Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Implementation of Living Labs for Circular Agrifood Innovation Across Six African Countries

Ranka Junge
Zurich University of Applied Sciences
Roland Azibo Balgah
Bamenda University of Science and Technology
Michael Reuter
Aquaponik Manufaktur GmbH
Zala Schmautz
zala.schmautz@zhaw.ch

Zurich University of Applied Sciences
Emmanuel Benjamin
Aglobe Development Center
Oyediran Olusegun Oyebola
University of Ibadan
Emmanuel Delwin Abarike
University for Development Studies
Sylvère Mboumba
Université des Sciences et Techniques de Masuku
Olufemi Julius Olapade
Njala University
Ibrahim Macharia
Kenyatta University
Josephine Ouma
Egerton University
Francesco Orsini
Alma Mater Studiorum – Università di Bologna
Giuseppina Pennisi
Alma Mater Studiorum – Università di Bologna
Sabine Desczka
Wageningen University and Research
Rolf Morgenstern
Fachhochschule SüdWestphalen
Gertrud Buchenrieder
University of the Bundeswehr Munich (UniBw M)

Research Article

Keywords:

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11296247/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.

Abstract

Rapid urbanisation and vulnerable rural–urban food supply chains have intensified interest in circular agri-food innovation across Sub-Saharan Africa. Living Labs are widely promoted as collaborative environments for developing and testing such innovations, yet empirical evidence on how they are established and operated under resource-constrained conditions remains scarce. This paper examines eight Living Labs implemented across six African countries within the Horizon Europe INCiTiS-FOOD project, drawing on three years of implementation plans, progress reports, onboarding records and technology validation reports. Using an exploratory qualitative multi-case design, the analysis identifies recurring implementation patterns and organisational features. Living Lab development did not follow a predefined pathway but proceeded through an iterative sequence of anchoring, sensemaking, structuring and iteration. A shared aquaponic prototype functioned as a boundary object that catalysed stakeholder engagement before governance structures and shared conceptual understanding had fully formed. Structured and continuous capacity building supported technical competence, but organisational learning remained vulnerable where knowledge was concentrated in individual staff rather than embedded in documentation, mentoring and organisational routines. Innovation outputs developed into portfolios combining system-level Minimum Viable Products with practice-level innovations. The findings extend existing Living Lab frameworks by highlighting the catalytic role of physical demonstration systems, structured capacity building as an organisational capability, and the changing contribution of Quadruple Helix actors over the Living Lab life cycle. They provide an operational framework for implementing circular agri-food Living Labs under resource-constrained conditions.

1. Introduction

Rapid urbanisation is reshaping food systems across Sub-Saharan Africa (SSA), placing growing pressure on cities to secure reliable, affordable, and nutritious food supplies. Urbanisation rates in the sub-continent increased from approximately 35% in the 1990s to 42% in 2022, and around 44% of the population (approximately 568 million people) now lives in urban areas (Kiribou et al., 2024; Statista, 2026). This demographic shift has intensified the dependence of urban populations on rural food supply chains that remain vulnerable to structural and environmental constraints, including weak transport infrastructure, high post-harvest losses, armed conflict, and climate-related disruptions (Balgah et al., 2023; FAO et al., 2023). Consequently, urban food insecurity has become an increasingly salient development challenge, with an estimated 34% of all food-insecure people in SSA now living in cities (Kiribou et al., 2024).

Although rural agriculture remains central to urban food provisioning in SSA, the vulnerability of rural-urban supply chains strengthens the case for complementary urban and peri-urban agriculture as part of more diversified and resilient city-region food systems (Davies et al., 2021). However, food production in urban and peri-urban environments is itself constrained by limited access to resources such as arable land and water, environmental contamination, fragile ecological conditions, inadequate infrastructure, and the continued use of obsolete technologies (Benjamin et al., 2024; FAO et al., 2023). Under these conditions, soilless production systems can complement conventional agriculture by enabling food production in locations where soil-based cultivation is difficult or impractical.

Sustainable urban food systems, particularly those based on circular agri-food approaches, therefore provide a relevant context for developing and testing innovations that respond to these interconnected challenges. This raises the question of how such innovations can be effectively implemented, adapted, and embedded within the diverse socio-economic and institutional realities of resource-constrained African urban and peri-urban settings.

Technologies such as aquaponics, hydroponics, and integrated aquaculture have been identified as promising “frontier” approaches to circular food production because they can improve resource-use efficiency while enabling production under constrained urban conditions (Verner et al., 2017, 2021). However, technological solutions alone are insufficient. Their successful implementation requires adaptation to local environmental, socio-economic, and institutional contexts, active stakeholder engagement, and the capacity to sustain innovations over time.

These requirements have stimulated interest in Living Labs: collaborative innovation environments in which multiple stakeholders jointly develop, test, and refine solutions under real-world conditions (European Network of Living Labs, 2026; Niitamo et al., 2006). Living Labs have also been described as adaptive intermediaries within the science-industry nexus. Nevertheless,

considerable ambiguity remains regarding their defining characteristics, the activities they encompass, and the conditions under which they operate.

Living Labs are commonly associated with the Quadruple Helix model, which brings together academia, industry, government and civil society in collaborative innovation processes (Almirall & Wareham, 2011; Leminen & Westerlund, 2019). The model provides a useful framework for organising innovation as a socially embedded process in real-world settings (Carayannis et al., 2018), where users become active contributors to problem definition, knowledge creation, policy development and technological innovation. Despite its growing popularity, the concept remains loosely defined, and empirical evidence of its effectiveness is limited (Hossain et al., 2019; Paskaleva & Cooper, 2021).

While recent conceptual contributions have advanced understanding of Living Lab frameworks and evaluation approaches (Bhatta et al., 2025; Sofronievska et al., 2025), empirical evidence on how Living Labs are established, structured, and sustained in practice remains limited. This is especially true for African agri-food contexts.

A targeted search of Scopus and Web of Science identified only a handful of publications addressing Living Labs in African agri-food systems. Only one (Pokupec et al., 2024) combined Living Labs, agroecological principles and an African setting, reporting on three demonstration sites under the PrAEctiCe project (European Commission, 2026b). Related studies have instead examined Living Labs in African urban contexts outside agriculture (Mbatha & Musango, 2022) or reviewed agroecology in Africa without applying a Living Lab lens (Romero Antonio et al., 2025). This near-absence of empirically grounded studies underscores the need for context-specific analyses of how Living Labs can be operationalised under African conditions.

This paper addresses this gap by analysing how a network of Living Labs was implemented within the Horizon Europe-funded project “INtegrated and Circular Technologies for Sustainable city region FOOD systems in Africa” (INCiTiS-FOOD) (European Commission, 2026a) under resource-constrained African conditions. INCiTiS-FOOD aims to strengthen food and nutrition security in African city regions through the co-creation of circular agri-food technologies, practices, and business models adapted to urban and peri-urban contexts. The project focuses on soilless cultivation (i.e., aquaponics, hydroponics, bioponics), recirculating aquaculture systems, and insect farming as circular agri-food solutions for African cities.

By examining the implementation of these Living Labs, the paper analyses how circular agri-food innovations were adapted to local conditions through stakeholder engagement, experimentation, organisational learning, and iterative development rather than simply transferred into SSA contexts.

Specifically, the paper is guided by the following research questions:

- **RQ1**: How can Living Labs be operationalised in resource-constrained African urban and peri-urban contexts to support circular agri-food innovation?
- **RQ2**: How do these implementations extend or challenge existing Living Lab frameworks, which are largely derived from European contexts?

The paper first reviews the conceptual foundations of Living Labs and their relevance for circular agri-food innovation. It then presents the study design and analytical approach used to examine the implementation of the INCiTiS-FOOD Living Lab network. The findings are discussed in relation to existing Living Lab concepts, leading to an operational framework for implementing Living Labs in resource-constrained circular agri-food systems.

