio), the Centre collégiaux de transfert et de technologies du Québec (CCTT). To address the bias of using the authors' networks, invitations were extended to authors identified in a scoping review focused on evaluation of living labs (Bronson et al., 2021) and a call for participation was shared during relevant events (e.g., EnoLL's Open Living Lab Days, ISPIM's innovation conference). We also used the questionnaire for snowball sampling, allowing us to recruit additional participants for the workshops.

2.2.2. Workshop recruitment and validation

All questionnaire participants and individuals identified through snowball sampling were invited to participate in the virtual workshops. We subsequently opened the virtual workshop to additional experts in the broader fields of evaluation, collaborative environmental research, and environmental social sciences. All participants from the questionnaire and workshop stages were invited to provide feedback and validate the draft of the research agenda.

2.3. Research activities

2.3.1. Prioritization questionnaire

The development of the questionnaire was informed by preliminary data from Bronson et al. (2021) scoping review on evaluation of living labs and one of the authors' previous work (Joncoux and Lewis, 2019). We were inspired by the "4R" method to build evaluation grids for collaborative processes, which was established through co-construction with actors in the environmental and agricultural sectors (Joncoux and

Table 1
Key stages of the research to elicit expertise and co-construct the research agenda.

Stage	Aim	Details	Analysis
Scoping Literature Review	To identify gaps within the literature related to the evaluation of living labs focused on environmental or agricultural sustainability.	Please see Bronson et al. (2021).	Data extracted from the scoping review informed research themes in the questionnaire.
Questionnaire	To enable participants to reflect on key knowledge gaps based on their expertise about living labs.	Please see Supplementary Material 1 for the questionnaire.	Participants ranking of themes was used to generate a list of high, medium, and low priority themes.
Workshop	To validate and explore with depth the themes prioritized in the questionnaire.	Participants engaged in a series of 3 exercises: (1) prioritisation exercise, (2) deepening of themes, (3) exploration through design fiction. Please see Supplementary Material 2 for details.	Research questions contributed by participants were coded and grouped resulting in sub-themes. Sub-themes were defined and synthesized by the authors.
Participant validation	To validate the research agenda with feedback from participants.	Participants were asked to validate the wording and clarity of the themes, sub-themes, research questions, and descriptions.	Each comment was taken into account in collective work by the authors to reformulate and clarify the questions and descriptions in the research agenda.

Lewis, 2019). The following 13 themes were selected: (1) role of evaluators, (2) role of stakeholders in evaluation, (3) temporality of the evaluation, (4) scales of evaluation, (5) objectives and use of the evaluation results, (6) funding methods of the evaluation, (7) evaluation repositories, (8) evaluation methods and tools, (9) specific objectives of the evaluation in collaborative approaches, (10) conditions for success, (11) measuring social impacts, (12) measuring environmental sustainability, and (13) efficiency of open innovation approaches (French questionnaire only due to a translation error).

A full copy of the questionnaire is available in Supplementary Material 1. We asked closed and open-ended questions about areas of expertise and involvement in living labs, effectiveness and social impacts of living labs, and ranking of the 13 selected themes above. We used NVivo 12 for inductive, thematic coding of open-ended questions. Participants' ranking of themes was analysed in MS Excel to generate a list of high, medium, and low priority themes of importance (see Supplementary Material 3 for findings). The ranking of themes was used as input for the workshop.

We invited 89 experts to participate in the Delphi questionnaire. Of those invited, 34 agreed to participate and were sent an online questionnaire (in both French and English) in January 2021. Twenty-three individuals responded to the questionnaire, 11 in French and 12 in English. Most (77%) reported living labs as an area of expertise. The majority were also researchers (68%), especially among respondents of the French questionnaire (82%). Fifty-nine percent of respondents also reported expertise in the field of agriculture, and 36% in the field of environment. Around a quarter (27%) reported evaluation as an area of expertise, and fewer (13%) reported having expertise as a practitioner. When asked about their involvement in living labs, half of participants mentioned working in organisations across Canada and Europe in the agriculture, food, and environmental sector. These include living labs at AAFC, the AcadieLab, Precision Agriculture Living Lab (PA4ALL) at the BioSense Institute, VitiREV, INRAE, and Laboratoire d'Innovation Territoriale.

2.3.2. Virtual workshops

Two recorded three-hour virtual workshops were held, one in French and one in English, using a video conference platform (Zoom) in combination with a digital collaborative whiteboard (Mural.co). Participants were encouraged throughout the workshops to write their thoughts on the Mural.co whiteboard, and the authors took additional notes on the whiteboard to capture key discussion among participants. The workshops were organized around three main activities: (i) a convergent prioritisation activity, (ii) a divergent exploration of the prioritized themes, and (iii) a design fiction exercise. The exercises were designed for participants to first reach consensus on priority research gaps and questions, second, to offer opportunities to discuss the prioritized themes, and finally to explore the main topic through a fictional case study tied to the Canadian context. The first two activities helped target priorities and identify key gaps and questions for the research agenda; the third activity is beyond the scope of this paper. Please see supplementary Material 2 for a detailed description of the three workshop exercises.

We qualitatively analysed content written by participants on the Mural.co whiteboard as well as notes taken by the author team. Recurrent themes prioritized across subgroups were identified and refined. Research questions tied to these themes were synthesized and redrafted through iterative processes to translate questions (by our bilingual research team), remove redundancies, improve clarity, and capture nuances of the participant discussions. Finally, to develop a more specific research agenda, the research questions were coded into sub-themes in relation to Who (actors), What (impacts and process as objects of evaluation), Why (objectives), How (process and methods), When (temporality), Where (scale), and How effective (efficiency and success). The result was a list of 49 synthesized research questions among 27 subthemes under seven focal research areas.

Twenty-seven individuals attended the virtual workshops, 10 in French and 17 in English, forming, respectively, two and three workshop groups. Just over half of the participants (59%) worked within a living lab program supported by France and Canada's public organisations such as AAFC, LLio and INRAE. The other half came from universities and colleges across Canada, France, Belgium, and Italy, and from agricultural producer associations. Participants had expertise in agroecosystem and sustainability living labs, evaluation, and environmental sociology. Few participants could claim to wear a practitioner's hat, but some of them evolved as living labs project coordinators.

2.3.3. Validation of the research agenda

The synthesized research questions, sub-themes and associated descriptions were sent to all participants in English and French along with the original questions for transparency. We invited participants to comment on the emergent questions ("If you agree with the wording, please write "Yes" in the corresponding box; if you do not agree, you can propose a rewording to clarify it.") with opportunities to provide general or transversal comments. Seven participants (4 in French, 3 in English) contributed to the validation. The authors reviewed and considered participants' comments from the validation round to reformulate and clarify questions and descriptions for the final research agenda.

