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LIVING LABS AND BIO-DISTRICTS AS DRIVERS OF SUSTAINABLE RURAL DEVELOPMENT: EVIDENCE FROM THE CALATINO INNER AREA

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discretion, capable of illuminating without ever invading. We have never openly said how deeply connected we are, but that's fine. I have learned to accept myself for who I am and to understand that words are often just shadows: you have taught me that the most authentic bonds are lived through gestures, through glances, through silent presence. I love you like one loves the night sky: immense, mysterious, infinite, and yet always there to brighten the darkness.

…Ah, damn, there's still one left!

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"There's no such thing as a painless lesson; they just don't exist. Sacrifices are necessary. You can't gain anything without losing something first. Although… if you can endure that pain and walk from it, you'll find that you now have a heart strong enough to overcome any obstacle… Yeah... a heart made Fullmetal."

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Research highlights

- Rural inner areas face structural challenges but also opportunities to activate sustainable development pathways through participatory territorial approaches.
- Living Labs and Bio-Districts represent promising tools for promoting agroecological transition and inclusive governance in marginal rural contexts.
- A systematic literature review explored the role of Living Labs in agri-food systems, identifying participatory models and their contribution to rural innovation.
- A Living Lab was applied in the SNAI area of Calatino (Sicily) to engage stakeholders and co-design a Bio-District initiative based on local resources and needs.
- A TPB-based survey among organic farmers in the Calatino revealed that attitudes, social norms, perceived utility, and institutional trust significantly influence their intention to join a Bio-District.
- Results from the behavioral analysis offer actionable insights for local policy-makers to foster farmers' participation in agroecological development schemes.
- A choice experiment tested consumer preferences for Bio-District certified olive oil and bread, revealing positive willingness to pay for sustainability and territorial attributes.
- The study also showed that activating a social identity linked to sustainability increases consumers’ valuation of certification, offering new perspectives for labeling strategies.

Abstract

Rural inner areas face long-standing socio-economic and environmental challenges, including depopulation, land abandonment, and limited access to innovation and services. However, these territories also offer significant opportunities to activate sustainable development processes based on local resources, community engagement, and agroecological principles.

This PhD thesis investigates how participatory and territorial approaches—specifically Living Labs and Bio-Districts—can support the agroecological transition and promote inclusive rural development.

The study focuses on the SNAI area of Calatino (Sicily, Italy) as an empirical case and builds upon a combination of qualitative and quantitative methodologies. The research is articulated in four scientific contributions. The first is a systematic review of the international literature on Living Labs in the agri-food sector, providing a conceptual framework and mapping their application in rural contexts. The second contribution consists of a territorial analysis and stakeholder engagement process using the Living Lab methodology to co-design a Bio-District in the Calatino area. The third article applies an extended Theory of Planned Behavior (TPB) to analyze the willingness of local organic farmers to join a potential Bio-District, identifying the psychological and institutional factors that influence their intention. Finally, the fourth contribution presents a choice experiment conducted among Sicilian consumers to assess their willingness to pay (WTP) for agroecological products certified by the Bio-District, with a focus on the effect of social identity labeling on consumer preferences.

The findings provide new empirical evidence on the enabling conditions for participatory agroecological transition in marginal rural areas. They highlight the role of Living Labs in supporting stakeholder co-creation processes, the relevance of trust and perceived utility for farmers' engagement in territorial initiatives, and the effectiveness of social identity cues in stimulating sustainable consumption patterns. By combining behavioral insights with territorial analysis, this thesis offers theoretical and practical contributions to the design of policies and governance models for sustainable rural development.

Keywords: Living Lab, Bio-District, agroecology, stakeholder engagement, sustainable rural development, farmers' intention, consumer behavior, willingness to pay

Riassunto

Le aree rurali interne devono affrontare sfide socioeconomiche e ambientali di lunga data, tra cui lo spopolamento, l'abbandono dei terreni e l'accesso limitato all'innovazione e ai servizi. Tuttavia, questi territori offrono anche significative opportunità per attivare processi di sviluppo sostenibile basati sulle risorse locali, sul coinvolgimento della comunità e sui principi agroecologici. Questa tesi di dottorato indaga come gli approcci partecipativi e territoriali, in particolare i Living Labs e i Bio-Distretti, possano sostenere la transizione agroecologica e promuovere uno sviluppo rurale inclusivo.

Lo studio si concentra sull'area SNAI del Calatino (Sicilia, Italia) come caso empirico e si basa su una combinazione di metodologie qualitative e quantitative. La ricerca è articolata in quattro contributi scientifici. Il primo è una revisione sistematica della letteratura internazionale sui Living Labs nel settore agroalimentare, che fornisce un quadro concettuale e mappa la loro applicazione nei contesti rurali. Il secondo contributo consiste in un'analisi territoriale e in un processo di coinvolgimento degli stakeholder che utilizza la metodologia Living Lab per co-progettare un Bio-Distretto nell'area del Calatino. Il terzo articolo applica una teoria estesa del comportamento pianificato (TPB) per analizzare la disponibilità degli agricoltori biologici locali ad aderire a un potenziale Bio-Distretto, identificando i fattori psicologici e istituzionali che influenzano la loro intenzione. Infine, il quarto contributo presenta un esperimento di scelta condotto tra i consumatori siciliani per valutare la loro disponibilità a pagare (WTP) per i prodotti agroecologici certificati dal Bio-Distretto, con particolare attenzione all'effetto dell'etichettatura dell'identità sociale sulle preferenze dei consumatori.

I risultati forniscono nuove prove empiriche sulle condizioni che favoriscono la transizione agroecologica partecipativa nelle aree rurali marginali. Essi evidenziano il ruolo dei Living Labs nel sostenere i processi di co-creazione delle parti interessate, l'importanza della fiducia e dell'utilità percepita per il coinvolgimento degli agricoltori nelle iniziative territoriali e l'efficacia dei segnali di identità sociale nello stimolare modelli di consumo sostenibili. Combinando le intuizioni comportamentali con l'analisi territoriale, questa tesi offre contributi teorici e pratici alla progettazione di politiche e modelli di governance per lo sviluppo rurale sostenibile.

Parole chiave: Living Lab, Bio-Distretto, agroecologia, coinvolgimento degli stakeholder, sviluppo rurale sostenibile, intenzioni degli agricoltori, comportamento dei consumatori, disponibilità a pagare

Rationale and structure of the thesis

In recent years, the growing interest in the sustainable development of rural and marginal areas has led to a renewed focus on participatory and place-based approaches capable of fostering socio-economic revitalization and ecological transition. Within this framework, innovative territorial governance models such as Living Labs and Bio-districts have emerged as promising tools to support bottom-up development processes, enhance stakeholder engagement, and promote agroecological practices.

The urgency to address the challenges posed by climate change, biodiversity loss, and demographic decline in inner areas—as emphasized by the EU Green Deal and the 2030 Agenda for Sustainable Development—requires the design of inclusive and context-specific strategies. In Italy, the National Strategy for Inner Areas (SNAI) represents an important policy framework to strengthen the resilience of fragile territories through innovation, cooperation, and sustainable agriculture.

This thesis responds to the need for empirical research on the potential of Bio-districts as catalysts of agroecological transition and territorial development. It adopts a multidisciplinary approach that combines territorial analysis, behavioral modeling, and experimental economics to investigate the role of Living Labs and Bio-districts in the context of the Calatino area in Sicily. The research aims to assess both the supply and demand sides of the transition toward sustainable agri-food systems, as well as the socio-institutional dynamics underpinning participatory governance models.