2. Living Labs: Conceptual Foundations and State of the Art

2.1 Living Labs: Origins and Conceptual Development

The Living Lab concept gained prominence in the early 2000s within information and communication technology (ICT) and open innovation contexts, where real-life environments were used to test user-oriented technologies (Eriksson et al., 2005; Niitamo et al., 2006). The establishment of the European Network of Living Labs (ENoLL) in 2006 marked a turning point by embedding the approach within European innovation policy (Schuurman et al., 2015). While individual African Living Labs also became

associated with ENoLL, a coordinated African Living Lab network did not emerge, prompting early calls for innovation platforms administered by African institutions and stakeholders (Nesti, 2015). At the time, however, these discussions remained largely aspirational, with only scattered documented examples of Living Lab-type activity on the continent. Nearly one decade later, several collaborative EU-AU initiatives have adopted Living Lab principles to support innovation in African agri-food systems. INCiTiS-FOOD is one such initiative, establishing a network of Living Labs across multiple African countries. Similar participatory approaches have also been adopted by projects such as FoodLAND through its network of "Food Hubs" (FoodLAND, 2026). These initiatives illustrate the growing application of Living Lab principles within African agri-food innovation.

Over time, Living Labs have evolved from technology-oriented testbeds towards more context-sensitive innovation environments that emphasise co-creation, stakeholder engagement and participatory governance. More recently, they have increasingly been positioned as instruments for supporting sustainability transitions and addressing complex societal challenges (Paskaleva & Cooper, 2021; Schuurman & Leminen, 2021).

Living Labs lack a unified definition despite their widespread use. Reviews identify more than 70 distinct formulations reflecting their application across diverse domains, including ICT, urban governance, health, and agri-food systems (Hossain et al., 2019). Depending on the context, Living Labs may be understood as physical environments, real-life experimentation environments, methodological approaches, multi-stakeholder innovation systems, participatory methodologies, and public-private-people partnerships (Dutilleul et al., 2010). While this plurality enables flexibility and cross-domain applicability, it also contributes to conceptual fragmentation, making comparison, evaluation, and cumulative learning more difficult (Greve et al., 2021).

2.2 Living Labs as Collaborative Innovation Environments

Living Labs are rooted in open innovation (Chesbrough, 2003) and user innovation, which emphasise distributed knowledge creation and the active involvement of users. They bring together academia, industry, government, and civil society to develop and test innovations under real-life conditions, while also facilitating knowledge integration, stakeholder interaction, and iterative experimentation. Their role therefore extends beyond technological development to include coordination, facilitation, and governance, including the reconciliation of differing stakeholder expectations under resource and institutional constraints (Veeckman & Temmerman, 2021; Westerlund et al., 2018).

Urban Living Labs apply this collaborative approach to complex sustainability challenges, combining experimentation, stakeholder participation, and governance to co-create public value rather than merely products or services (Steen & van Bueren, 2017). Their longer-term contribution depends on embedding learning in governance and decision-making structures and supporting institutionalisation beyond individual projects (Steen & van Bueren, 2017; Veeckman & Temmerman, 2021). Although most documented examples originate from European urban contexts, these insights are also relevant to rapidly urbanising regions such as SSA, where Living Labs can link technological innovation, stakeholder engagement, and urban food governance while supporting locally adapted circular agri-food solutions.

2.3 Living Labs and Sustainability Transitions

Living Labs are increasingly positioned as mechanisms for supporting sustainability transitions. In agriculture, Agroecosystem Living Labs emphasise co-design, long-term experimentation, place-based innovation, and the integration of scientific and local knowledge under real-world conditions (McPhee et al., 2021). This reflects a broader shift from technology-oriented experimentation towards longer-term processes of stakeholder collaboration, adaptive learning, governance, and organisational development through which innovations become embedded in local contexts.

Despite these conceptual developments, empirical evidence remains concentrated in European settings. Comparatively little is known about how Living Labs are established and sustained in African agri-food systems, particularly under resource-constrained conditions (Mbatha & Musango, 2022; Ondiek & Moturi, 2019). This study therefore examines how Living Lab principles were operationalised across a network of African circular agri-food Living Labs, focusing on the implementation processes and organisational conditions that shaped their development.

3. Study Design and Analytical Approach

3.1 The INCiTiS-FOOD Living Lab Network

The Horizon Europe INCiTiS-FOOD project (European Commission, 2026a) established eight Living Labs across six African countries (Table 1): Aglobe Development Center (ADC, Nigeria), Bamenda University of Science and Technology (BUST, Cameroon), Egerton University (EGE, Kenya), Kenyatta University (KU, Kenya), Njala University (NUSL, Sierra Leone), University of Development Studies (UDS, Ghana), University of Ibadan (UI, Nigeria), and Université des Sciences et Techniques de Masuku (USTM, Gabon). The network aimed to strengthen urban and peri-urban food systems by improving food and nutrition security, resource efficiency, and community resilience.

All Living Labs began with a common conceptual and technical baseline: a standardised aquaponic training system (**Supplementary Material S1**). They subsequently diversified their innovation portfolios according to local priorities, available materials, and emerging opportunities, introducing technologies such as simplified hydroponics, Black Soldier Fly (BSF) production, bioponics, recirculating aquaculture hatcheries, snail farming, and soil-based cultivation. Their stakeholder orientation also varied, encompassing different combinations of education and training, farmer outreach, entrepreneurship support, community engagement, and food production.

This variation among eight sites operating under a shared project framework and during the same period provided a comparative basis for identifying recurring implementation dynamics and context-specific adaptations.

Table 1
Structure and characteristics of INCITIS-FOOD Living Labs.

Living Lab	Lead institution	Location	Coordinates (Latitude, Longitude)	Core system(s)	Complementary technologies	Stakeholder focus	Context-specific adaptations
ADC	Aglobe Development Center	Lagos, Nigeria	6.5844752, 3.2998071	Aquaponics (Screenhouse)	Snail farming	Urban entrepreneurs	Adaptation to dense urban context (greenhouse systems)
BUST	Bamenda University of Science and Technology	Bamenda, Cameroon	10.2180068, 5.9952272	Aquaponics	Hydroponics	Local communities	Combination of standard and adapted system variants
EGE	Egerton University	Nakuru, Kenya	-0.369734, 35.932779	Aquaponics + hydroponics	BSF, bioponics	Youth, schools, local communities	Outreach oriented (school visits), system diversification, focus on indigenous vegetables
KU	Kenyatta University	Nairobi, Kenya	-1.182591, 36.929328	Aquaponics + simplified hydroponics	Black Soldier Fly (BSF), hydroponics	Students, urban farmers	Strong educational function
NUSL	Njala University	Moyamba, Sierra Leone	8.117364, -12.069393	Aquaponics	Aquaculture, vegetable crops	Students, local farmers	Focus on locally relevant crops (e.g., okra)
UDS	University for Development Studies	Tamale, Ghana	9.41405, -0.97986	Aquaponics	Chop-and-flip aquaponics, off-grid systems	Smallholders	Comparison soil vs. soilless; adaptation to local farming practices
UI	University of Ibadan	Ibadan, Nigeria	7.4412742, 3.9025738	Aquaponics + simplified hydroponics	BSF	Farmers, trainees	Emphasis on low-tech, accessible systems
USTM	Université des Sciences et Techniques de Masuku	Franceville, Gabon	1.6196441, 13.6015463	Aquaponics (greenhouse)	Aquaculture (hatchery), vegetable crops in soil	Students, farmers, trainees	Focus on capacity building and training

3.2 Research Design

The study follows an exploratory, qualitative multi-case study design (Yin, 2017). The individual Living Lab constituted the unit of analysis, with the eight Living Labs treated as embedded cases within the shared INCiTiS-FOOD project framework.

The aim was not to evaluate or rank individual sites or test pre-specified hypotheses, but to identify cross-cutting implementation patterns and structural features relevant to Living Lab operationalisation under resource-constrained conditions. The analysis was therefore interpretive and comparative, drawing on project documentation produced between January 2023 and May 2026.

Several authors were directly involved in designing, coordinating, and delivering capacity-building activities across the Living Lab network. This involvement provided detailed contextual insight but also introduced a potential risk of interpretive bias. To mitigate this risk, the analysis was grounded in documented evidence from all eight Living Labs and focused on patterns supported by multiple sources. The implications of the authors' embedded roles are discussed further in Section 5.6.