3. Results

Participants' views of living labs may be biased by the nature of their work and backgrounds. Thus, it is important to keep in mind the composition of participants described above, and the potential biases introduced such as the focus on environmental and agricultural expertise and the lack of end-users among our participants.

Table 2
13 initial themes presented to questionnaire participants, ranked by priority.

Priority Level	Themes
High priority	The role of stakeholders in evaluation
	The objectives and use of evaluation results
	Efficiency of open innovation approaches (French Only)
	The specific objectives of evaluation
	Evaluation methods and tools
Medium Priority	Measuring environmental sustainability
	Conditions for success
	The role of evaluators
	Measuring social impacts
	Scales of evaluation
	Temporality of evaluation
Low Priority	The funding methods of the evaluation
	Evaluation repositories

3.1. Expert perspectives of gaps in evaluation of living labs

Participant views on the relative importance of research themes help identify and prioritize perceived gaps in the literature on evaluation of living labs (Table 2). Detailed findings of questionnaire results are found in Supplementary Material 3. We noted that many participants who ranked a theme as low priority were also not aware of references in the literature on that topic, leading us to question whether the themes were ranked as low priority because of a lack of knowledge. Thus, we tested the priority ranking during the workshops.

3.2. An integrated research agenda on the evaluation and effectiveness of living labs

Seven themes were highly prioritized by at least three groups from both workshops. These themes aligned with five prioritized themes from the questionnaire phase (Table 2). A number of sub-themes also emerged from our analysis (e.g., coding and synthesis) of research questions provided by participants during the workshops. To organize and prioritize the themes and subthemes, we redefined and framed them using the simple and effective model of Who, What, Why, How, Where, When, and How effective, which we present and discuss in the remainder of this paper (Table 3). The complete research agenda, including themes, sub-themes, synthesis questions as well as descriptions of the synthesis questions, and original questions provided by participants during the workshops can be found in English in Supplementary Material 4, and in French in Supplementary Material 5.

3.2.1. Who: The role and diversity of relevant actors in the evaluation of living labs

The Who theme focuses on actors found in living labs, whether they are innovation champions, users, lab pilots, evaluators, or stakeholders outside the lab. Participants felt it was a priority to clearly define the *role of different actors* in a living lab, and the respective roles each actor can or should play in evaluation processes (McPhee et al., 2021; Hagy et al., 2017; Joncoux and Lewis, 2019). The second sub-theme, *differentiated actors' involvement*, explores the specificities of each category of actor, and how evaluation could be conducted in ways that integrate and respect these specificities. In addition, several groups mentioned the key *role of the evaluators* (Dekker et al., 2021) and the diversity of postures they can adopt in evaluation (internal, external, etc.); the third sub-theme deals with these tensions.

The notion of *diversity of actors* (fourth sub-theme) emerged in the questionnaire and was selected as a priority by three of the five working groups (Bronson et al., 2021). This sub-theme focuses on understanding how diversity can foster success in living labs, and how it can be considered in evaluation. Workshop discussions revealed that diversity is as much about the attributes of people (e.g., their roles and skills) (Imset et al., 2018) as it is about the integration of non-human actors (e.g., animals, plants, soil, water) (Latour, 2005). Questions about the roles and diversity of actors are tied to concerns about *equity and power relations* between actors (human and non-human). The fifth sub-theme raises questions about the evaluation of equity, the respect of diversity in the evaluation process, and the impact of evaluation results on the distribution of power within living labs (Taylor, 2021; Galway et al., 2022).

3.2.2. What: The objects of evaluation

The What theme focuses on living lab impacts and the objects of living lab evaluations (Joncoux and Lewis, 2019), from which four sub-themes emerged. *Impacts in general* aims to unpack what methods can be used to evaluate living lab impacts. For example, some participants emphasized the need to use mixed methods to evaluate social impacts and outcomes of living labs. This sub-theme also raises connections between impacts and other key dimensions of living labs such as sustainability, best practices, and diversity of actors (McPhee et al., 2021). The second sub-theme highlights living lab *processes* as a possible object of evaluation such as investigating the development of impact goals, trade-offs between efficiency and co-creation, and methods to encourage participation in evaluation (Bronson et al., 2021; Joncoux and Lewis, 2019).

The *social impacts* sub-theme addressed how the diversity of living lab actors can have a range of values and views on social impacts, including methods, key dimensions, and indicators for evaluating social impacts and outcomes (Bronson et al., 2021; Hagy et al., 2017). Questions also emerged around best management practices, indirect social impacts (e.g., social learning, knowledge sharing), and the different scales at which impacts can occur (e.g., individuals, groups, and society). The last sub-theme, *social-environmental impacts*, aims to improve understanding of the interlinkages between social and environmental impacts and outcomes from living labs (McPhee et al., 2021). It raises questions about simultaneous assessment of different types of impacts, and how living labs approaches can contribute to solving complex, socio-technical issues (e.g., water quality, innovations in gene technology). Discussions among authors also highlighted that sustainability can be defined in a variety of ways when evaluating living labs (Hossain et al., 2019); this should be considered when addressing these research questions.

3.2.3. Why: The objectives of evaluation and the use of results

The Why theme pertains to the underlying purposes and perspectives motivating an evaluation: why the evaluation is being conducted, how the results will be applied, and for whom the results will be relevant. When considering the *purpose of evaluation*, participants highlighted the diversity of actors in a living lab, and the challenge of considering and integrating their various perspectives and (possibly conflicting) interests in the design of an evaluation (Bronson et al., 2021; Joncoux and Lewis, 2019). For example, participants discussed the *use of evaluation results* and the need to derive benefits not only for the "driving organisation or funder", but also for the stakeholders and participants (Joncoux and Lewis, 2019). Evaluation was seen as a potential feedback mechanism to influence processes and results of a living lab (e.g., influencing its evolution, stimulating reflection for best practices, enabling knowledge sharing by disseminating results or lessons learned) (Bronson et al., 2021). The potential influences of the *funding* context were deemed particularly important as it may influence the timing and frequency of evaluation (Joncoux and Lewis, 2019). Funding requirements may also introduce trade-offs such as fulfilling specific data reporting requirements rather than performing evaluations intended to improve the processes or effectiveness of living labs.

3.2.4. How: The methods and tools for evaluating living labs

The How theme touches on methods and tools of evaluation (Joncoux and Lewis, 2019). This theme explores tensions between the fact that many methods and tools are available, but that these are not standardized, and it is not always clear which method or tool should be used (Bronson et al., 2021). Discussions about *methods* for evaluation included the need to establish a common methodology for evaluation,

Table 3
An integrated research agenda on the evaluation and effectiveness of living labs.