In addition to this rationale, the thesis is structured as follows:

- Contribution I: Provides a systematic literature review of the application of Living Lab approaches in the agri-food sector, exploring their conceptual foundations, implementation models, and contributions to rural innovation and sustainability.
- Contribution II: Analyzes the territorial context of the Calatino

area and maps key stakeholders for the creation of a Bio-district, using the Living Lab methodology to support inclusive decision-making and participatory planning.

- Contribution III: Investigates the willingness of organic farmers in the area to join a potential Bio-district, applying the Extended Theory of Planned Behavior to identify the psychological, institutional, and economic factors influencing their intentions.
- Contribution IV: Explores consumer preferences and willingness to pay for sustainable agri-food products certified by the Bio-district, through a choice experiment that tests the effect of social identity labels on purchase behavior and the perceived value of agroecological certifications.
- Discussion and Conclusions: This section integrates and critically discusses the findings of the four contributions, emphasizing the theoretical and practical implications for the development of agroecological Bio-districts and participatory governance in inner rural areas. It also identifies challenges, research gaps, and future directions for enhancing the effectiveness of these models in supporting sustainable territorial transitions.

Contribution I - Promoting innovations in agriculture: Living Labs in the development of rural areas

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Abstract

Living Labs (LLs) has become a cutting-edge approach to research and innovation across several domains, including agriculture. Research on using novel techniques for agricultural development in practice is lacking. This knowledge gap significantly hampers current research efforts. This study investigates the valuable functionality of agricultural LLs to alleviate the dearth of thorough research. A systematic literature review of 18 academic articles on LLs implemented in the agricultural sector was performed. Our findings show significant geographical distribution, thematic orientation, and organizational structure variation across these LLs. Two essential elements comprise the dimensions on which agricultural LLs are based: the innovation process and the actors involved. Examining these elements allows for a deeper understanding of the various methods used in agricultural LLs and provides a theoretical framework for contextualizing them within current research. The study concludes by revealing promising directions for future research. It emphasizes the importance of examining the interdependent interactions among actors participating in LLs projects. Furthermore, it highlights the importance of implementing flexible approaches that can accommodate the distinct features of every agricultural setting to facilitate a sustainable transition

Keywords

Open Innovations; Sustainability; Living Labs; Stakeholders; Co-creation

1 Introduction

Rural areas, which cover almost fifty per cent of the European Union's land area and are home to around a fifth of its population, continue to be characterized by inadequate infrastructure, ageing demographics, depopulation, and various natural barriers to economic activity (Kalantaryan et al., 2021). These factors have contributed to development disparities exacerbated by the onset of the COVID-19 pandemic (Visagie and Turok, 2021).

Agriculture in rural areas emerges as a crucial point of intervention, as it represents a vital economic sector and a key pillar for tackling challenges related to infrastructure, demographic ageing, and obstacles to economic activity in these regions. Several challenges must be addressed when considering agriculture in rural areas (Sánchez-Zamora et al., 2014). These challenges are interconnected and encompass dealing with the effects of climate change on ecosystems, pressures on local and global food systems, and guaranteeing that agriculture can advance to organizational models that meet society's requirements. To effectively address the multiple challenges ahead, it is essential to encourage and facilitate changes in the behaviour and accountability of different stakeholders. These stakeholders represent a broad spectrum of individuals, including farmers, suppliers of agricultural components, technology innovators, researchers, agricultural advisors, policymakers, and the wider community, including consumers (McPhee et al., 2021). This underscores the critical need to establish a more robust agricultural knowledge and innovation system, providing comprehensive support for the ecological transition (Timpanaro et al., 2023; Fałkowski et al., 2017).

Šūmane et al. (2018) argue that innovation in agriculture requires the engagement of multiple actors. Therefore, successfully implementing approaches to foster innovation in complex, multi-stakeholder settings is crucial. Recent research suggests that a continuous exchange between farmers and researchers results in knowledge creation within fields in both chemical labs and agricultural environments (Toffolini et al., 2023). In knowledge production and agricultural innovation, systems-based approaches have developed in theory and practice (Klerkx et al., 2012). Furthermore, participatory research and co-design methods have been widely acknowledged in theoretical and practical contexts.

The Living Lab (LL) concept has gained significant traction among politicians and investors in the European Union in response to the challenges. The LL approach focuses on the user, with stakeholders working together to develop and create innovative solutions tested in the actual user context. (Følstad, 2008; Kviselius, 2009). LLs are designed to address complex societal issues involving diverse stakeholders from different backgrounds and disciplines. They collaborate in the iterative process of co-developing solutions, including prototyping, testing, and validating new ideas (Niitamo et al., 2006). This approach empowers stakeholders by promoting a participatory approach to problem-solving (Dell'Era et al., 2019), ultimately creating sustainable solutions for agriculture and food.

Several syntheses have investigated the application of LLs across various contexts. These works have explored innovation in medicine (Swinkels et al., 2018; Thordardottir et al., 2019), energy systems (Mbatha and Musango, 2022), and the development of innovation within the public sector (Fuglsang et al., 2021). Additional studies have examined sustainability (Evans et al., 2015; Zen, 2017) and the approach of urban LLs (Paskaleva, 2011; Voytenko et al., 2016).

In the field of agriculture, LLs can be used to address various sustainability challenges, including issues such as food security, water management, and climate change adaptation. LLs provide a unique opportunity for researchers to collaborate directly with end-users, including farmers, in real-world contexts. This practical form of collaboration amplifies the understanding of concrete challenges, facilitating the development of contextually relevant solutions. Furthermore, it promotes synergy between researchers from different disciplines, encourages a multidisciplinary approach, and involves farmers actively co-creating solutions in LLs (Ciaccia et al., 2021). This ensures that innovations are aligned with the direct needs of farmers, enhancing the relevance and acceptance of new technologies. Innovative practices developed in this context often result in efficiency gains, cost reductions, and increased output, contributing to agricultural sustainability. Farmers also benefit from skills development initiatives in LLs, participating in training workshops, and knowledge-sharing sessions that strengthen the farming community.

Despite the potential advantages of this methodology, the current literature on agricultural LLs is limited and inadequate. In a global context of increasing food insecurity, intensified by climate change, such as droughts, extreme weather events and fires, and armed conflicts, highlighted by high energy prices and difficulties in supplying agricultural fertilizers and food, the urgency of agricultural innovation becomes imperative. However, conventional solutions with a top-down, internally oriented approach to agricultural innovation have significant limitations. These approaches show a limited capacity to deal with complex problems that require the participation of multiple stakeholders. In addition, they often ignore the basic needs and knowledge of farmers and local communities, which results in solutions that are not adapted to the specific context (Vanloqueren and Baret, 2017).

Consequently, to address the challenges of agricultural innovation more effectively, it is essential to put agrifood enterprises at the centre of the innovation process. LL is an appropriate choice among the tools to foster this change. Our research aims to fill the gap in the literature by exploring the functionality of agricultural LLs in real-world contexts with the fundamental research question:

"Since LLs are still not very widespread, what should be the direction of future research to ensure that this tool becomes more and more a tool to facilitate practical innovation and respond effectively to the specific needs of farmers, encouraging the adoption of sustainable practices and contributing to the development of farming communities?"