3.3 Data Sources

The empirical basis of the study comprised project documentation produced systematically by Living Lab staff and the wider consortium during the first three years of implementation. Together, these sources provided a longitudinal record of organisational development, stakeholder engagement, capacity building, and technology co-creation. The cited deliverables are publicly available through the INCiTiS-FOOD project website (https://incitis-food.eu/deliverables/) and the CORDIS platform (European Commission, 2026a). The following sources were included:

Living Lab Implementation Plans (D2.2). Each Living Lab produced a structured Implementation Plan covering governance, physical infrastructure, stakeholder mapping, training activities, dissemination, and operational logbooks. These plans constituted the primary qualitative source on Living Lab establishment, stakeholder engagement, capacity-building, and operational development.

Progress and coordination reports (D2.1 and D2.3). Two rounds of communication and capacity-building reports documented the evolution of the network, including weekly coordination meetings conducted through MS Teams, Training of Trainers events, Training of Stakeholders sessions, and inter-Living Lab knowledge exchange. D2.3 also documented the first batch of *Practice Abstracts*.

Onboarding data. Onboarding records were compiled retrospectively from the eight Living Labs, which operated under a common project framework but used locally adapted procedures. An onboarded member was defined as an external stakeholder whose formal engagement was documented through an onboarding form, declaration of intent, partnership agreement, or equivalent instrument, and whose participation in at least one Living Lab activity beyond initial registration was confirmed by the respective Living Lab manager. Because procedures evolved during implementation and were not standardised across the network, functionally equivalent instruments were treated consistently for analytical purposes. Discrepancies or ambiguities were resolved in consultation with the respective Living Lab managers, and only verified data were included in the analysis.

Stakeholders were assigned to Quadruple Helix categories based on information provided during onboarding, including occupation, organisational affiliation, and sector. The respective Living Lab managers reviewed the lead author's initial classifications, and ambiguous cases were resolved jointly. Twelve participants who did not report their age were excluded from age-specific analyses but were retained in all other analyses.

Technology validation reports (D2.4). Documentation of validated *Minimum Viable Products* (MVPs) provided evidence of technological development, local adaptation, and implementation challenges across the Living Labs.

3.4 Analytical approach

The analysis combined descriptive cross-case comparison with the inductive identification of recurring implementation patterns and organisational features. Documentary evidence was reviewed systematically across six areas: Living Lab establishment, stakeholder engagement, governance, capacity building, technological development, and organisational adaptation. The eight cases were then compared to identify common features, recurring patterns, and context-specific variations. These patterns informed the synthesis presented in Sections 4 and 5, including the operational framework in Table 2.

The analysis was conducted primarily by the lead authors (R.J., A.R.B., and G.B.), with iterative input from co-authors at each Living Lab site, who reviewed the cross-site characterisations. Interpretive disagreements were resolved through discussion during consortium coordination meetings.

Consistent with the exploratory design, the findings are intended to support analytical rather than statistical generalisation. They provide empirically grounded insights relevant to theory building and to comparable Living Lab initiatives in resource-constrained African urban and peri-urban agri-food systems and contribute to a field where comparable case evidence remains limited.

4. Implementing Living Labs for Urban African Circular Agri-Food Systems

4.1 Implementation Framework

Implementation across the INCiTiS-FOOD Living Labs followed a structured but adaptive approach, combining several common features with context-specific variation. First, technology provided a practical entry point for stakeholder engagement. Although the Living Labs could select from several circular agri-food options, all initially established aquaponic prototypes. These systems offered a tangible demonstration of circular food production and, owing to their modular design, could be adapted to local conditions and extended through the integration of complementary technologies. Subsequent developments included simplified hydroponics, Black Soldier Fly (BSF) rearing, snail farming, organic-waste digesters, and sand filtration for water pre-treatment. Second, capacity building was organised as a continuous rather than ad hoc process (**Supplementary Material S2**). Living Lab leaders and managers participated in an online course, on-site Training of Trainers sessions, webinars, and mentoring exchanges. This structured training programme developed local technical expertise and enabled the subsequent training of additional stakeholders. Third, stakeholder engagement was actively developed. Each Living Lab involved a locally specific combination of students, non-governmental organisations (NGOs), smallholder farmers, women and youth groups, entrepreneurs, public authorities, and research institutions. Although stakeholder composition varied, all sites adopted a multi-actor approach involving representatives of the Quadruple Helix. Fourth, governance structures incorporated inclusive co-management. Each Living Lab was managed by at least two staff members differing in gender and/or age, supported by academic leads, technicians, and trainees. Fifth, all Living Labs operated within a shared ethical and operational framework comprising Codes of Conduct, laboratory safety rules, and fish welfare guidelines adapted to local contexts (**Supplementary Material S3**). Finally, digital communication tools, primarily WhatsApp and MS Teams, supported continuous communication, cross-site coordination, knowledge exchange, and joint problem-solving.

4.2 Implementation Dynamics

Implementation did not follow a linear sequence but proceeded through repeated cycles of experimentation, adaptation, and learning. Although all sites began with aquaponic prototypes, their subsequent development varied according to resource availability, institutional support, stakeholder composition, and emerging priorities. Adjustments in training, stakeholder engagement, and organisational practices accompanied technical modifications. Over time, the emphasis shifted from establishing and operating the prototypes towards collaborative problem-solving and the co-development of locally adapted solutions.

Staff turnover

Staff continuity varied across the network between months 12 and 41 of the project **(Supplementary Material S4)**. Of the 61 staff members documented at month 12, 18 (30%) were no longer involved by month 41; however, this figure included student trainees who had completed their academic programmes. Excluding students, retention of core operational personnel exceeded 80% across the network, with ADC and NUSL experiencing the highest turnover.

Onboarding of External Members

Across the eight Living Labs, 202 external members were onboarded, exceeding the contractual minimum of ten members per site. Membership ranged from 11 at NUSL and UDS to 74 at UI, with an average of approximately 25 members per Living Lab (**Supplementary Material S5**).

Gender composition

Female participation averaged 47.3% and male participation 51.4%; two participants preferred not to declare their gender. Female representation ranged from 37.8% at UI to 55.9% at KU, with near gender parity achieved in most Living Labs. This pattern was consistent with the project's commitment to gender-inclusive recruitment and stakeholder-engagement approach.

Age composition

Youth participation, defined according to the African Youth Charter (African Union, 2006) as persons aged 15–35 years, averaged 50.6%. Twelve participants who did not report their age were excluded from this analysis. Youth representation ranged from 35.0% at EGE to 66.7% at USTM.

Quadruple Helix composition

Citizens and NGO representatives constituted the largest stakeholder group (83.7%; n = 169), followed by industry (8.4%; n = 17), academia (5.4%; n = 11), and government (2.5%; n = 5). Government representatives were present only at the UDS and UI.

4.3 Innovation Outputs of the Living Labs

Co-creation activities generated an Innovation Portfolio spanning crop production, aquaculture, nutrient management, infrastructure, business development, and capacity building (**Supplementary Material S7**). The portfolio comprised *Minimum Viable Products*, representing functional system-level solutions, and Practice Innovations, representing technical, operational, or management improvements emerging during implementation. Practice Innovations were documented and disseminated through *Practice Abstracts* published on the project's Knowledge Hub.

5. Discussion

5.1 From Technology Demonstration to Living Labs: Sequencing Implementation in Resource-Constrained Settings

One of the principal findings of this study concerns the sequence through which the Living Labs developed. The eight Living Labs did not follow a predefined implementation pathway but evolved through interactions among technological experimentation, stakeholder engagement, capacity building, and organisational adaptation. The Living Lab concept therefore acquired operational meaning progressively through implementation rather than being fully established at the outset.

The choice of aquaponics as the initial demonstration technology played a central role in this process. By visibly integrating fish production, plant cultivation, water recirculation, nutrient recycling, and biological processes, the prototype made key principles of circular agri-food production directly observable. It functioned not only as a demonstration technology but also as a boundary object through which stakeholders from different disciplinary and societal backgrounds could develop a shared understanding of the technology and the broader purpose of the Living Lab. The prototype thus provided a material anchor for dialogue, experiential learning, and context-specific innovation. This suggests that selecting an initial demonstration technology is a strategic as well as a technical decision: technologies that visibly integrate multiple sustainability principles may be particularly effective in catalysing stakeholder engagement under resource-constrained conditions.