Theme	Sub-theme	Code	Synthesis question	Description
Who: The role and diversity of relevant actors in the evaluation	Role of the different actors	A1	What conditions enable each category of actors to fully participate in evaluation of living labs?	Consider the different categories of actors (including but not limited to stakeholders and rights holders, participants, and partners from public and private sectors), as well as the conditions for each category or group to fully participate in the processes of living labs and their evaluation.
	Differentiated actor involvement	A2	What forms of evaluation are most conducive to including actors in the process? Which moments of evaluation are most conducive to including actors in the process?	Given that there are multiple phases of evaluation, the involvement and influence of different actors may differ at different stages.
		A3	How can evaluations take into account differing needs and priorities of actors who work within different timelines and timescales?	Define the concept of timeline, timescale, and temporalities, and how these relate to the various actors involved in the evaluation (e.g., evaluators and participants).
	Role of the evaluators	A4	What issues are tied to the different positions of evaluators?	Evaluators may qualify their position in the living labs and evaluation processes. Positions of evaluators can be considered as internal, external, both, or other.
	Diversity of actors	A5	What types of diversity should be considered in the evaluation of living labs?	Diversity can be tied to attributes of the individual, but also to the context within which they were trained and worked. Examples of types of diversity can include gender, culture, experience, community representation, discipline, sectors, knowledge, among others.
		A6	How can the contributions of non-human actors be evaluated in living labs?	Non-humans (e.g., soil, agricultural infrastructure, plants, animals, water) may be considered as participating actors and not only passive objects.
	Equity and power relations	A7	How can representation and power be balanced between the different actors in the evaluation process?	Representation of different actors can be balanced in the evaluation process. There may be attempts to distribute power and decision-making to make the process equitable and representative.
		A8	How does the process of evaluation influence the balance of relationships among actors? How can the process be taken into account?	The evaluation process itself, from the selection of indicators and reporting parameters to the use of the results, may influence the behaviour of actors, power dynamics, and structural (in)equity within the evaluation and living labs.
What: The objects of evaluation	Impacts in general	B1	What methods are appropriate to evaluate the impact of living labs?	Different expected and unexpected impacts (e.g., innovations, practices or living labs processes) can be evaluated with different methods that may contribute to the development of living labs.
		B2	How could mixed methods design provide tools for the evaluation of living lab outcomes?	Mixed methods designs may support the evaluation of practices and impacts of living labs. For example, systems thinking or network analysis could be combined with qualitative or participatory methods.
		B3	How do specific mechanisms of living labs relate to the various types of innovation adoption?	Different participatory approaches and mechanisms may promote different types of innovation adoption and may reveal different strategies and system dynamics.
		B4	What are the connections and mutual influences between key dimensions of living labs? How can these connections be established and influenced?	Impacts of living labs are complex and multi-dimensional, and there may be different connections and mutual influences between key elements of living labs (e.g., social impacts and sustainability, social impacts and best practices, diversity of actors and environmental impacts).
	Process	B5	Can cost-benefit analysis be used to outline project goals for living labs?	Cost-benefit analyses may improve alignment and sustainability of living labs and their evaluation. For example, cost-benefit analyses could reveal if and how the cost of a living lab influences its environmental goals.
		B6	How can concerns for efficiency in co-creation be balanced in living labs and their evaluation? What are the trade-offs?	There are assumptions about the need to compromise between the burden of co-creation (resource intensive, e.g., time and money) and the efficiency of participatory approaches. This may influence the evaluation of living labs.
		B7	How can participation in the evaluation of living labs be encouraged? How can tensions related to the lack of willingness to participate be overcome?	Actors may have different levels of willingness to participate in living labs processes and evaluation. For example, tensions may arise around lack of willingness to participate.
	Social impacts	B8	How does the value of social impact differ according to the specific characteristics of the actors in a living lab?	Actors with different characteristics (e.g., type, diversity, benefits sought, etc.) may hold differing views and values about social impacts. These values may change over time and be influenced by living labs processes.
		B9	What key dimensions of evaluation can capture the social impacts of living labs?	Multiple dimensions may be considered when evaluating the social impacts and outcomes of living labs. These include organisational transformation, the evolution of relationships between actors and groups, dynamics within social systems and innovation ecosystems, among others.
		B10	What are the indicators of social impacts for a variety of actors at different scales of living labs?	Appropriate indicators to investigate the social impact of living labs may include well-known indicators of social impacts in other fields. Social impacts may differ according to scales (e.g., time, geography, and individual, community, or global level) and for actors with different levels of involvement (e.g., participants, partners, facilitators).

(*continued on next page*)

Table 3 (*continued*)