A scoping review will be conducted, engaging farmers, industry experts, scientists, and other related stakeholders to investigate the role of low-input farming techniques in the metamorphosis of agriculture in rural regions and their potential to assume a more significant position in the agro-ecological transformation launched in the EU with the Green Deal. The aim is to provide evidence-based results to inform agricultural policies and practices and promote conscious, inclusive, and environmentally responsible agriculture.

1.1 Generalities on LLs according to current literature

The main objectives of Living Labs are twofold: to act as practice-based organizations that enable and implement open and collaborative innovative practices and to provide real-world environments that allow for the simultaneous study and testing of open and user innovation processes (Ballon and Shuurman, 2015; Leminen and Westerlund, 2019).

In the early 2000s, Professor William Mitchell from the Massachusetts Institute of Technology coined the term 'Living Lab' to describe a research methodology prioritizing user-centered approaches. The methodology aims to recognize, identify, and scale solutions in constantly evolving and developing environments (Van Geenhuizen, 2019).

With the establishment of the European Network of Living Labs (ENoLL) in 2006, the European concept of Living Labs experienced remarkable progress. ENoLL brought a unique element to the European Union policy framework, intending to tackle the continent's economic downturn and social difficulties (Ståhlbröst, 2013). National networks were established in several countries, such as Belgium, the Netherlands, Spain, Portugal, Slovenia, the UK, and Italy.

Despite almost two decades of research, the precise definition of LLs remains unclear. LLs are innovation ecosystems, as stated by the European Network of Living Labs (ENoLL), designed to address users' needs. These ecosystems are created following a structured, co-creation process that includes research and innovative procedures within tangible communities and contexts. They act as intermediaries, accelerating innovation and business scaling, fostering value co-creation, rapid prototyping, and validation between citizens, cities, research organizations, businesses, and regions. According to Leminen et al. (2012), LLs collaborates while generating, examining, and authenticating new technologies, services, products, and systems in real-life conditions. They are defined as either physical spaces or virtual environments. Stakeholders, including companies, public agencies, universities, institutions, and users, participate in public-private partnerships.

Bergvall-Kåreborn et al. (2009) defined LLs as an innovative user-centered environment. The environment is based on everyday practice and research, with an approach that promotes user influence in open and distributed innovation processes involving all relevant partners in authentic contexts. The overarching aim of this "milieu" or "context environment" is to establish sustainable value.

LLs have different definitions but share common characteristics, with innovation as the basis and main objective (Almirall et al., 2012; Schuurman et al., 2011). LLs are an emerging open innovation and a productive mechanism for innovation development (Hossain et al., 2019). Available networks are collaborations amongst diverse parties to innovatively progress and concomitantly value customers and consumers (Westerlund and Nyström, 2014; Westerlund et al., 2018).

Mastelic et al. (2015) emphasized the importance of collaborative efforts between researchers, companies, consumers, civil society members, and policymakers. Essentially, LLs functions to advance co-creation by engaging diverse audiences (Franz, 2015; Ståhlbröst, 2012). Active participation by stakeholders at all stages of the innovation process is vital to maintain their interest in an iterative manner (Brankaert et al., 2015). Adopting an innovation and co-creation paradigm substantially enhances the potential for creating new solutions that can effectively tackle present-day socio-economic and environmental challenges (Zavratnik et al., 2019).

2 Materials and methods

A review aims to offer original and extensive insights grounded in reliable and stringent evidence (Palmatier et al., 2018; Peterson et al., 2017). Three key elements are emphasized in systematic literature reviews:

- The data collection process demands a comprehensive exploration of pertinent scientific publications from a diverse range of sources, ensuring relevance and inclusivity;
- To ensure the validity of scientific evidence, it is essential to establish a well-defined protocol for its systematic collection. This guide should provide clear direction for the review procedure, leaving no room for ambiguity or uncertainty;
- The selection process should focus on collecting empirical evidence and follow a rigorous strategy to ensure transparency and replication of findings (Pakseresht et al., 2022).

This review followed PRISMA guidelines (Page et al., 2021). It presents a critical and systematic literature analysis on implementing Living Labs in agriculture.

A thorough review of existing literature involves identifying important works and summarising their main ideas (Sutton et al., 2019; Grant and Booth, 2009). Figure 1 presents the review process followed in this study.

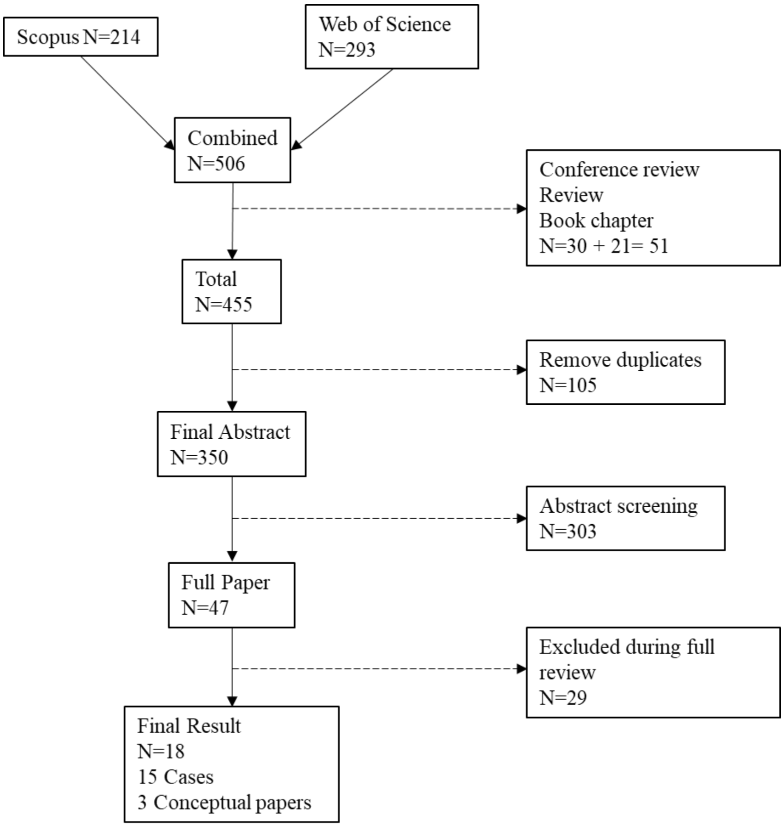

Figure 1 Flow diagram of included and excluded studies in the review.

2.1 Data collection

A specific set of keywords was selected to initiate a search query for relevant articles. The resulting search string was restricted to 'living lab*' to account for variations in the definition and designation of Living Labs. This was undertaken to avoid superfluous outcomes that could arise using similar terms for the concept. The study was confined to Living Labs methodology in agriculture, providing a benchmark. Consequently, the keywords "agr*" and "rural" were included in the research process. Other keywords were included in the search query to exclude clinical laboratories, medical practices, and research infrastructures. To refine and strengthen the selection process, ‘AND NOT' search terms were introduced to remove "clinical*," "animal*," "labour*," "labour*," and "label*."

Articles were collected using Scopus and Web of Science (WoS) scientific databases. Tawfik et al. (2019) recognized these databases as two primary repositories for multidisciplinary scientific articles. The search was executed on 22nd March 2023 to facilitate a wide-ranging exploration across various disciplines. The time range was set between 2000 and 2023, considering that LLs research has gained significant relevance and development in the last 15 years. The exclusion of non-peer-reviewed results, editorials, and reviews guaranteed objectivity. Books were not included to ensure accessibility. The metadata and documents were downloaded as CSV files and combined into tables using Microsoft Excel. The resulting collection of articles is precise, reliable, and free from duplicates and incorrect data. The abstracts of each article were included in the tables for the subsequent stages of the review process. The result of this initial phase was a preliminary sample of 350 articles. The selection was guided by exclusion criteria relating to the involvement in the agricultural sector (Table 1). These criteria were applied to maintain methodological consistency with the objective, i.e., using LLs in agricultural contexts as the object of study.