Implementation proceeded through repeated cycles of experimentation, reflection, and adaptation. Technological refinement, stakeholder participation, and organisational development continuously influenced one another, gradually transforming the sites from technology-centred demonstrations into spaces for collaborative problem-solving and locally adapted innovation. This differs from the emphasis in much of the Living Lab literature, which foregrounds participation and co-creation but gives less attention to the catalytic role of physical demonstration systems (Schuurman et al., 2015; Schuurman & Leminen, 2021). In the INCiTiS-FOOD Living Labs, innovation emerged as a co-evolutionary process in which technologies, stakeholder capabilities, and organisational practices developed together.

Across the eight Living Labs, this process can be summarised as a recurring implementation sequence (Fig. 1):

- **Anchor**: Establish minimal physical infrastructure to provide a tangible reference point for experimentation.
- **Sensemaking**: Facilitate stakeholder reflection and develop a shared understanding of system purpose and functions.
- **Structuring**: Define organisational roles, governance arrangements, and operational processes.
- **Iteration**: Conduct repeated cycles of co-creation, experimentation, evaluation, and adaptation.

This sequence is consistent with transition management frameworks that emphasise interaction between experimentation, reflexive learning, and knowledge integration across strategic, tactical, and operational levels (Loorbach et al., 2017; Schot & Steinmueller, 2018). It also accords with evidence that experiential learning benefits from structured conceptual scaffolding (Sundman et al., 2025).

A central challenge, however, was the different pace of material and organisational development. Physical infrastructure and stakeholder networks could be established relatively quickly, whereas organisational routines, institutional memory, and shared

working practices required more time and deliberate management. This tension between rapid deployment and slower institutionalisation has important implications for Living Lab design and continuity.

The iteration stage shown in Fig. 1 is further elaborated in Fig. 2, illustrating how the shared prototype diversified into multiple system- and practice-level innovation pathways. Testing, stakeholder feedback, evaluation, and cross-Living Lab learning connected these pathways through a continuing process of refinement.

5.2 Knowledge retention and organisational learning

The structured capacity-building programme implemented across the INCiTiS-FOOD Living Labs successfully established technical competencies and supported the development of local expertise. However, the implementation experience also revealed that sustaining organisational learning requires more than capacity building alone. Although more than 80% of core operational personnel were retained in most Living Labs, staff turnover varied considerably across the network (**Supplementary Material S4**). Where key trained personnel left, practical experience and competencies acquired through Training of Trainers activities were only partially transferred to their successors.

These experiences demonstrated that capacity building is essential for maintaining innovation capacity over time, particularly because it enables teams to gain hands-on experience in practical management and knowledge transfer. However, its long-term impact needs to be strengthened by institutionalising the knowledge gained through documentation, mentoring, shared responsibilities, and organisational routines, thereby ensuring that it remains available beyond the individuals initially trained.

Organisational learning emerged through iterative implementation and adaptation to local practice, building on formal training and the original project design. This highlights the value of Living Labs as environments in which knowledge develops continuously through co-creation, practical experience, and reflection. Deliberate mechanisms for preserving and transferring this knowledge can support its accumulation over time and ensure that the benefits of capacity building extend across teams and organisations.

These findings extend previous Living Lab research, which has primarily emphasised stakeholder participation, co-creation, and experimentation (Schuurman et al., 2015), by identifying organisational memory as an equally important dimension. In resource-constrained environments, where personnel changes may be unavoidable, embedding competencies in documentation, mentoring structures, shared digital repositories, and routine organisational practices may be as important as developing technical expertise itself.

Future Living Lab initiatives should therefore combine individual capacity building with strategies that embed practical knowledge within organisations. These may include codification through protocols and manuals, training multiple actors to strengthen shared responsibilities, and continuously updating knowledge as personnel, technologies, and local conditions change. The effectiveness of these complementary approaches remains an important area for future research.

The implementation experience further suggests that organisational learning should ultimately translate into a broader set of operational capabilities. Drawing on observations across the eight Living Labs, we synthesised these capabilities into an operational framework describing the principal stakeholder-oriented functions of Living Labs together and the organisational conditions required to sustain them (Table 2).

Table 2
Operational framework for Living Lab implementation derived from the INCiTiS-FOOD experience.

Stakeholder-oriented functions (offers)	Description	Enabling conditions	Rationale
1. Solution portfolio	Portfolio of locally adapted, feasible circular and agroecological solutions across the food value chain	Access to scientific expertise and technical backstopping	Ensures relevance, feasibility, and credibility of proposed solutions
2. Dialogue and listening space	Neutral and inclusive platform for stakeholders to express needs, constraints, and aspirations	Skilled facilitation and inclusive participation mechanisms	Builds trust and ensures stakeholder relevance
3. Stakeholder facilitation	Structured methods (e.g., focus groups, participatory design, scenario planning) to support co-creation	Trained facilitators and methodological capacity	Translates stakeholder input into actionable innovation pathways
4. Participation support	Practical support to enable inclusive participation (e.g., covering basic participation costs)	Flexible funding mechanisms	Ensures inclusion of underrepresented groups
5. Advisory and decision-support services	Continuous support through human interaction and simple digital tools (e.g., messaging platforms)	Communication infrastructure and follow-up mechanisms	Enables sustained engagement and context-specific guidance
6. Small-scale experimentation capacity	Ability to test and adapt solutions under real-world conditions	Physical infrastructure and basic research capacity	Supports learning, validation, and local adaptation
7. Access to financing and business support	Guidance on funding opportunities and business development	Links to financial actors and advisory tools	Facilitates scaling and long-term sustainability
8. Knowledge continuity and retention	Mechanisms to preserve, share, and transfer knowledge within and across LLs	Documentation systems, training redundancy, digital repositories, structured routines	Prevents loss of competencies due to staff turnover and stabilises long-term learning processes

The operational framework in Table 2 builds on individual capacity building by identifying the broader organisational capabilities required for effective Living Lab implementation. It shows, first, that circular agri-food innovation depended not on transferring a single technology, but on combining and adapting a portfolio of technical options to local constraints and stakeholder priorities. Second, dialogue, stakeholder facilitation, and participation did not arise automatically from the establishment of physical infrastructure; meaningful co-creation required deliberate facilitation, inclusive governance, and sufficient resources for sustained engagement. Third, small-scale experiments and physical prototypes served as boundary objects, making concepts such as circularity, nutrient recycling, and resource efficiency tangible while supporting shared learning among different actor groups. Finally, knowledge continuity required deliberate mechanisms for documentation, mentoring, shared responsibilities, and organisational routines. Together, these capabilities position Living Labs not merely as technology demonstration sites, but as organisations that sustain continuous learning, adaptation, and innovation.

5.3 Living Labs as Evolving Innovation Ecosystems: From Prototypes to Innovation Portfolios

Beyond the implementation process itself, one of the most important findings of this study concerns the nature of innovation generated within the Living Labs. Rather than producing isolated technological outputs, the Living Labs progressively evolved into innovation ecosystems in which system-level and practice-level innovations co-developed through iterative stakeholder interaction.

Existing Living Lab literature characterises Living Labs as environments for co-creation, experimentation and user involvement (Leminen & Westerlund, 2019; Niitamo et al., 2006; Schuurman & Leminen, 2021). However, comparatively little attention has been

paid to the different forms of innovation generated during implementation and how they interact as Living Labs evolve.

In the INCiTiS-FOOD Living Labs, *Minimum Viable Products* and *Practice Abstracts* proved not to be two independent output categories, but a continuum of system- and practice-level innovations. *Minimum Viable Products* represent functional technological solutions, whereas Practice Innovations capture the operational knowledge required to adapt, simplify, maintain or replicate these systems under local conditions. The *Practice Abstract* serves as the dissemination format for this knowledge rather than constituting the innovation itself. In practice, both forms of innovation co-evolved through repeated cycles of stakeholder feedback, experimentation and refinement. Consequently, Living Lab innovation is better understood as an iterative knowledge-generation process than as the production of discrete technological outputs.

Our findings are consistent with the observation by Ballon et al. (2018) that Living Labs predominantly foster incremental rather than disruptive innovation. Rather than generating entirely new technological paradigms, the INCiTiS-FOOD Living Labs continuously improved existing systems through numerous practice-level innovations, such as simplified filtration, substrate adaptations, locally available fertilisers, or improved cultivation protocols. Collectively, these incremental innovations substantially increased the usability and local relevance of the developed systems.