Theme	Sub-theme	Code	Synthesis question	Description
		B11	What are the best methods to evaluate specific social processes and outcomes of living labs?	Specific social processes and outcomes of living labs may include influence on mental health and well-being, transfer and acquisition of skills and knowledge, relationships between actors, collaboration, trust, willingness to participate, data-sharing, and behaviour change, among others.
		B12	What key criteria of best management practices can be measured and compared? How can we operationalize these criteria?	Key criteria to measure and compare best management practices (e.g., environmental sustainability, cost) may be identified and operationalised in the evaluation of living labs.
		B13	What indirect impacts and outcomes do living labs have on individuals, groups and society?	Living labs can have indirect impacts (e.g., social learning, social impact, knowledge sharing). Evaluation of these indirect impacts may be inclusive of different actors.
	Social-environmental impacts	B14	How is sustainability defined in the evaluation of living labs?	Definitions of sustainability (including social, environmental, economic...) may vary and could be considered in the evaluation of living labs, along with the measurement of outcomes and impacts at different scales.
		B15	How can social and environmental impacts of living labs be assessed simultaneously?	Some methods may simultaneously assess the interrelated impacts of living labs across communities and ecosystems (e.g., ties between social, economic, and environmental impacts).
		B16	What are the qualitative approaches used to measure social, environmental, and socio-environmental impacts?	Qualitative and technology-oriented approaches may have distinct methods, with different strengths and limitations, for the evaluation of social impacts of living labs.
		B17	How do living labs and their evaluation relate to solving complex problems (wicked problems)?	Living labs and their evaluation may play a role in helping understand and solve complex issues (e.g., water quality, lack of social-ecological resilience, complex networks and communications, innovations in gene technology).
Why: The objectives of evaluation and the use of results	Purpose of evaluation	C1	How can the different objectives and interests of actors be considered and integrated in the evaluation of living labs?	Reflect on why the evaluation is being conducted, as multiple objectives and different interests in living labs may be conflicting at times (e.g., evaluate adaptive learning, validate desired outcomes).
	Use of evaluation results	C2	What are different uses of living labs evaluations in diverse contexts?	Results of evaluation can be used in different ways (e.g., to benefit different actors) and in different contexts (e.g., social, economic).
		C3	How can evaluation itself influence the process and results of the living lab?	Evaluation and its results may influence living labs, for example by influencing its evolution, generating best practices and/or enabling knowledge sharing across sectors.
	Funding	C4	How do various funding contexts impact the evaluation process of the living labs?	Funding (its timelines and agenda) can influence the success of living labs as well as the evaluation process, may require trade-offs and could be leveraged to improve the evaluation and the impacts of living labs.
How: Methods and tools for evaluation	Methods	D1	How can a common methodology be established for the evaluation of living labs?	Common evaluation methods and frameworks for all living labs (processes and impact), as well common visions for each living lab, may be established at the start of the process.
		D2	What are the strengths and limitations of different methods to evaluate living labs?	Different methods may be used to evaluate Living Labs (processes and impact), but it is not always clear what their roles and effects are. Examples include co-construction, qualitative methods and methods tied to social-ecological systems.
		D3	How might existing frameworks from other fields be used to evaluate the "building blocks" of living labs across sectors and contexts?	Multiple methods and frameworks from different fields may be used to evaluate the “building blocks” of living labs (e.g., infrastructure, level of openness, real-world context, etc.) across sectors and contexts (e.g., health versus agriculture).
	References	D4	How can a collection of references and tools support the evaluation of living labs?	Various references and guides available for the evaluation of living labs or similar models may play different roles in evaluation. A collection of references and tools like academic papers and handbooks may take various forms (e.g., repositories, archives or inventories, toolkits).
		D5	How can evaluation support improved understanding of the different points of reference of actors in living labs?	Actors in living labs may have different disciplinary, political, social, and cultural points of references as they come from a wide range of disciplines, sectors, and contexts.
	Perspectives	D6	What are the roles of subjectivity and objectivity in the different evaluation processes of living labs?	Subjectivity and objectivity are in tension in living labs and may influence evaluation processes (e.g., self-evaluation, comparison, and setting objectives).
	Trust	D7	What role do trust and willingness to share data play in the evaluation of living labs?	The relationship between trust and willingness to share data (e.g., does sharing data strengthen trust? does trust imply willingness to share?) may play a role in the evaluation process.
	Comparison	D8	How does the evaluation of living labs compare with evaluation of other approaches?	Living labs are distinct but share commonalities with other approaches (e.g., collaborative and non-collaborative approaches); some lessons from other fields or models may apply to the evaluation of living labs and vice versa.
		D9	What methods, metrics, and criteria of evaluation for living labs are needed to compare between projects, sectors, contexts, specific processes, and overall approaches?	Evaluation methods and tools (e.g., metrics, indicators, measurements) may enable comparison and transfer of knowledge between living labs and other approaches, and among living labs from different sectors, different contexts, or which use distinct processes (e.g., centralised versus decentralised, creation versus validation).

(*continued on next page*)

Table 3 (*continued*)

Theme	Sub-theme	Code	Synthesis question	Description
Where: The scales of evaluation and impacts	Scales	E1	Which evaluation methods and tools should be used at what scales?	Evaluation of living labs may occur at different scales, understood as a complex and multidimensional concept which includes temporal scales, social levels (micro, meso, macro), and location (geography, institutions).
	Integration	E2	How can evaluation methods be integrated across various scales to obtain a holistic understanding of living labs?	Social, environmental, and social-environmental impacts and outcomes may occur at various scales and timelines, for example in regional and national networks, and among the different layers of living labs.
When: The temporality of evaluation and impacts	Temporality	F1	What are the evaluation methods and tools specific to the different stages of evaluation?	Different methods, tools, and criteria can be used at different stages of the evaluation process. These may contribute to the growth of living labs, and there may be a range of views among participants around the expected length of each stage.
	Measurement	F2	How can the different dimensions of living labs be measured at each stage?	Different dimensions of living labs (activities, process, products, outcomes, impact) may be evaluated over time. Specific examples include sustainability, governance, innovation, and the projects themselves.
	Alignment	F3	How can different timelines of actors be aligned in living labs? What are the impacts of mismatches?	Alignment or mismatch between the timelines of different actors (e.g., funders, users, communities, staff, researchers) and processes (e.g., evaluation, funding, management activities, and cycles of living systems like crops) may influence living labs processes and evaluation.
	Evolution	F4	How do behaviours, perspectives, and knowledge of living lab actors change over time?	The views, values, knowledge, and behaviours of actors may evolve over the course of living lab processes and evaluation.
How effective: Enabling conditions for success	Definition and measure of success	G1	How is success defined in different living labs?	Many different dimensions and perspectives can be defined and measured when thinking of success in a living lab, including but not limited to social, economic, temporal, procedural, institutional, and organisational dimensions.
		G2	How can the diversity of definitions of success among actors be considered in the evaluation of living labs? How do these definitions influence evaluation?	Actors may have different definitions and ways to measure success, which can influence the evaluation of living lab processes, outcomes, and impacts.
	Conditions for success	G3	What are enabling conditions for successful living labs?	Various short- and long-term conditions may enable success of living lab initiatives, including but not limited to willingness to change, certain investments or collaborative approaches.
		G4	What participant characteristics enable successful living labs?	Specific social and psychological characteristics of participants may play a key role in enabling success and effectiveness of a living lab.
	Role of mistakes and failure	G5	What are the roles of mistakes and failure in success of living labs?	Trial and error, as well as failure, are key to the living lab approach (developing, implementing, and evaluating), though some actors may be averse to failure (e.g., funders).

to identify strengths and limits of different methods (e.g., co-creation, qualitative research), and to transfer frameworks from other fields (e.g., social-ecological systems) to the living labs context (Bronson et al., 2021; Joncoux and Lewis, 2019; Galway et al., 2022).

The second sub-theme, discussed by a French workshop group, raised the role of collections of *references* or guides about methods and tools to support evaluation of living labs (Joncoux and Lewis, 2019), and to support the inclusion of external actors (Hagy et al., 2017), for example by accounting for the diverse points of references of actors involved in living labs. The question of *perspectives*, and specifically objectivity versus subjectivity, was discussed by one of the English groups. *Trust* was another sub-theme, specifically the role of trust and willingness to share data in the evaluation process. The final sub-theme brings into question *comparison* (Bronson et al., 2021; Joncoux and Lewis, 2019). Discussions related to adapting evaluation methods from similar approaches (e.g., other co-innovation or participatory approaches) and other fields (e.g., systems thinking) to the living lab context, how living lab evaluation methods are distinct from those of other fields, how to mobilize evaluation for cross-sectoral comparison, and how to compare the living lab approach to other approaches (Kovács, 2016; Mulder et al., 2008). Some questions from the What, When, and Where themes also relate to the How theme, as we can ask how to evaluate the objects of evaluation, and we can ask which methods and tools can be used at different times, at different scales.