Table 1 Exclusion criteria for the abstract screening process.

	Exclusion criteria 1	Exclusion criteria 2
Related to the Living Lab context	This abstract refers to Living Labs in contexts other than agriculture (e.g., clinical trials, digital testing, education, waste, etc.).	This abstract refers to specific types of Living Labs not related to agriculture.
	Exclusion criteria 3	Exclusion criteria 4
Related to Agriculture	In this abstract, agriculture represents a secondary background aspect for the framing of the study rather than the focus of the study itself.	The abstract refers to agriculture in a way irrelevant to this research.

2.2 Analysis of papers

From the analysis of the abstracts, 47 articles were chosen for a comprehensive review. All the articles were read and the various themes were coded. Data analysis was conducted using an inductive approach, allowing the identification of patterns and emerging themes. Coding took place in two main stages. During the first phase, interest segments were collected systematically. This phase facilitated the identification of key concepts and recurring themes. Subsequently, similar aspects were grouped into broader analytical categories. This process made identifying deeper relationships between the emerging concepts possible, facilitating an organized view of the results. This review adopts some of the themes identified in existing literature review studies on Living Labs. During the coding process, it was discovered that compared to other sectors, agricultural LLs tend to discuss fewer specific aspects. This observation guided our analysis to identify peculiarities and gaps in agricultural LLs compared to other contexts. The categories aimed to capture information about the discourses surrounding the laboratories in agricultural contexts and general descriptive data suitable for aggregative results (Table 2). To ensure robustness and reliability, different researchers conducted the coding process independently, reducing the risk of biased interpretations, and each step of the analysis was documented in detail, allowing the process to be replicated and transparent. Finally, 29 articles were excluded during the analysis process. Eighteen articles, including three conceptual and 15 case studies representing agriculture-oriented LLs, were considered suitable for full review. The limited number of publications included in the review indicates that the LL concept is still in the developmental stage in agricultural research and practice.

Table 2 Categories adopted in the analysis of articles.

Categories	Category description	Sub-categories
Descriptive information	Generally identifiable information associated with lab case	Country of lab/Location of first author (University and country) Current status of lab Case study/Conceptual Thematic and topical focus Description of specific lab
Process information	Methods and key steps in the implementation of agricultural Living Labs	Methodological Identification Structural Approaches Impact of Methodologies
Actors information	Type of actors involved relations between them and nature of the partnership within the Living Lab	Stakeholder involvement phases in the Living Lab Type of collaboration in the Living Lab Variety of actors involved in the Living Lab activities Representativeness and inclusiveness of the actors Involvement of researchers in the Living Lab Involvement of the public sector in the Living Lab

3 Results

The findings of the review were classified into three different levels. Section 3.1 presents a descriptive overview of the agricultural Living Labs examined in the sample. In section 3.2, the key concepts that define agricultural LLs are explored through the analysis of conceptual documents. Section 3.3 identifies the key dimensions within agricultural LLs.

3.1 Descriptive overview

The results of this section include several aspects: 1) the subdivision of the articles according to the year of publication, 2) their national orientation, 3) the thematic field or topic, and 4) the geographical and physical distribution. A total of 18 articles that discuss the application of Living Labs in agriculture were found (for an overview of the articles and their descriptions, refer to Appendix A). Analyzing the number of articles published on agricultural LLs by year, an increasing trend can be observed in recent years, which was expected given the increasing importance attached by policymakers to these tools for disseminating innovation. In 2019, three articles were published on this topic, while in 2020, there was a slight decrease, with only one article published. However, in 2021, the number of articles on LLs in agriculture increased to 4, and a significant increase of seven articles was recorded in 2022 (Figure 2).

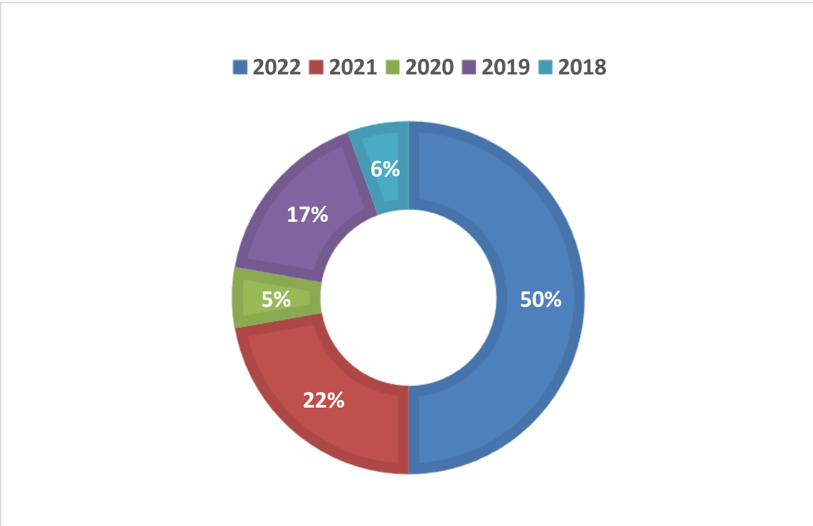

Figure 2 Sample papers included by year of publication.

Figure 3 shows the distribution of articles by country; a diverse geographical representation is evident, with various papers from different parts of the world. For conceptual articles, the country of the first author was considered. Most LLs belong to Europe, with a total of eight published articles. Three of these articles come from France, while the rest are evenly distributed (one on each side) between Italy, Spain, Portugal, Norway, Poland, Greece, Belgium and Latvia. Regarding non-European countries, Canada is represented by two publications, while Nigeria is the only African country to appear on the list. In addition, three articles were found covering several LLs located in different countries, and these were counted under the label "Multinational."

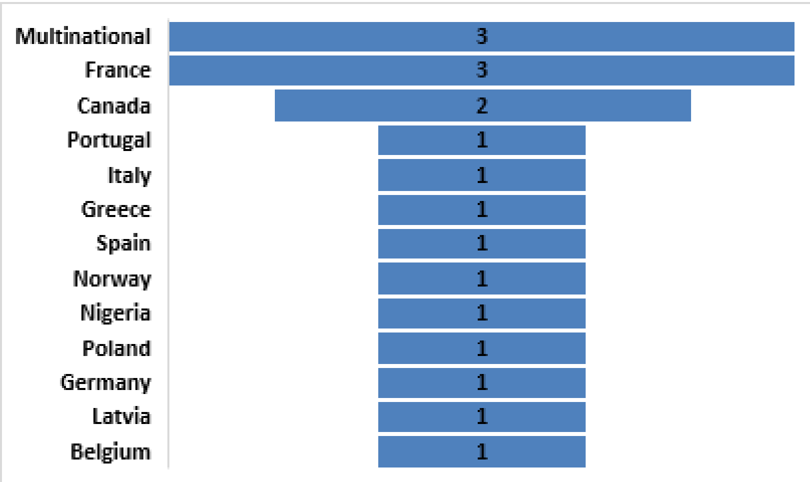

Figure 3 Geographical distribution of papers.