This evolution was reflected not only in the diversity of innovations but also in the diversification of Living Lab functions. Across the network, additional plant species, complementary production systems and new combinations of circular technologies emerged (**Supplementary Material S6**). Rather than remaining centred on a single aquaponic prototype, the Living Labs progressively evolved into multi-actor innovation ecosystems characterised by increasing biological diversity, technological diversification, stakeholder learning and organisational adaptation. These trajectories differed among Living Labs, illustrating context-specific rather than linear pathways of innovation.

The Innovation Portfolio of INCiTiS-FOOD (**Supplementary Material S7**) provides empirical support for conceptualising Living Labs as innovation ecosystems rather than merely technology demonstration sites (Schuurman & Leminen, 2021; Westerlund et al., 2018). Innovation occurred simultaneously at system, component, operational and organisational levels, reflecting continuous interaction between technological experimentation, stakeholder knowledge and local contextual adaptation.

Rather than evaluating Living Labs solely by the maturity of technological products, future assessments should also consider the accumulation of transferable practice knowledge generated during implementation. From this perspective, Innovation Portfolios provide a more comprehensive representation of Living Lab outcomes by integrating technological, organisational and practice-based innovations. The Innovation Portfolios proposed here extend current Living Lab thinking by explicitly recognising multiple interconnected levels of innovation, rather than viewing technological development as the primary outcome of Living Lab activities.

5.4 Implementing Living Labs Under Resource-Constrained African Conditions

The INCiTiS-FOOD Living Labs retained core Living Lab principles, including real-life experimentation, stakeholder co-creation, and multi-actor engagement, but adapted their implementation to resource-constrained African urban and peri-urban contexts. Unlike Living Labs emerging from stable institutional settings with established governance and methodological frameworks, these sites began with functioning demonstration systems. These aquaponic prototypes provided material anchors that triggered engagement and learning, while stakeholder relationships, conceptual understanding, and organisational structures developed progressively through implementation.

Four interrelated adaptations are particularly important. First, the Living Labs had a strong thematic orientation towards circular agri-food systems and therefore functioned both as innovation platforms and as demonstrators of resource-efficient production. Second, structured and continuous capacity building was treated as a central implementation component rather than a supporting activity. Third, inclusivity, ethics, and safety were explicitly operationalised through co-management arrangements, codes of conduct, ethical oversight, and locally adapted guidelines. These features, together with the integration of experimentation and education, enabled the Living Labs to operate as locally embedded competence hubs rather than solely as experimental platforms.

Finally, the findings indicate that the Quadruple Helix should be understood dynamically. Universities and civil-society organisations provided much of the initial momentum, with physical demonstration systems serving as implementation anchors, while government participation remained limited during establishment. Public actors may, however, become increasingly important during institutionalisation, policy integration, long-term financing, and scaling. Table 3 summarises how these features extend established Living Lab principles under resource-constrained circular agri-food conditions.

Table 3
Operationalisation of Living Lab principles in INCiTiS-FOOD compared to general Living Lab concepts.

Dimension	General Living Lab Concept	INCiTiS-FOOD Living Labs
Core principle	User-centred innovation and co-creation under real-life conditions	Circular agri-food innovation addressing urban and peri-urban food security
Implementation entry point and pathway	Iterative prototyping and user-driven adaptation, often within an established organisational setting	Functioning aquaponic prototypes as initial anchors, followed by diversification into locally adapted technologies and practices
Stakeholder configuration	Quadruple Helix participation involving academia, government, industry, and civil society	Context-adapted and evolving configuration involving universities (academic leads), NGOs, farmer groups, women and youth organisations, entrepreneurs, and public actors
Innovation approach	Iterative prototyping and user-driven adaptation	Sequential and adaptive pathway: initial aquaponics prototypes followed by diversification into lower-cost, locally adaptable systems (hydroponics, insect farming, snail farming) using locally available materials
Capacity building	Often project-specific or treated as a supporting function	Structured and continuous programme comprising an online course, Training of Trainers, webinars, mentoring, and peer exchange
Inclusivity, ethics, and safety	Increasingly recognised but inconsistently operationalised	Embedded through co-management arrangements, women peer-to-peer engagement formats, codes of conduct, ethical oversight, laboratory safety rules, and fish welfare guidelines adapted to local contexts
Learning and coordination function	Real-life experimentation, validation, and stakeholder interaction	Combined experimentation, demonstration, education, and inter-Living Lab learning supported by digital communication and shared repositories
Role of resource constraints	Frequently implicit or insufficiently represented in implementation frameworks	Explicit and formative: limitations in infrastructure, inputs, finance, and institutional capacity shaped technology selection, system design, and innovation pathways

Taken together, these findings suggest that the INCiTiS-FOOD Living Labs do not merely apply existing Living Lab concepts but reinterpret them under the conditions of resource-constrained circular agri-food innovation. Rather than questioning established Living Lab principles, the findings extend them by highlighting the importance of physical demonstration systems as implementation catalysts, structured capacity building as an organisational capability, and the dynamic contribution of Quadruple Helix actors throughout Living Lab development.

5.5 Practical implications and future directions

The implementation experience of the INCiTiS-FOOD Living Labs highlights several practical considerations for the design and long-term sustainability of future Living Lab initiatives. While the project demonstrated that resource-constrained Living Labs can successfully introduce and adapt circular agri-food technologies, maintaining these innovation ecosystems beyond project funding remains a major challenge.

The SmartAgriHubs Self-Assessment Tool (Berkers et al., 2021) was applied as a reflective, team-facilitation exercise rather than an analytical instrument, to stimulate discussion among Living Lab teams regarding their demonstration capacities and organisational development. This exercise surfaced issues extending beyond technical implementation: the long-term viability of Living Labs will depend on retaining trained personnel, embedding knowledge within organisational routines rather than individual staff members, securing sustainable financing, maintaining physical infrastructure, and strengthening institutional anchoring.

These observations suggest that future Living Lab initiatives should devote greater attention to post-project governance and exit strategies. The recent establishment of the African Network of Living Labs (ANoLL, 2026) and the engagement of several partner cities with the Milan Urban Food Policy Pact (MUFPP, 2026) illustrate how project-based Living Labs can begin to evolve towards more durable institutional and governance structures. Although these developments remain at an early stage, they indicate possible pathways through which Living Labs may contribute to longer-term urban food-system transformation.

The findings also suggest opportunities to strengthen future implementation approaches. Capacity-building programmes could increasingly complement Training of Trainers models with more horizontal peer-learning approaches, enabling trained participants to become facilitators within their own communities and reducing dependence on individual key people. Likewise, the substantial tacit implementation knowledge generated during Living Lab operation would benefit from more systematic codification. Drawing inspiration from design-pattern approaches developed in software engineering and collaborative innovation (Ohlig & Weiler, 2007), future work could develop a **Living Lab Design Patterns** framework that captures recurring implementation solutions in a structured, context-sensitive and transferable form.

5.6 Study scope and future research

The findings should be interpreted within the scope of the study design. The analysis drew primarily on project documentation, internal reports, training records, questionnaires, meeting records, and partner materials generated during implementation. These sources provided rich longitudinal and contextual evidence but may underrepresent challenges or unsuccessful experiences compared with independent external evaluation. Several authors also held embedded roles in designing, coordinating, and implementing the Living Lab network. This proximity enabled access to decision-making processes and tacit organisational knowledge but introduced a potential risk of interpretive bias. To strengthen the credibility of the findings, evidence from multiple sources and all eight Living Labs was triangulated throughout the analysis.

Furthermore, this study examined a single network established within a common Horizon Europe framework. As is characteristic of exploratory case study research, its purpose was therefore analytical rather than statistical generalisation: the findings may be transferable to comparable circular agri-food innovation contexts characterised by similar organisational, institutional, and resource constraints.

The study focused on implementation, organisational development, and innovation dynamics rather than long-term impacts. Future research should examine the organisational sustainability of Living Labs beyond project funding, including mechanisms for knowledge retention and institutional anchoring; assess the adoption and broader food-system effects of the innovations generated; and compare Living Lab networks across geographical and institutional contexts to distinguish broadly applicable implementation principles from context-specific ones.