3.2.5. *Where: The scales of evaluation and impacts of living labs*

The Where theme relates to scales of evaluation. The first sub-theme pertains to *scale* itself and which tools or methods should be used at what scale (Joncoux and Lewis, 2019). There is a need to account for different social levels of analysis (micro, meso, macro) (Serpa and Ferreira, 2019), as well as geographic (e.g., farm, watershed, region), and institutional scales when thinking of where the evaluation of living labs should occur (McPhee et al., 2021, Guimont and Lapointe, 2016). The second sub-theme relates to *integration* of methods across scales to generate holistic understandings of living labs (Sterling et al., 2017). Participants wondered how living labs can reach systemic levels and how to evaluate regional and national networks of living labs.

3.2.6. *When: The temporality of evaluation and impacts of living labs*

The temporality of the evaluation and processes of living labs was frequently mentioned in questionnaire results and workshop discussions. The first sub-theme relates to *temporality* in general, and more specifically the need to identify which methods and tools to use at different stages of evaluation (Bronson et al., 2021). This is closely tied to *measurement*, which emphasizes the need to measure different dimensions of living labs at each stage of the process (Joncoux and Lewis, 2019). *Alignment*, the third sub-theme, came into question as different actors of living labs operate on different timelines which may be aligned or misaligned. There were discussions on the timing of the various iterations of evaluation and careful alignment with the temporality of partners and users so that the evaluation can be successful. This highlights the importance of understanding who is involved **when** in the evaluation of living labs. The fourth sub-theme relates to *evolution* and the need to consider changes in institutional culture, behaviour, perspective, and knowledge of the different actors over time.

3.2.7. How effective: Enabling effective conditions for successful open innovation approaches

Three sub-themes emerged related to conditions and factors that enable open innovation to be impactful and successful. The need to *define and measure success* was a prominent sub-theme, including dialogue about what is success or perceived success, and who defines success (from what perspective) in a living lab. For instance, success can be understood differently at various individual, group, professional, and organisational levels (Joncoux and Lewis, 2019). Further, participants felt it was important for living labs to include participants and stakeholders in the evaluation process with particular attention to scoping the evaluation, participant diversity, value chain, and setting an engagement culture with shared expectations and learning processes. This type of engagement and involvement was considered to enable *conditions for success* in open innovation approaches (Sivam et al., 2019). There was also interest in better understanding how certain characteristics of actors can enable effective or successful living labs. Lastly, the *role of mistakes and failure* in enabling success also emerged as a sub-theme (Joncoux and Lewis, 2019).

4. Discussion

Living labs provide a framework for applying open innovation approaches to identify, test and implement environmental and agricultural solutions. The approach moves away from using exclusively technocratic and top-down approaches to include bottom-up activities and community-based approaches (Leminen, 2013), thus aligning with the increased recognition and use of participation and collaboration in environmental research and governance (Perz, 2019; Berkes, 2017). The great complexity of environmental and agricultural management makes it difficult to forecast the future in any meaningful way, as uncertainties are difficult to estimate, especially in the context of sustainability transitions and agroecosystem living labs (McPhee et al., 2021; McRoy et al., 2020). However, the living lab approach is well suited to manage certain types of uncertainties and risks such as those associated to emerging technologies like market acceptance, price acceptability, and technology testing (Greve and O'Sullivan, 2019). While there is still a lack of environmental and agricultural sustainability focused living labs (Bronson et al., 2021), ULLs have contributed to the diffusion of more sustainable practices, structures, and cultures within set boundaries (von Wirth et al., 2019). Nevertheless, there is a need to evaluate the effectiveness and impacts of environmental and agriculture focused living labs to assess their true potential for sustainability (McPhee et al., 2021; Hagy et al., 2017) and environmental justice (Galway et al., 2022).

We present an integrated research agenda on the evaluation of living labs emerging from an adapted Delphi process. The iterative steps in our method allowed us to confirm and validate the prioritisation of themes and gaps for the resulting research agenda. However, there are limits to our approach. For example, during the validation of the research agenda, participants were primarily concerned about the complexity of the questions, which highlights the challenge of synthesizing 100+ questions tied to priority themes in a clear and precise way that capture the range of views and gaps identified. The final verification from participants, however, allowed us to clarify and breakdown complex questions, thus strengthening our research agenda. Other limitations include the lack of user perspective and fewer practitioners relative to researchers (Sections 2.2 and 2.3). The fact that there are few environmental and agricultural focused living labs, and that we included experts from other fields, is also a limit of our research agenda resulting in challenges with identifying gaps specific to these types of living labs. However, this generalizability is also a strength, as the research agenda can used by the broader field of open innovation and living labs. Finally, we had to limit the number of themes included in the research agenda. Although our process led to a well-supported prioritisation of research gaps, interesting elements such as the theme of creativity had to be left out as it was not prioritized by all participants.

This novel research agenda presents areas that need to be investigated to benefit the application of the living labs framework in the environmental and agricultural sector, and beyond. We present a simple model to thematically organize areas of investigation in the research agenda (Who, What, Why, How, Where, When, and How effective) which will need to be considered by environment and agriculture focused researchers and practitioners who want to implement a living lab approach and assess its effectiveness. Target areas from our research agenda align with requirements for adaptive environmental governance (e.g., consider the interdependence of social and ecological systems, improve resilience to deal with uncertainty, foster collaboration that improve social and institutional learning) (Berkes, 2017). Our objectives for this research agenda are thus two-fold. First, we hope to encourage the use of the living lab approach so that complex, socio-ecological-technical problems can be tackled collaboratively by researchers, practitioners, and users, among others. Second, we hope researchers will engage with the research questions to fill knowledge gaps in the literature and contribute to the effective application of the living labs framework in the environmental and agricultural sustainability domain. As such, this research agenda may be implemented both in the field of living lab research as well as collaborative environmental research and governance.

Given the rise of environmental and agricultural living labs in Canada (Acadie Lab, LLio, AAFC, see introduction), our research agenda has potential to be applied and investigated in a Canadian context that could offer insight for others looking to adopt a living labs approach to environmental and agricultural management. The research agenda is also relevant for better understanding the evaluation and impacts of living labs in other sectors and across the world. We note that research and implementation of environmental and agricultural living labs in other areas of the world with different geopolitical and cultural contexts may reveal differing priorities than those in our research agenda (Baran and Berkowicz, 2020). We encourage future research to attend to these potential differences. A variety of actors tied to living labs may also benefit directly from our research agenda and, through their activities, could contribute to exploring questions in the research agenda that in turn could strengthen their operations and evaluation processes. In this context, a living lab itself, or networks of living labs, can become case studies to better understand the effectiveness of collaborative approaches for solving complex socio-environmental problems. In addition, the research agenda will improve our understanding of, and knowledge-sharing between, different collaboration models in environment and conservation-focused domains (e.g., multi-stakeholder collaboration, action research frameworks, co-production models) by fostering comparative research.