The analysis results show the distribution of LLs in different thematic areas within agriculture (Figure 4). 39% of the analyzed LLs focused on agricultural policy, 22% on environmental sustainability, and the rest on agricultural innovation. This latter category was further divided according to whether the LLs aimed to promote and support innovative agricultural practices (28%) or digital innovations (11%).

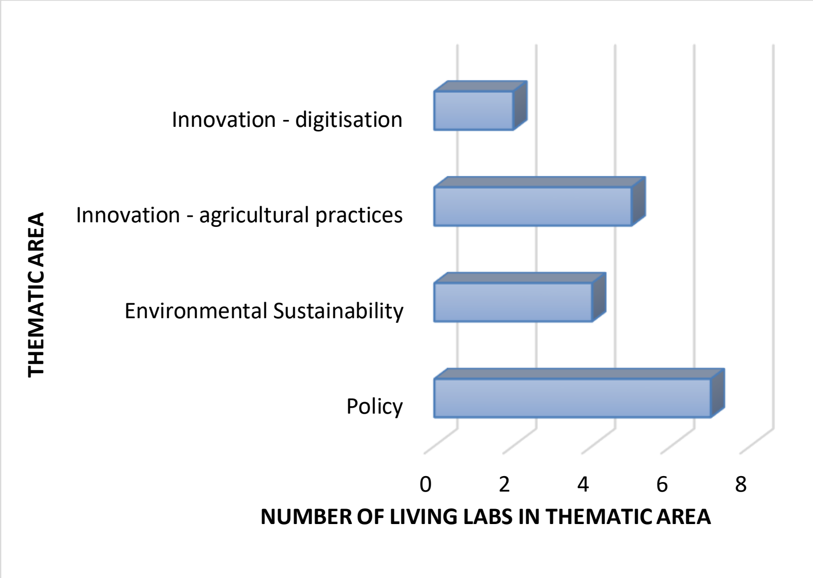

Figure 4 The thematic focus of papers.

Figure 5 shows the number of LLs by level and geographical location. The levels refer to the stated ambitions of the LLs regarding geographical scale. The results show various relationships between the location of the LLs and the geographical scales at which they are expected to operate. This categorization refers to case study articles, excluding the three conceptual articles, as they do not refer to a specific location. From a geographical perspective, most of the LLs had ambitions at the regional level (6), while the rest were linked to the local (5), international (2), or national (2) levels. At all these levels, the LLs manifest themselves in different ways.

Regarding physical location, the survey identified 7 (46%) LLs without a precise physical location. They are based on laboratories, seminars, or specific processes but have no explicit geographical ambitions. In addition, only two LLs identified specific physical locations as their workplace; they were physically organized within agribusinesses. Three LLs adopted a mixed mode, organizing workshops in physical locations alternating with online solutions for participant engagement. Finally, only two LLs were conducted entirely online.

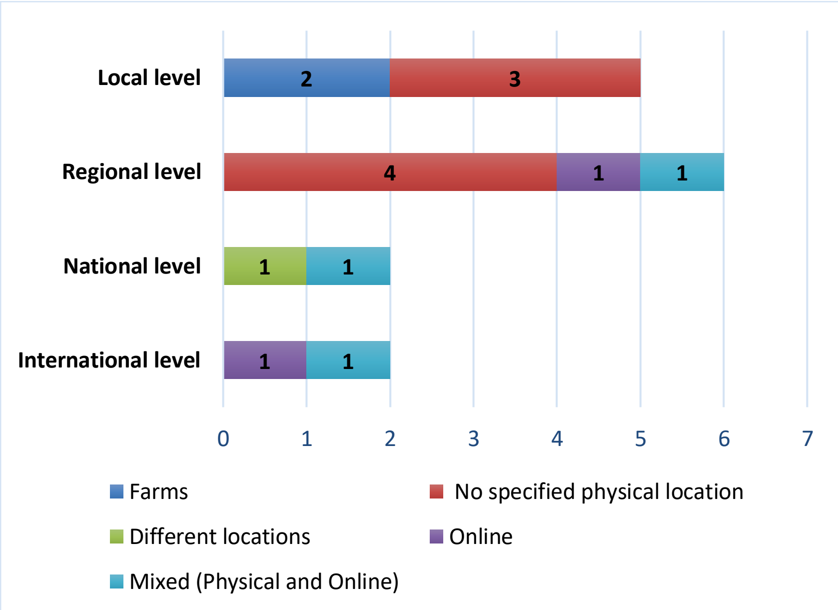

Figure 5 Number of Living Labs at various geographical levels and locations.

3.2 Agricultural Living Lab: Key Concepts

In this section, the conceptual frameworks that define agricultural Living Labs will be explored. Presenting the theoretical perspective, the analysis will focus on how these concepts provide the conceptual framework for understanding the role and effectiveness of

LLs in the agricultural context.

According to McPhee et al. (2021), agricultural LLs share three common principles with urban and rural LLs (sustainability, complexity, and context-based locality). However, their integration and operation within agri-food systems offer a distinct perspective for efficient implementation and management (e.g., seasonal cycles, quantity, and diversity of stakeholders involved). One of the main themes addressed concerns the evaluation of LLs. There is a pressing need to create suitable evaluation frameworks since current versions remain restricted (Beaudoin et al., 2022). This approach ensures a comprehensive and precise evaluation of LLs' impact and effectiveness (Bouwma et al., 2022). Each region and agricultural system have distinctive features requiring adaptable LL approaches to accommodate local needs. This necessitates a particular focus on co-creation and active participation of all stakeholders, encompassing farmers, researchers, institutions, and local communities (McPhee et al., 2021). The data highlight the need to promote a comprehensive approach that includes both human and non-human and environmental factors (Beaudoin et al., 2022; Gamache et al., 2020). Such an all-encompassing approach can be facilitated by implementing initiatives like citizen-centred Living Labs or Common Living Labs (CLL), which aim to construct, manage, and share common resources (Gamache et al., 2020).

3.3 Key Dimensions of Living Labs case studies

After analyzing the distribution of Living Labs at continental, national and local levels and describing the main research themes, this section focuses on the practices of the laboratories. In the context of agriculture, which is traditionally less inclined to value LLs as a form of shared development than other sectors, two key dimensions emerge process and actors. This sector specificity is a peculiarity found in our analysis, differentiating the focus of the dimensions from other literature reviews on LLs in broader contexts. This evidence underlines the need to consider agricultural dynamics differently, highlighting how the centrality of process and actor dimensions can be a valuable resource for future developments. While other literature reviews have often identified multiple dimensions, the agricultural context seems to emphasize exploring these two specific dimensions, suggesting the possibility of future developments to align more closely with other sectors in terms of complexity and multidimensional approaches.

3.3.1 Process

In this section, different tools and methodical approaches employed to attain the goals of Living Labs were analyzed, alongside the influence that such selections can have on the overall efficiency of these agricultural projects. One of the relevant approaches identified in the context of agricultural LiLs is the application of theoretical frameworks to the methodology of LLs. This approach provides strategies for managing and integrating roles in LLs, ensuring full participation of stakeholders, and producing outstanding results. An example is the Systems Innovation Approach (SIA) used in the Living Lab in Greece, which made it possible to coordinate activities and structure the involvement of actors (Alamanos et al., 2022). Through a step-by-step process that includes an analysis of existing processes and systems and presentation and communication of stakeholder initiatives, broader participation and a better understanding of the challenges and opportunities for agricultural LLs can be achieved. Another methodology adopted is Participatory Action Research (PAR), which was implemented in the AgroforSyLL Living Lab in Metaponto (Ciaccia et al., 2021). In this case, close collaboration with local communities was established to clearly understand the role, resources, and skills of researchers and other actors involved in the LL definition process. Creating the Actor Platform (AP) and the Research

Platform (RP) improved communication and activities, leading to more engagement, information exchange, and better explanations of the LL. In the Polish context, an approach combining several methods, such as backcasting, the Analytical Hierarchy Process (AHP), and Cumulative Voting (CV), was adopted (Wieliczko and Floriańczyk, 2022).