6. Conclusions and Outlook

This study examined how eight INCiTiS-FOOD Living Labs were operationalised and evolved as an exploratory case of circular agri-food innovation in resource-constrained African urban and peri-urban contexts. The findings show that Living Labs can support the introduction and local adaptation of circular agri-food technologies when technological experimentation is combined with stakeholder engagement, structured capacity building, and inclusive governance.

Implementation followed context-specific pathways rather than a predefined blueprint. Aquaponics prototypes served as effective entry points for stakeholder engagement and experiential learning, particularly when they made principles such as circularity and resource efficiency directly observable. However, transforming technology demonstration sites into multi-actor innovation ecosystems required continued facilitation, reflection, and organisational development. Knowledge retention emerged as a critical challenge, indicating that competencies must be embedded in documentation, mentoring, shared responsibilities, and organisational routines rather than remaining concentrated in trained individuals.

The Living Labs also generated an Innovation Portfolio combining system-level innovations, represented by *Minimum Viable Products*, with practice-level innovations documented through *Practice Abstracts*. These outputs emerged through iterative interaction among experimentation, stakeholder knowledge, and local adaptation. Together with the operational framework developed in this study, the findings extend Living Lab scholarship by showing how resource limitations, institutional variability,

and evolving stakeholder configurations shape implementation. They also suggest that Quadruple Helix participation changes over the Living Lab life cycle: universities, civil-society organisations, and practitioners provided much of the initial momentum, whereas government actors may become increasingly important for institutionalisation, policy integration, financing, and scaling.

The long-term continuity of such Living Labs will depend on institutional anchoring, sustainable financing, continued stakeholder participation, and mechanisms for preserving organisational knowledge beyond individual project cycles. The establishment of the ANoLL offers a potential platform for sustaining collaboration, knowledge exchange, and mutual support across Living Labs, while the engagement of several partner cities with the Milan Urban Food Policy Pact illustrates a complementary pathway for linking local experimentation with wider urban food governance. Although both developments remain at an early stage, they indicate how project-based Living Labs may evolve towards more durable networked and institutional arrangements.

Future research should examine the durability of Living Labs beyond project funding, the effectiveness of knowledge-retention mechanisms, the evolution of stakeholder roles, and their longer-term contribution to food-system transformation.

Author contribution statements (CRediT taxonomy)

Ranka Junge: conceptualisation, data curation, writing – original draft, review and editing.

Roland Azibo Balgah: conceptualisation, data collection at LL site, writing - contribution to original draft, review and editing.

Michael Reuter: visualisations, writing – review and editing.

Zala Schmautz: writing – review and editing.

Emmanuel Benjamin: data collection at LL site, writing – review and editing.

Oyediran Olusegun Oyebola: data collection at LL site, writing – review and editing.

Emmanuel Delwin Abarike: data collection at LL site, writing – review and editing.

Sylvère Mboumba: data collection at LL site, writing – review and editing.

Olufemi Julius Olapade: data collection at LL site, writing – review and editing.

Ibrahim Macharia: data collection at LL site, writing – review and editing.

Josephine Ouma: data collection at LL site, writing – review and editing.

Francesco Orsini: writing – review and editing.

Giuseppina Pennisi: writing – review and editing.

Sabine Desczka: writing – review and editing.

Rolf Morgenstern: writing – review and editing.

Gertrud Buchenrieder: funding acquisition, writing - contribution to original draft, review and editing.

Declarations

Author contribution statements (CRediT taxonomy)

Ranka Junge: conceptualisation, data curation, writing – original draft, review and editing.

Roland Azibo Balgah: conceptualisation, data collection at LL site, writing - contribution to original draft, review and editing.

Michael Reuter: visualisations, writing – review and editing.

Zala Schmautz: writing – review and editing.

Emmanuel Benjamin: data collection at LL site, writing – review and editing.

Oyediran Olusegun Oyebola: data collection at LL site, writing – review and editing.

Emmanuel Delwin Abarike: data collection at LL site, writing – review and editing.

Sylvère Mboumba: data collection at LL site, writing – review and editing.

Olufemi Julius Olapade: data collection at LL site, writing – review and editing.

Ibrahim Macharia: data collection at LL site, writing – review and editing.

Josephine Ouma: data collection at LL site, writing – review and editing.

Francesco Orsini: writing – review and editing.

Giuseppina Pennisi: writing – review and editing.

Sabine Desczka: writing – review and editing.

Rolf Morgenstern: writing – review and editing.

Gertrud Buchenrieder: funding acquisition, writing - contribution to original draft, review and editing.

Competing interests

The authors declare that they have no competing interests.

Acknowledgements

The authors gratefully acknowledge Linda Tschirren (Nofima, Norway) for developing the fish welfare concept; Fridolin Tschudi (ZHAW) for co-developing the Training of Trainers programme; Laura Bernard (WECF) for developing the gender inclusion and code of conduct concepts; and Ingo Blaeser (APM) for contributing to the development of the aquaponic prototype and the establishment of the EGE Living Lab.

The authors also thank Sulaimon Babalola, Victoria Aghaji, and Abiola Adegoke (ADC) for managing the Living Lab's operations and day-to-day activities; Estelle Dumont and Armel Mouketou (USTM) for supporting its daily operation and delivering stakeholder training; and George Owuor, Steve Oduor, Arnold Opiyo, Benard Karanja, Paul Kahenya, Peter Akoko, and Margaret Ndanu (EGE) for their contributions to the management of the Living Lab; and Sarah Milliken (University Greenwich, UK) for editing the final manuscript.

Funding

This research was funded by the European Union under Horizon Europe, grant agreement No. 101083790, and by Staatssekretariat für Bildung, Forschung und Innovation (SBFI, Switzerland), REF-1131-52104 under the project name "Integrated and Circular Technologies for Sustainable city region FOOD Systems in Africa" (INCiTiS-FOOD). The views and opinions expressed are, however, those of the author(s) only and do not necessarily reflect those of the European Union or SBFI. Neither the European Union nor the granting authority can be held responsible for them.

Data Availability Statement

Data supporting the findings of this study are available within the article and its Supplementary Information. Additional project documentation underlying the analysis is available through the publicly accessible INCiTiS-FOOD project deliverables cited in the article and from the corresponding author on reasonable request.

Artificial Intelligence (AI) Use Statement

ChatGPT (OpenAI, GPT-5.5) was used to assist with language refinement and to generate initial drafts of conceptual schematic figures based on the authors' instructions. No AI tools were used for data generation, analysis, or interpretation. The authors reviewed and edited all outputs, verified their scientific accuracy, and assume full responsibility for the content of the manuscript.

Consent to participate

Informed consent was obtained from all adult participants. Participation was voluntary. No minors were included in the onboarding data analysed in this study.

Ethics Statement

The research was conducted within the Horizon Europe INCiTiS-FOOD project (Grant Agreement No. 101083790), which received a favourable ethics assessment from the Ethics Committee of Universität der Bundeswehr München, Germany, on 16 January 2023 (File No. EK UniBw M 23-05).

Research activities within the broader project were additionally reviewed and approved by the relevant institutional ethics committees in the participating African countries:

- Cameroon: Ethics Committee of Bamenda University of Science and Technology (25 April 2023; Ref. 0023/BUST/VC/DVCI&II/REG/FC/ADM/03/2023).
- Kenya (Egerton University): Egerton University Institutional Scientific and Ethics Review Committee (13 July 2023; Approval No. EUISERC/APP/272/2023; renewed 27 August 2025).
- Kenya (Kenyatta University): Kenyatta University Ethics Review Committee (24 April 2023; Approval No. PKU/2693/11816).
- Sierra Leone: Njala University Institutional Review Board (30 May 2023).
- Ghana: University for Development Studies Institutional Review Board (5 September 2023).
- Nigeria: University of Ibadan Social Sciences and Humanities Research Ethics Committee (14 June 2023; Ref. UI/SSHREC/2023/0052). The approved research protocol included activities conducted by both the University of Ibadan Living Lab and its collaborating partner, Aglobe Development Center (ADC), Lagos.
- In Gabon, research activities at Université des Sciences et Techniques de Masuku were authorised by the Centre National de la Recherche Scientifique et Technologique (CENAREST; 27 December 2023; Authorisation No. AR 37/23/MESRSIT/CENAREST/CG/CST/CSAR).