The emergence of the diversity of stakeholders was consistently an important theme for participants at all stages, leading to conversations about equity and fair distribution of power in living lab processes and their evaluation (Imset et al., 2018). In addition, non-humans (e.g., plants, climate, technologies) were recognized in workshop discussions as actors who actively participate in living lab processes (Latour, 2005). This type of discussion aligns with broader discourse on the fact that working towards environmental sustainability must go hand in hand with working towards equity and environmental justice, as social and ecological processes are deeply interconnected (Galway et al., 2022; Young, 2013). Another element, not captured by participants but that emerged among the authors during the co-creation of the research agenda, is the need to consider different types of impacts and how to account for unexpected and unintended impacts, as it can be challenging to capture and measure unpredicted impacts.

Those wishing to implement the research agenda should thus be mindful of the different types of impact they will target. Social, environmental, political, and economic impacts are all intertwined, and innovations brought forth by living labs may lead to adopting new practices

that can interact with values and culture, people's livelihoods, policy and regulations, and/or the state of the environment (McPhee et al., 2021; Baran and Berkowicz, 2020). Although the research agenda specifically highlights social and social-environmental impacts, we recognize the interconnectedness of these dimensions in the processes and impacts of living labs. It is important to consider these dimensions simultaneously, as the impacts of living labs can be felt throughout the complex systems in which they are embedded (McPhee et al., 2021). Thus, living labs must ensure that their operations align with broader trends that foster environmental sustainability, for example by choosing the right materials, encouraging environmental-friendly processes, and evaluating their social-ecological impacts (Ståhlbröst, 2012). We are also cognizant that living labs are not a panacea, but rather experimental governance arrangements that can be challenging (von Wirth et al., 2019). For example, mismatches may emerge between the expectations of actors involved in living labs (e.g., desire for a socially embedded sustainability transition) and the context of the experiments (e.g., small scale projects cannot always be scaled up, institutional support is required for large scale implementation) (Ersoy and van Bueren, 2020).

5. Conclusion

As we face increasingly complex environmental threats and climate change, there is a need to find and accelerate the adoption of sustainable solutions and innovations that improve the resilience of our social-ecological and agricultural systems. Our work responds to the need to reflect on the potential of living labs, as a collaborative open innovation approach, to contribute to sustainability transitions. Specifically, this empirical work revealed priority gaps to investigate to promote effective evaluation of living lab processes and impacts.

The research agenda is organized around seven themes: Who (the actors involved), What (the objects of evaluation), Why (the objectives of evaluation), How (the methods of evaluation), Where (the scales of evaluation), When (the temporality of evaluation), and How effective (the enabling conditions for success in living labs). Each theme is formed of multiple sub-themes and research questions that address methodological, operational, social, and environmental dimensions of living labs. Our work also highlights the importance of simultaneously considering the different components that form social-ecological systems when mobilizing the living lab approach in the environmental and agricultural sector.

Overall, the research agenda provides a path forward for those looking to apply the living lab approach to the environmental and agricultural sector in order to work collaboratively on innovations (e.g., products, services, practices) that can improve social-ecological resilience and sustainability. It also provides a path forward by presenting priority gaps and research questions to investigate when applying the living lab approach in this emerging domain. These research questions can also be taken up by other sectors as they raise general tensions tied to the evaluation of living labs. Living lab practitioners, users, and other participants in living labs can also mobilize our research agenda to explore and strengthen their evaluation processes.

Funding sources

This work was supported by the Social Sciences and Humanities Research Council of Canada [Knowledge synthesis grant Living Within the Earth's Carrying Capacity grant number 872-2019-1020, 2020-2021]. The funding agency played no role in the design, data collection or analysis of this research.

Declaration of Competing Interest

Some of the co-authors, Christine Beaudoin, Vivian Nguyen, participated in the English and R. Sandra Schillo in the French virtual workshops as participants in order to provide input based on their expertise in collaborative research, environmental social science and innovation.

Acknowledgements

We want to thank all participants of this research as it would not have been possible to co-produce the research agenda without their participation. We also acknowledge the contributions of Kelly Bronson as a member of our research team on the living lab research project and Jessika Guay for research assistantship. This research was funded by the Social Sciences and Humanities Research Council Knowledge Synthesis Grant related to Living with Earth's Carrying Capacity. Finally, we thank the three anonymous reviewers whose comments helped strengthen the paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.envc.2022.100505.

References

Adams, V.M., Moon, K., Alvarez-Romera, J.G., Bodin, O., Spencer, M., Blackman, D., 2018. Using multiple methods to understand the nature of relationships in social networks. Soc. Nat. Resour. 31 (7), 722–755. doi:10.1080/08941920.2018.1425514.

Ballon, P., Van Hoed, M., Schuurman, D., 2018. The effectiveness of involving users in digital innovation: measuring the impact of living labs. Telemat. Inform. 35 (5), 1201–1214. doi:10.1016/j.tele.2018.02.003.

Baran, G., Berkowicz, A., 2020. Sustainability living labs as a methodological approach to research on the cultural drivers of sustainable development. Sustainability 12 (12), 4835. doi:10.3390/su12124835.

Barrett, D., Heale, R., 2020. What are delphi studies? Evid. Based Nurs. 23 (3), 68–69. doi:10.1136/ebnurs-2020-103303.

Berkes, F., 2017. Environmental governance for the anthropocene? Social-ecological systems, resilience and collaborative learning. Sustainability 9, 1232. doi:10.3390/su9071232.

Bronson, K., Devkota, R., Nguyen, V., 2021. Moving toward Generalizability? A scoping review on measuring the impact of living labs. Sustainability 13 (2), 502. doi:10.3390/su13020502.

Cech, F., Wagner, M., 2019. eRollin'On green: a case study on eco-feedback tools for eMobility. In: Proceedings of the 9th International Conference on Communities & Technologies - Transforming Communities, pp. 121–125. doi:10.1145/3328320.3328402.

Charles, A., Loucks, L., Berkes, F., Armitage, D., 2020. Community science: a typology and its implications for governance of social-ecological systems. Environ. Sci. Policy 106, 77–86. doi:10.1016/j.envsci.2020.01.019.

Cunningham, P., Cunningham, M., 2016. Report on Innovation Spaces and Living Labs in IST-Partner Countries Version 2. IIMC International Information Management Corporation Ltd (IST-Africa Consortium) http://www.ist-africa.org/home/files/ist-africa_innovationspaces_ll_v2_310116.pdf. (15 February 2022).