Another approach for agricultural LLs is based on workshops as the primary method for involving critical actors in decision-making and co-creation processes. Agricultural LLs use workshop methods to involve essential actors in decision-making and co-creation processes. A common aspect of many LLs is the organization of needs assessment workshops, where farm representatives and other relevant figures meet to address sector-specific challenges and opportunities (Campos et al., 2019; García-Llorente et al., 2019). By actively attracting actors, those workshops can become aware of realistic answers and techniques for improvement. Other LLs have taken a more structured and iterative approach to fostering collaboration and co-creation. For example, the Teaser Lab in France (Fèche et al., 2021) created a healthier and more sustainable agri-food system using facilitation values and creating a common ground between the partners involved.

Another example is the LL conducted by Plaisier et al. (2019), which addressed the problem of post-harvest losses in Nigeria's tomato sector. The “World Café” was utilized to support deliberation and examination of the information garnered, exploration of conceivable resolutions, and innovation of strategies. An agricultural LL in Norway (Hvitsand et al., 2022) demonstrated a more collaborative and co-creative approach through participatory processes. Participants were assigned to mixed groups to carry out work sessions incorporating participatory and co-creative methodologies. This approach enabled participants to think freely, exchange ideas, create a possible future, and set specific actions for change. Despite the methodological differences, agricultural LLs aim to improve farmer, stakeholder, and community engagement.

Regarding the two international agricultural LLs analyzed, there are notable parallels and distinctions in the methods used. One of the shared features of the analyzed LLs is the utilization of multi-actor workshops. Hebrard et al. (2022) emphasize the utilization of workshops to involve farmers, experts, and communities. These organizations have a joint aim for the future of farming, which is to simplify the process to meet the requirements of consumers. Likewise, Metta et al. (2022) involve stakeholders, key informants, and users through interactive workshops that permit widespread participation and the exchange of information and perspectives.

Nonetheless, LLs diverge in the methodologies employed during the workshops. Hebrard et al. (2022) stress the importance of analyzing critical success components (CSFs) to help decision-making. Additionally, a SWOT evaluation is carried out to evaluate the use instances' strengths, weaknesses, opportunities, and threats. In contrast, Metta et al. (2022) use the concept of a physical socio-cybernetic system (SCPS) to assess the impact of digitization in the agricultural sector. Despite methodological differences, both LLs prioritize active stakeholder participation and co-creating innovative agricultural solutions. This inclusive approach integrates diverse perspectives and expertise, enabling more informed decision-making and greater sector adaptability (Björgvinsson et al., 2010).

Toffolini et al. (2021) investigated the dynamics of agricultural LLs and analyzed how actors' roles are formed and re-distributed within such innovation contexts. Semi-structured interviews were conducted with exclusive groups of actors, and files such as framing notes and pastime reviews were analyzed. The techniques utilized aimed to investigate the strategies and processes of change of the community of actors involved in LL. In the context of the LL under consideration, a long-term participatory observation approach was employed, whereby the researcher actively engaged in various activities and meetings.

In summary, the analysis of methodologies in agricultural LLs has revealed a diversity of approaches, ranging from the use of theoretical frameworks to strategies based on multi-stakeholder workshops. This variety highlights the importance of evaluating success factors in specific contexts and the central role of LLs in overcoming innovation barriers.

In the context of challenges associated with innovation, the LL approach, particularly through user-centred innovation, emerges as a fundamental catalyst for overcoming initial scepticism. User-centred innovation in the context of agricultural LLs becomes a means to make innovation not only accessible but also acceptable. Practical demonstrations and user-friendly solutions can help overcome initial barriers, fostering a more positive approach and increasing the likelihood of widespread adoption. This approach, combined with a focus on workshops as a key tool, suggests significant opportunities for developing authentic solutions that fully reflect user needs.

3.3.2 Actors

Stakeholders are critical in Living Labs. This approach to innovation relies partly on dialogue and collaboration between specific stakeholders in the innovation process. Participants help at every stage, from defining the problem to developing and implementing the answer. Active participation encourages the co-generation of alternative responses and assures participation in choices. The participation of each stakeholder in the agricultural and agri-food system varies depending on their values and reasons. This diversity is reflected in different agricultural LLs, where partners with distinct interests and values contribute to different end-user experiences. Several points of convergence emerged in the analyzed studies on stakeholder participation in agricultural LLs. It is commonly agreed by most authors that including stakeholders in every phase of the agricultural innovation process, beginning from problem definition through to solution design and implementation, is pertinent. In agricultural LLs, academics, researchers, and producers have consistently been present in various capacities. Many LLs aim to provide interdisciplinary or even interdisciplinary networks to address complex agri-food system issues, encouraging researchers from different disciplines. Agricultural LLs provide partners, standards, and multiple interests, requiring a unique form of governance to meet these challenges effectively. Due to this, the public sector has traditionally assumed a dominant role in LL management, serving as a mediator for the varied stakeholders, values, and interests. In particular, the significance of incorporating government officials, regional authorities, farming associations, professionals, and scientific and technical specialists is highlighted (Alamanos et al., 2022). It also highlights the role of competent moderators as facilitators in the agricultural innovation process, involving local people who hold critical positions in the region (Ciaccia et al., 2021). In addition, the articles draw attention to the involvement of typically marginalized or underrepresented actors in community agri-food initiatives, such as organic farmers and local associations (Fèche et al., 2021). García-Llorente et al. (2019) emphasize the participation of rural development organizations, local authorities, and farmers as agroecological trainers. Another study discusses an effort incorporating various stakeholders, including universities, agri-food businesses, farmers, representative groups, nonprofit organizations, and technological centres (Hebrard et al., 2022). It is emphasized that LLs has shifted its focus from concentrating on specific digital technologies to addressing broader sociotechnical issues. This allows for the involvement of entities that might be overlooked or underestimated. Attention to the representativeness of the involved actors has proven to be crucial (Wieliczko and Floriańczyk, 2022) in ensuring effective governance and inclusive decision-making. This requires adequate representation of farmers' voices, NGOs, and other relevant actors (Toffolini et al., 2021; Amon et al., 2022). The significance of mapping actors participating in LLs is also stressed to pinpoint discrepancies, duplications, and hindrances in resource administration and coordination of multi-actor procedures (Majore and Majors, 2022).

One research study underlined that the vibrant involvement of actors in the value chain in solution design and implementation can diminish post-harvest losses and encourage the uptake of suggested innovations (Plaisier et al., 2019). The importance of local pilots and trials to evaluate proposed improvements is emphasized in the cases reviewed. This requires the direct involvement of stakeholders in implementing interventions so that they can experience and evaluate the effectiveness of the proposed innovations and provide feedback for continuous improvement (Fèche et al., 2021; Pertry et al., 2018). The importance of considering the contextual aspects and infrastructures involved in the LL, such as information management, collective experimentation, and farmer-consultant interactions, has been highlighted. The redistribution of roles in LLs is a dynamic process marked by contingency and uncertainty and characterized by collective action.