The present study comprises a secondary analysis of existing project implementation records and aggregated onboarding data from eight Living Labs. No additional human-participant research procedures were undertaken specifically for this study, and no identifiable personal data are reported.

Ethical Accordance

The research was conducted in accordance with the ethical principles established under Article 19 of Regulation (EU) 2021/695 (Horizon Europe), the applicable provisions of Regulation (EU) 2016/679 (General Data Protection Regulation), and the INCiTiS-FOOD Ethics Framework (Deliverable D7.2), which establishes procedures for informed consent, voluntary participation, confidentiality and protection of personal data.

Clinical trial number

Not applicable.

Consent to publish

Not applicable.

References

1. African Union. (2006). *African youth charter*. https://au.int/sites/default/files/treaties/7789-treaty-0033_-_african_youth_charter_e.pdf
2. Almirall E, Wareham J. Living Labs: Arbiters of mid- and ground-level innovation. Technol Anal Strateg Manag. 2011;23(1):87–102. https://doi.org/10.1080/09537325.2011.537110.
3. ANoLL. (2026). African Network of Living Labs. https://anoll.incitis-foodenvilab.net/
4. Balgah RA, Ngwa KA, Buchenrieder GR, Kimengsi JN. Impacts of Floods on Agriculture-Dependent Livelihoods in Sub-Saharan Africa: An Assessment from Multiple Geo-Ecological Zones. Land. 2023;12(2):334. https://doi.org/10.3390/land12020334.
5. Ballon P, Van Hoed M, Schuurman D. The effectiveness of involving users in digital innovation: Measuring the impact of living labs. Telematics Inform. 2018;35(5):1201–14. https://doi.org/10.1016/j.tele.2018.02.003.
6. Benjamin EO, Adegoke A, Buchenrieder GR. The Disenfranchisement of Practitioners and the Public Sector in Innovative Urban Farming in Sub-Saharan Africa: Insights from Nigeria. Land. 2024;13(7):963. https://doi.org/10.3390/land13070963.
7. Berkers F, van der Weerdt C, Karanikolova K, Gijsbers G, Issa A, Tsitouras S, Butter M, Vonder M. (2021). *D4.2 DIH Capability maturity model, V3*. https://www.smartagrihubs.eu/Deliverables/pdfs/D4.2-DIH-Capability-Maturity-Model.v3.pdf
8. Bhatta A, Vreugdenhil H, Slinger J. A living lab learning framework rooted in learning theories. Environ Impact Assess Rev. 2025;114:107894. https://doi.org/10.1016/j.eiar.2025.107894.
9. Carayannis EG, Grigoroudis E, Campbell DFJ, Meissner D, Stamati D. The ecosystem as helix: An exploratory theory-building study of regional co-opetitive entrepreneurial ecosystems as Quadruple/Quintuple Helix Innovation Models. R&D Manage. 2018;48(1):148–62. https://doi.org/10.1111/radm.12300.
10. Chesbrough HW. (2003). The Era of Open Innovation. MIT Sloan Manage Rev. https://sloanreview.mit.edu/article/the-era-of-open-innovation/
11. Davies J, Hannah C, Guido Z, Zimmer A, McCann L, Battersby J, Evans T. Barriers to urban agriculture in Sub-Saharan Africa. Food Policy. 2021;103:101999. https://doi.org/10.1016/j.foodpol.2020.101999.
12. Dutilleul B, Birrer F, Mensink W. Unpacking European Living Labs: Analysing Innovation's Social Dimensions. In: Müller K, Roth S, Zak M, editors. Social Dimension of Innovation. Social Science Research Network; 2010. https://papers.ssrn.com/abstract=2533251.
13. Eriksson M, Niitamo V-P, Kulkki S. (2005). State-of-the-art in utilizing Living Labs approach to user-centric ICT innovation-a European approach. *Lulea: Center for Distance-Spanning Technology. Lulea University of Technology Sweden: Lulea*, *12*. https://www.academia.edu/download/50573062/stateoftheart_livinglabs_eriksson2005.pdf
14. European Commission. (2026a). *INtegrated and Circular Technologies for Sustainable city region FOOD systems in Africa (INCiTiS-FOOD)*. CORDIS. https://cordis.europa.eu/project/id/101083790
15. European Commission. (2026b). *Potentials of Agroecological practices in east Africa with a focus on Circular water-energy-nutrient systems (PrAEctiCe)*. CORDIS. https://cordis.europa.eu/project/id/101084248
16. *European Network of Living Labs*. (2026). https://enoll.org/living-labs/
17. FAO, IFAD, UNICEF, WFP, & WHO. The State of Food Security and Nutrition in the World 2023: Urbanization, agrifood systems transformation and healthy diets across the rural–urban continuum. FAO; IFAD; UNICEF; WFP; 2023. https://doi.org/10.4060/cc3017en. WHO.

18. FoodLAND. (2026). *Food Hubs, FOOD and Local, Agricultural and Nutritional Diversity*. https://foodland-africa.eu/foodhubs/
19. Greve K, Vita RD, Leminen S, Westerlund M. Living Labs: From Niche to Mainstream Innovation Management. Sustainability. 2021;13(2):791. https://doi.org/10.3390/su13020791.
20. Hossain M, Leminen S, Westerlund M. A systematic review of living lab literature. J Clean Prod. 2019;213:976–88. https://doi.org/10.1016/j.jclepro.2018.12.257.
21. Kiribou R, Djene S, Bedadi B, Ntirenganya E, Ndemere J, Dimobe K. Urban climate resilience in Africa: A review of nature-based solution in African cities' adaptation plans. Discover Sustain. 2024;5(1):94. https://doi.org/10.1007/s43621-024-00275-6.
22. Leminen S, Westerlund M. Living labs: From scattered initiatives to a global movement. Creativity Innov Manage. 2019;28(2):250–64. https://doi.org/10.1111/caim.12310.
23. Loorbach D, Frantzeskaki N, Avelino F. Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annu Rev Environ Resour. 2017;42(1):599–626. https://doi.org/10.1146/annurev-environ-102014-021340.
24. Mbatha SP, Musango JK. A Systematic Review on the Application of the Living Lab Concept and Role of Stakeholders in the Energy Sector. Sustainability. 2022;14(21):14009. https://doi.org/10.3390/su142114009.
25. McPhee C, Bancerz M, Mambrini-Doudet M, Chrétien F, Huyghe C, Gracia-Garza J. The Defining Characteristics of Agroecosystem Living Labs. Sustainability. 2021;13(4):1718. https://doi.org/10.3390/su13041718.
26. MUFPP. (2026, June 5). *Milan Urban Food Policy Pact*. https://www.milanurbanfoodpolicypact.org/
27. Nesti G. (2015, July 1). *Urban living labs as a new form of co-production. Insights from the European experience*. ICPP-International Conference on Public Policy II.
28. Niitamo V-P, Kulkki S, Eriksson M, Hribernik KA. (2006). State-of-the-art and good practice in the field of living labs. *2006 IEEE International Technology Management Conference (ICE)*, 1–8. https://doi.org/10.1109/ICE.2006.7477081
29. Ohlig J, Weiler L. (2007, December 27). *Building a Hacker Space*. 24th Chaos Communication Congress (24C3), Berlin, Germany. https://fahrplan.events.ccc.de/congress/2007/Fahrplan/attachments/1003_Building%20a%20Hacker%20Space.pdf
30. Ondiek MA, Moturi C. An assessment of the sustainability of Living Labs in Kenya. Innov Manage Rev. 2019;16(4):391–403. https://doi.org/10.1108/INMR-08-2018-0058.
31. Paskaleva K, Cooper I. Are living labs effective? Exploring the evidence. Technovation. 2021;106:102311. https://doi.org/10.1016/j.technovation.2021.102311.
32. Pokupec D, Lešnik T, Borec A. Agroecology principles in aquaculture: A case study of East Africa. J Cent Eur Agric. 2024;25(3):800–6. https://doi.org/10.5513/JCEA01/25.3.4345.
33. Romero Antonio ME, Faye A, Betancur-Corredor B, Baumüller H, Von Braun J. Productivity effects of agroecological practices in Africa: Insights from a systematic review and meta-analysis. Food Secur. 2025;17(1):207–29. https://doi.org/10.1007/s12571-024-01504-6.
34. Schot J, Steinmueller WE. Three frames for innovation policy: R&D, systems of innovation and transformative change. Res Policy. 2018;47(9):1554–67. https://doi.org/10.1016/j.respol.2018.08.011.
35. Schuurman D, De Marez L, Ballon P. (2015). Living Labs: A systematic literature review. *Open Living Lab Days 2015, Proceedings*. Open Living Lab Days 2015. http://hdl.handle.net/1854/LU-7026155
36. Schuurman D, Leminen S. Living Labs Past Achievements, Current Developments, and Future Trajectories. Sustainability. 2021;13(19):10703. https://doi.org/10.3390/su131910703.
37. Sofronievska A, Cheshmedjievska E, Stojcheska D, Taneska M, Gjorgievski VZ, Kokolanski Z, Taskovski D. Understanding Living Labs: A Framework for Evaluating Sustainable Innovation. Sustainability. 2025;18(1):117. https://doi.org/10.3390/su18010117.
38. Statista. (2026). *Share of urban population Sub-Saharan Africa from 1960 to 2024*. Statista. https://www.statista.com/statistics/805657/urbanization-in-sub-saharan-africa/
39. Steen K, van Bueren E. The Defining Characteristics of Urban Living Labs. Technol Innov Manage Rev. 2017;7(7):21–33.