Davies, A., 2022. Homelabs: domestic living laboratories under conditions of austerity. In: Marvin, S., Bulkeley, H., Mai, L., McCormick, K., Palgan, Y.V. (Eds.), Urban Living Labs: Experimenting with City Futures. Routledge, London, pp. 126–146. doi:10.4324/9781315230641.

Dekker, R., Geuijen, K., Oliver, C., 2021. Tensions of evaluating innovation in a living lab: moving beyond actionable knowledge production. Evaluation 27 (3), 347–363. doi:10.1177/1356389021997848.

Delina, L.L., 2020. A rural energy collaboratory: co-production in Thailand's community energy experiments. J. Environ. Stud. Sci. 10, 83–90. doi:10.1007/s13412-019-00572-x.

Ersoy, A., van Bueren, E., 2020. Challenges of urban living labs towards the future of local innovation. Urban Plan 5 (4), 89–100. doi:10.17645/up.v5i4.3226.

European Network of Living Labs, Living Labs. https://enoll.org/network/living-labs/ (accessed 4 May 2020).

Fazey, I., Evely, A.C., Reed, M.S., Stringer, L.C., Kruijsen, J., White, P.C.L., Newsham, A., Jin, L., Cortazzi, M., Phillipson, J., Blackstock, J., Entwistle, N., Sheate, W., Armstrong, F., Blackmore, C., Fazey, J., Ingram, J., Gregson, J., Lowe, P., Morton, S., Trevitt, C., 2012. Knowledge exchange: a review and research agenda for environmental management. Environ. Conserv. 40 (1), 19–36. doi:10.1017/S037689291200029X.

Følstad, A., 2008. Living labs for innovation and development of information and communication technology: a literature review. Electron. J. Organ. Virtualness 10, 99–131. http://hdl.handle.net/11250/2440026.

Franco, S., 2021. Assessing the environmental sustainability of local agricultural systems: how and why. Curr. Res. Environ. Sustain. 3, 100028. doi:10.1016/j.crsust.2021.100028.

Galway, L.P., Levkoe, C.Z., Portinga, R.L.W., Milun, K., 2022. A scoping review examining governance, co-creation, and social and ecological justice in living labs literature. Challenges 13 (1), 1. doi:10.3390/challe13010001.

Glaser, M., Krause, G., Ratter, B.M.W., Welp, M., 2012. Human-Nature Interactions in the Anthropocene Potentials of Social-Ecological Systems Analysis, 1st ed. Routledge, New York, London.