The analysis of stakeholders within agricultural LLs has revealed key dynamics. The participatory and synergistic collaboration of stakeholders throughout the innovation process is a crucial element. This approach facilitates the co-generation of alternative solutions and serves as an effective tool for overcoming innovation barriers, such as mistrust. The importance of fair and inclusive representation in decision-making is underscored by the diversity of interests and values observed across various LLs. Efficient management of interdisciplinary networks often requires a unified governance, mediated by the public sector, which acts as a mediator among diverse stakeholders. Fundamental practices to ensure effective and inclusive governance include the involvement of marginalized actors and comprehensive stakeholder mapping.

4 Discussion and identification of some areas for further research

4.1 Areas of operation and thematic areas of LLs

The number of scientific papers about Living Labs in agriculture has increased in the last few years. This rise in publications indicates a growing interest and recognition of the crucial role of engaging critical stakeholders in agricultural innovation (Bronson et al., 2021). However, a careful assessment is vital to determine whether this enlargement results in extensive actual-world consequences and if LLs efficiently remodels progressive thoughts into realistic measures to improve the rural region. One of the demanding situations highlighted by the findings pertains to the geographical distribution of LLs. Although there is an apparent diversity with participation from different countries worldwide, many LLs are still mainly concentrated in Europe. Increased international collaboration and knowledge exchange between LLs is needed to fully realize the potential for mutual learning and develop innovative solutions with global impact (Greve et al., 2020; Hossain et al., 2019).

Another critical attention pertains to the thematic areas explored utilizing LLs. The significant number of LLs concentrating on agricultural policy and environmental sustainability highlights the increasing attention to agriculture governance and sustainable management (McPhee et al., 2021). However, it is imperative to guarantee a broader range of topics to be covered, encompassing the investigation of technological and digital advancements in farming (Keyson et al., 2013). This augmentation would facilitate a more all-encompassing strategy for addressing present and future trials within the agricultural industry and fostering inventive and sustainable resolutions (Guzmán et al., 2013).

A crucial issue is the absence of a distinct physical location for most LLs analyzed. Although this could indicate the utilization of adaptable and creative running methods, it also activates inquiries about the cooperation and personal interplay between the engaged stakeholders. It evaluated the potential repercussions of not having a designated physical space on knowledge sharing, trust building, and co-creation efficiency (Rădulescu et al., 2022; Lucchesi et al., 2021). At the same time, it should be noted that online modalities can increase participation and accessibility, especially for actors who are physically unable to participate in an LL (Kovács, 2016). However, stability among bodily and online modalities is vital to comprehend the potential of LLs completely as areas for innovation and co-introduction.

4.2 Sustainability and value of LLs in rural area development

From our research on Living Labs in agriculture, many conceptual aspects emerge that confirm pre-existing visions and enrich the construct with new perspectives.

First, the analysis emphasizes the central role of farmers in the solution development process within LLs. Contrary to traditional perspectives, it highlights the active participation of farmers, who become true protagonists in agricultural innovation. Acknowledging the richness of their practical experience, the importance of incorporating farmers' knowledge into the design of solutions is emphasized. A significant contribution emerges from adopting a multidisciplinary approach within agricultural LLs. The analysis shows how the synergetic integration of heterogeneous disciplines, such as agriculture, technology, and social sciences, generates creative perspectives that fuel innovation. This integrated approach amplifies the vision and creates more adaptable solutions, significantly impacting.

One of the main points emphasized is the significance of LLs as crucial instruments for promoting the shift toward more sustainable and resilient agricultural practices. These open innovation frameworks are based on interaction and collaboration among various stakeholders throughout the innovation process, from defining the problem to designing and implementing the solution. Active involvement of stakeholders in this process promotes collaborative development of innovative solutions and ensures shared and participatory decision-making. Theoretical articles emphasize the importance of tailoring LLs to specific contexts. Every region and agricultural system has distinct traits and necessitating LL approaches that are adaptable to local requirements. This necessitates authentic collaboration and active involvement from all stakeholders in the agricultural sector, including farmers, research institutions, and local communities. Such collaboration is essential to maximize the impact and effectiveness of LLs in agriculture.

Implementing a LL in a natural area can transform it into a thriving spatially localized and digitally connected innovation hub (Scuderi et al., 2023). This transformation can revitalize the whole area by providing significant development opportunities. An agricultural LL can be intentionally designed to improve the food chain by serving as a central innovation hub involving all key stakeholders. Creating an agricultural LL brings together a range of stakeholders, enabling the sharing knowledge and ideas. This collaboration occurs in an open environment that provides the resources to create imaginative concepts and transform them into innovative practices, products, and services.

A crucial area for future research is delineating appropriate evaluation criteria for agricultural LLs, considering their experimental nature. This aspect becomes even more relevant considering the complexity and diversity of interactions that characterize such collaborative contexts. Integrating interdisciplinary perspectives can play a crucial role in formulating evaluation criteria that reflect the multidimensionality of LLs. Accurate evaluations should cover methodological, operational, social, and environmental aspects on several dimensions to understand the impact and efficiency of LLs in agriculture. Adopting a comprehensive strategy is crucial to address human, technological, environmental, and economic challenges in food distribution. Combining participatory and evidence-based approaches is essential to generate operational, democratic, and academic knowledge in the complex contexts of LLs (Dekker et al., 2021). Evaluating the human elements, non-human factors, and surrounding environment is necessary to overcome these obstacles effectively (Compagnucci et al., 2021; McCrory et al., 2020).

4.3 4.3 Organization, approach, actors, and governance of LLs

The role of Living Labs is to organize networks of knowledge among all stakeholders, both inside and outside of the task. Furthermore, due to the high complexity of agricultural and agri-food systems, better quantitative and qualitative assessments are needed in agricultural LLs. This complexity is highlighted by the wide range of partners involved in these types of LLs (McPhee et al., 2021). Adopting a wide range of qualitative methods is central to the success of the Agricultural LLs.

The “mode” factor of laboratory exercise is fundamental to knowing the effect and effectiveness of these strategies completely. One of the number one issues relates to using theoretical frameworks as guiding equipment for the development and execution of LLs. Theoretical frameworks are helpful because they allow a complete comprehension of the patterns and limitations that define creative techniques in farming. This strengthens our information about the demanding situations and methods linked to agricultural creativity.

Using a theoretical framework can expedite the formation of a shared imagination and prescient, the establishment of expressed desires, and the identity of appropriate study techniques. However, it is necessary to acknowledge that adjusting these frameworks to the distinct context of each LL is vital to guarantee the efficiency of the methodologies utilized.

Multi-approach methods in agricultural LLs involve complementary qualitative techniques to reap a radical and nuanced expertise of challenges, opportunities, and solutions within the agricultural sector. Using numerous qualitative methods allows the acquisition of multiple viewpoints from actors collaborating in agricultural LLs, including farmers, specialists, representatives of communities, and different stakeholders. These views are important to understand the extraordinary necessities, evaluations, and principles of the entities worried about the agricultural innovation system.

Among the qualitative methods often combined in the multi-method approach in agricultural LLs are interviews, workshops, backcasting, Analytical Hierarchy Process (AHP), and Cumulative Voting (CV). Implementing a multi-method approach in agricultural LLs allows overcoming limitations inherent in each method. For instance, while interviews can provide an in-depth view of actors' opinions and experiences, workshops facilitate interaction and synergy among participants. Simultaneously, the employment of backcasting and AHP assists in directing decision-making toward sustainable and desirable future solutions.