40. Sundman J, Feng X, Shrestha A, Johri A, Varis O, Taka M. Experiential learning for sustainability: A systematic review and research agenda for engineering education. Eur J Eng Educ. 2025;1–31. https://doi.org/10.1080/03043797.2025.2532591.
41. Veeckman C, Temmerman L. Urban Living Labs and Citizen Science: From Innovation and Science towards Policy Impacts. Sustainability. 2021;13(2):526. https://doi.org/10.3390/su13020526.
42. Verner D, Roos N, Halloran A, Surabian G, Tebaldi E, Ashwill M, Vellani S, Konishi Y. Insect and Hydroponic Farming in Africa: The New Circular Food Economy. World Bank; 2021. https://doi.org/10.1596/978-1-4648-1766-3.
43. Verner D, Vellani S, Klausen A-L, Tebaldi E. (2017). *Frontier agriculture for improving refugee Livelihoods: Unleashing climate-smart & water-saving agriculture technologies in MENA* (No. AUS22794). World Bank. https://documents1.worldbank.org/curated/en/103361524057787356/pdf/RWSAT-AUS.pdf
44. Westerlund M, Leminen S, Habib C. Key Constructs and a Definition of Living Labs as Innovation Platforms. Technol Innov Manage Rev. 2018;8(12):51–62. https://doi.org/10.22215/timreview/1205.
45. Yin RK. Case Study Research and Applications: Design and Methods. 6th ed. SAGE; 2017.

Figures

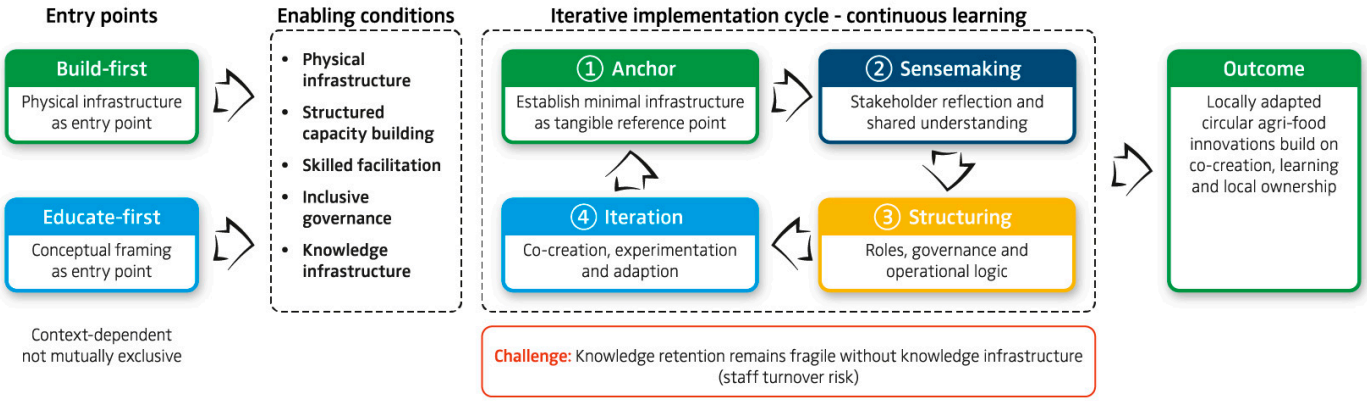


Figure 1

Living Labs as mediating structures for circular agri-food innovation in resource-constrained urban and peri-urban settings.

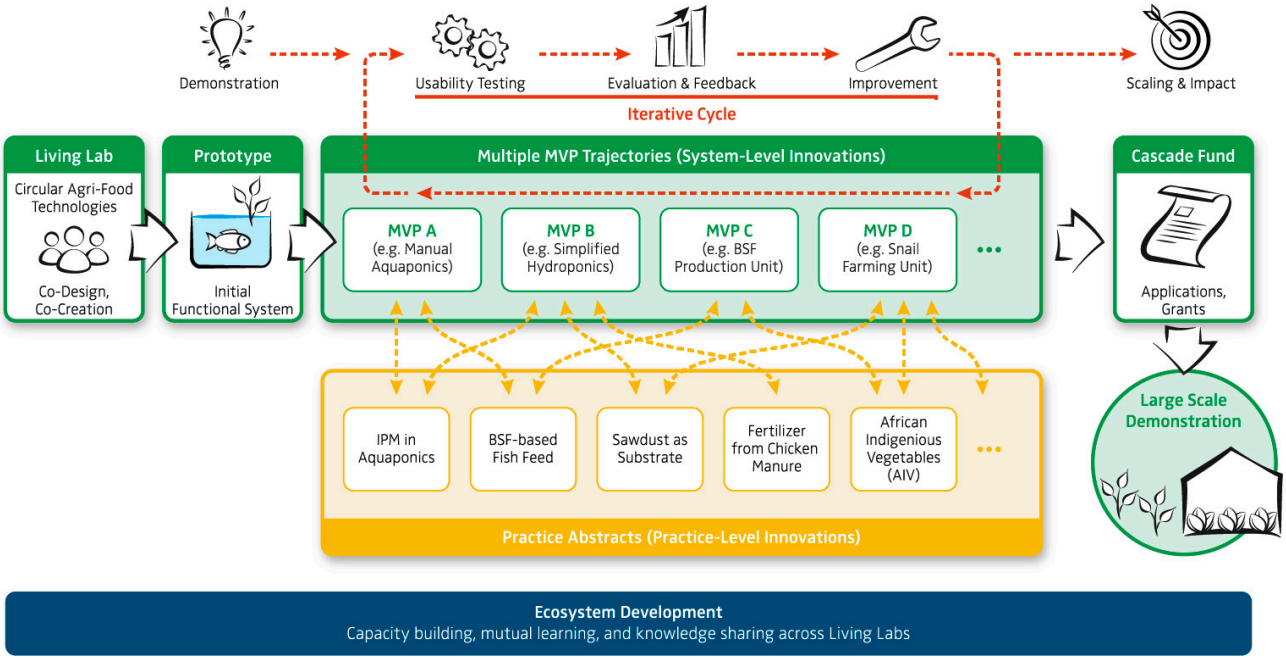


Figure 2

Conceptual model of Living Lab implementation derived from the INCiTiS-FOOD experience. All Living Labs started from a shared aquaponic prototype but subsequently followed multiple innovation trajectories. System-level innovations evolved into different Minimum Viable Products (MVPs), while Practice Innovations (documented as Practice Abstracts) emerged during MVP development and subsequent implementation. Continuous stakeholder feedback, evaluation and cross-Living Lab learning linked these pathways within an iterative co-creation process.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ImplementingLLinAfricaSupplementary.docx