Greve, K., Leminen, S., De Vita, R., Westerlund, M., 2020. Unveiling the diversity of scholarly debate on living labs: a bibliometric approach. Int. J. Innov. Manag. 24 (8), 2040003. doi:10.1142/S1363919620400034.
Greve, K., O'Sullivan, E., 2019. Demonstration environments for emerging technologies: insights for a living lab. In: Proceedings of the International Society for Professional Innovation Management Conference.
Guijt, I., Shah, M.K., 1999. The Myth of Community: Gender Issues in Participatory Development. Sage Publications, New Delhi.
Guimont, D., Lapointe, D., 2016. Empowering local tourism providers to innovate through a living lab process: does scale matter? Technol. Innov. Manag. Rev. 6 (11), 18–25. doi:10.22215/timreview/1031.
Hagy, S., Bard, F., Sasic, A., Sredanovic, E., Camarasa, C., 2017. Next Generation Living Labs: Comprehensive Report. Chalmers University of Technology and Climate-KIC https://research.chalmers.se/publication/506932/file/506932_Fulltext.pdf (Accessed 15 February 2022).
Hoffman, P., 1998. The Man Who Loved Only Numbers: The Story of Paul Erdös and the Search for Mathematical Truth. Hyperion, New York.
Holtorf, C., May, S., 2020. Uncertainty, Collaboration and Emerging Issues. In: Harrison, R., DeSilvey, C., Holtorf, C., Macdonald, S., Bartolini, N., Breithoff, E., Fredheim, H., Lyons, A., May, S., Morgan, J., Penrose, S., Högberg, A., Wollentz, G. (Eds.), Heritage Futures: Comparative Approaches to Natural and Cultural Heritage Practices. UCL Press, London, pp. 336–344. doi:10.2307/j.ctv13xps9m.28.
Hossain, M., Leminen, S., Westerlund, M., 2019. A systematic review of living lab literature. J. Clean. Prod. 213, 976–988. doi:10.1016/j.jclepro.2018.12.257.
Imset, M., Haavardtun, P., Tannum, M.S., 2018. Exploring the use of stakeholder analysis methodology in the establishment of a living lab. Technol. Innov. Manag. Rev. 8 (12), 26–39. doi:10.22215/timreview/1203.
International Agroecosystem Living Laboratories Working Group, 2019. Agroecosystem Living Laboratories: Executive Report. G20 Meeting of Agricultural Chief Scientists (G20-MACS) https://www.macs-g20.org/fileadmin/macs/Annual_Meetings/2019_Japan/ALL_Executive_Report.pdf. (Accessed 3 December 2021).
S. Joncoux, N. Lewis, 2019. Méthode « 4R » de construction d'une grille d'évaluation pour les démarches collaboratives. https://www.uqar.ca/uqar/recherche/unites_de_recherche/grideq/publications/evaluation_methode_4r_joncoux_et_lewis_2019.pdf (Accessed 3 December 2021).
Kovács, K., 2016. Evaluation and practice of interactive value production in living labs. Period. Polytech. Soc. Manag. Sci. 24 (1), 52–59. doi:10.3311/PPso.8336.
Latour, B., 2005. Reassembling the Social: An Introduction to Actor-Network-Theory. Oxford University Press, Oxford, New York.
Leminen, S., 2013. Coordination and participation in living lab networks. Technol. Innov. Manag. Rev. 3 (11), 5–14. doi:10.22215/timreview/740.
Leminen, S., Westerlund, M., 2019. Living labs: from scattered initiatives to a global movement. Creat. Innov. Manag. 28 (2), 250–264. doi:10.1111/caim.12310.
Lemos, M.C., Arnott, J.C., Ardoin, N.M., Baja, K., Bednarek, A.T., Dewulf, A., Fieseler, C., Goodrich, K.A., Jagannathan, K., Klenk, N., Mach, K.J., Meadow, A.M., Meyer, R., Moss, R., Nichols, L., Sjostrom, K.D., Stults, M., Turnhout, E., Vaughan, C., Wong-Parodi, G., Wyborn, C., 2018. To co-produce or not to co-produce. Nat. Sustain. 1, 722–724. doi:10.1038/s41893-018-0191-0.
McLoughlin, S., Maccani, G., Prendergast, D., Donnellan, B., 2018. Living labs: a bibliometric analysis. In: Proceedings of the 51st Hawaii International Conference on System Sciences, pp. 4463–4472. doi:10.24251/HICSS.2018.563.
McPhee, C., Bancerz, M., Mambrini-Doudet, M., Chrétien, F., Huyghe, C., Gracia-Garza, J., 2021. The defining characteristics of agroecosystem living labs. Sustainability 13 (4), 1718. doi:10.3390/su13041718.
McRoy, G., Schäpke, N., Holmén, J., Holmberg, J., 2020. Sustainability-oriented labs in real-world contexts: an exploratory review. J. Clean. Prod. 277, 123202. doi:10.1016/j.jclepro.2020.123202.
Mistry, I., Beaudoin, C., Kotecha, J., Evans, H., Stevens, M., Vermaire, J.C., Cooke, S.J., Young, N., 2021. Action research to improve water quality in Canada's Rideau Canal: how do local groups reshape environmental governance? Local Environ. 26 (5), 575–594. doi:10.1080/13549839.2021.1904857.
Moore, T., Horne, R., Doyon, A., 2022. Housing industry transitions: an urban living lab in Melbourne, Australia. Urban Policy Res. 38 (2), 118–131. doi:10.1080/08111146.2020.1730786.
Mulder, I., Velthausz, D., Kriens, M., 2008. The living lab harmonization cube: communicating living labs' essentials, the electron. J. Virtual Organ. Netw. 10, 1–14.
Ondiek, M.A., Moturi, C., 2019. An assessment of the sustainability of living labs in Kenya. Innov. Manag. Rev. 16 (4), 391–403. doi:10.1108/INMR-08-2018-0058.
Perz, S.G., 2019. Collaboration Across Boundaries for Social-Ecological Systems Science Experiences Around the World, 1st ed Palgrave Macmillan, Cham.
Schuurman, D., De Morr, K., De Marex, L., Evens, T., 2011. A living lab research approach for mobile TV. Telemat. Inform. 28 (4), 271–282. doi:10.1016/j.tele.2010.11.004.
Schuurman, D., Mahr, D., De Marez, L., Ballon, P., 2013. A fourfold typology of living labs: an empirical investigation amongst the ENoLL community. In: Proceedings of the International Conference on Engineering, Technology and Innovation (ICE) & IEEE International Technology Management Conference, pp. 1–11. doi:10.1109/ITMC.2013.7352697.
Schwartz, T., Stevens, G., Jakobi, T., Denef, S., Ramirez, L., Wulf, V., Randall, D., 2014. What people do with consumption feedback: a long-term living lab study of a home energy management system. Interact. Comput. 27 (6), 551–576. doi:10.1093/iwc/iwu009.
Serpa, S., Ferreira, C.M., 2019. Micro, meso and macro levels of social analysis. Int. J. Soc. Sci. Stud. 7 (3), 120–124. doi:10.11114/ijsss.v7i3.4223.
Sivam, A., Dieguez, T., Ferreira, L.P., Silva, F.J.G., 2019. Key settings for successful open innovation Arena. J. Comput. Des. Eng. 6 (4), 507–515. doi:10.1016/j.jcde.2019.03.005.
Ståhlbröst, A., 2012. A set of key principles to assess the impact of living labs. Int. J. Prod. Dev. 17 (1-2), 60–75. doi:10.1504/IJPD.2012.051154.
Steffen, W., Sanderson, A., Tyson, P.D., Jäger, J., Matson, P.A., Moore, B., Oldfield, F., Richardson, K., Schellnhuber, H.J., Turner, B.L., Wasson, R.J., 2004. Global Change and the Earth System: A Planet Under Pressure. Springer, Berlin.
Sterling, E.J., Filardi, C., Toomey, A., Sigouin, A., Betley, E., Gazit, N., Newell, J., Albert, S., Alvira, D., Bergamini, N., Blair, M., Boseto, D., Burrows, K., Bynum, N., Caillon, S., Caselle, J.E., Claudet, J., Cullman, G., Dacks, R., Eyzaguirre, P.B., Gray, S., Herrera, J., Kenilorea, P., Kinney, K., Kurashima, N., Macey, S., Malone, C., Mauli, S., McCarter, J., McMillen, H., Pascua, P., Pikacha, P., Porzecanski, A.L., de Robert, P., Salpeteur, M., Sirikolo, M., Stege, M.H., Stege, K., Ticktin, T., Vave, R., Wali, A., West, P., Winter, K.B., Jupiter, S.D., 2017. Biocultural approaches to well-being and sustainability indicators across scales. Nat. Ecol. Evol. 1, 1798–1806. doi:10.1038/s41559-017-0349-6.
Stewart, A.G., Hursthouse, A.S., 2018. Environment and human health: the challenge of uncertainty in risk assessment. Geosciences 8 (1), 24. doi:10.3390/geosciences8010024.
Sutherland, W.J., Shackelford, G., Rose, D.C., 2017. Collaborating with communities: coproduction or co-assessment? Oryx 51 (4), 569–570. doi:10.1017/S0030605317001296.
Taylor, L., 2021. Exploitation as innovation: research ethics and the governance of experimentation in the urban living lab. Reg. Stud. 55 (12), 1902–1912. doi:10.1080/00343404.2020.1826421.
Veal, A.J., 2006. Research Methods for Leisure and Tourism: A Practical Guide. Pearson Education, Sydney.
Vogel, C., Zwolinsky, S., Griffiths, C., Hobbs, M., Henderson, E., Wilkins, E., 2019. A Delphi study to build consensus on the definition and use of big data in obesity research. Int. J. Obes. 43, 2573–2586. doi:10.1038/s41366-018-0313-9.
von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., Coenen, L., 2019. Impacts of urban living labs on sustainability transitions: mechanisms and strategies for systemic change through experimentation. Eur. Plan. Stud 27 (2), 229–257. doi:10.1080/09654313.2018.1504895.
Voytenko, Y., McCormick, K., Evans, J., Schliwa, G., 2016. Urban living labs for sustainability and low carbon cities in Europe: towards a research agenda. J. Clean. Prod. 123, 45–54. doi:10.1016/j.jclepro.2015.08.053.
Westerlund, M., Leminen, S., Rajahonka, M., 2018. A topic modelling analysis of living labs research. Technol. Innov. Manag. Rev. 8 (7), 40–51. 10.22215/timreview/1170.
White, D.D., Larson, K.L., Wutich, A., 2018. Boundary organizations and objects supporting stakeholders for decision making on sustainable water management in Phoenix, Arizona USA. In: Sato, T., Chabay, I., Helgeson, J. (Eds.), Transformations of Social-Ecological Systems: Studies in Co-Creating Integrated Knowledge Toward Sustainable Futures. Springer, Singapore, pp. 333–352.
Young, O.R., 2013. On Environmental Governance: Sustainability, Efficiency and Equity, 1st ed. Routledge, London, New York.