Integrating more than one method calls for cautious making plans and an intensive comprehension of research goals. Analysis of the findings has highlighted both the benefits and difficulties of using workshops as the primary tool for engaging critical stakeholders in selection and co-creation tactics within agricultural LLs. Workshops as the primary method in agricultural LLs help to involve critical stakeholders, stimulate innovation, and generate sustainable answers.

Stakeholder engagement fosters cooperative networks and partnerships, proving valuable in selling innovation. Firstly, it is imperative to establish an inclusive participation environment to avoid the exclusion or marginalization of certain voices (Björgvinsson et al., 2012). Stakeholders with limited resources or representation may feel uncomfortable or reluctant to participate actively. Therefore, adequate facilitation of the workshops should promote the inclusion of all stakeholders by ensuring that all individuals feel at ease when sharing their opinions and suggestions (Engels et al., 2019). The analysis of methodologies and stakeholders within agricultural LLs has revealed a complex landscape. The variety of methods used, such as workshops, back casting, and evaluation techniques, demonstrates the complex nature of the challenges encountered in the agricultural industry. This variety, although valuable, presents a significant issue of standardization. The lack of shared best practices can hinder widespread application. Therefore, it is crucial to balance the need for customization with the goal of developing generalizable approaches to address familiar challenges.

The organization of workshops is a crucial factor to contemplate (Akasaka et al., 2022). Implementing facilitation strategies consisting of lateral wondering, brainstorming, and multicriteria assessment may aid in unveiling new viewpoints and strategies, cultivating precise answers. At the same time, it is essential to ensure that discussions concentrate on the specified goals of the LL, thus avoiding diverting attention towards peripheral concerns. The utility of participatory evaluation techniques may be treasured in attaining a collective appraisal of proposed solutions. These procedures entail the involvement of essential stakeholders within the assessment manner, thereby enabling a vast scope of views and requirements to be considered. To ensure that such gatherings are sincerely effective in accomplishing agricultural sustainability desires, it's crucial to cope with problems of inclusivity, structure, and assessment. An important consideration is the long-term sustainability of agricultural LLs. Since these projects are frequently short-term in nature and focused on research and innovation, there is a possibility that collaborative efforts may cease once they are concluded. The suggested innovations may not be fully adopted in the agricultural industry. Developing strategies for knowledge change and integrating those advances into the broader agricultural and food zone framework is critical to ensure progressive solutions' continued dissemination and implementation.

Extra attention issues the widespread position related to neighborhood communities in agricultural LLs. Local groups are essential for implementing sustainable answers within the farming enterprise, as they, in the end, get hold of innovations and maintain important neighborhood information. This requires an inclusive strategy surpassing mere community consultation, engaging individuals in objective establishment, design, and outcome assessment (Huang et al., 2021; Nyström et al., 2014). Establishing support systems and capabilities that enable communities to participate actively in decision-making is vital, including training, access to suitable resources and technologies, and acknowledgement of traditional and regional knowledge (Veeckman et al., 2013). The active involvement of stakeholders in agricultural LLs is an essential component for open innovation in agriculture and agri-food systems (Verloop et al., 2009). A relevant element from the literature assessment is the extensive type of stakeholders worried in agricultural LLs, everyone with unique values, interests, and roles inside the agricultural system. Nevertheless, effectively dealing with this diversity is an important task. The active involvement of stakeholders requires a unique form of governance that can combine and harmonize the different complexities present in LLs (Leminen, 2013).

The involvement of typically overlooked or underrepresented actors in agri-food projects, such as farmers with alternative organic models and local associations, emphasizes the inclusive and participatory character of involving stakeholders in agricultural LLs. The complexity of the relationships between the actors worried is a crucial issue that requires careful consideration. A specific mapping of these actors' relationships and interaction dynamics is vital to realizing this revolutionary ecosystem's complexities. This analysis helps discover strengths, such as powerful collaboration and synergy among actors. It also highlights capacity challenges, which include misalignments, conflicts, or inefficiencies in resource control and multi-actor technique coordination. A critical initial consideration is the diversity of interests and objectives among the involved actors. For example, farmers may be motivated by improving agricultural practices and productivity, while consumers may prioritize environmental sustainability and the quality of the final product. Differing viewpoints can lead to contrasting ideas on innovation and evaluating results. Stakeholder collaboration may also require sharing resources such as evidence, infrastructure, understanding, and funding. Inadequate coordination may want to bring about setbacks, conflicting activities, or maybe the desertion of promising tasks. To deal with these complications, it is critical to include appropriate governance processes that facilitate participation, transparency, and agreement among actors. Governance must be devised to enable the participation of all stakeholders in the decision-making manner, ensuring that each viewpoint is heard and valued.

User-centered innovation is a promising approach to overcoming barriers, but its effectiveness depends on the ability to translate practical demonstrations into tangible impacts on a large scale. A systemic approach is required to address deep resistance to the adoption of new agricultural practices. In summary, while LLs provide fertile ground for innovation, the main challenge lies in navigating complexities and transforming local successes into widespread impacts. The success and sustainability of these initiatives depend on a participatory and collaborative approach from stakeholders, coupled with effective governance.

5 Conclusion

This study aimed to examine the characteristics of Living Labs, especially regarding their use in agriculture, and this was achieved through a systematic review. The results of this review provide a basis for informing current user-centred innovations in agriculture using LL methodology. The detailed analysis of the methodologies used in the LLs has revealed a variety of approaches, highlighting the importance of assessing success factors in specific contexts. The use of complementary qualitative approaches, such as interviews, workshops and backcasting, proved crucial in overcoming the specific limitations of each approach. The analysis of stakeholders in agricultural LLs highlighted the centrality of the participatory approach and the synergistic collaboration of stakeholders. The diversity of interests underlines the importance of fair and inclusive representation in decision-making. Effective management of interdisciplinary networks has often required unified governance mediated by the public sector. LL approaches are proving to be catalysts in promoting access to innovation, mitigating resistance and enabling greater uptake of proposed solutions. The insights gained from this review are expected to form the foundation for informed decision-making and strategic planning in current user-centred innovations in agriculture, all underpinned by the robust LL methodology. The LLs model could be a valuable resource for policymakers searching for resolutions to the issues arising from the COVID-19 outbreak and the Russia/Ukraine conflict, which have led to inflated prices of raw materials and manufacturing costs.

It is essential to recognize that the study has certain limitations. These include the limited number of published cases included in our review. Furthermore, solely analyzing experimental procedures from academic and technical publications may hinder the perception of potential tensions between actors within LLs. Power imbalances, competing interests, and different abilities to participate in the collective process may be the source of these tensions. An analysis of agricultural LLs has identified several essential research perspectives that can help advance this field of study. The relationships between actors in LLs could significantly impact resource management and coordination of multi-actor processes.

The adaptability of LLs in specific contexts and the need to develop recognised evaluation frameworks emerge as key research perspectives for the future. Collective innovation and inclusive participation remain at the forefront of these considerations, with a keen eye on environmental pressures and climate change that could affect the landscape of agricultural LLs.

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Supplementary Materials

Table S1 Completed review matrix (18 reviewed articles).

Author	Year	Country	Title	Source	Thematic area	Approach
Pertry et al.	2018	Belgium	Agrotopia, a living lab for high-tech urban horticulture within Europe	Acta Horticulturae, 1215, 153 - 158	Innovation - agricultural practices	Case study
Campos et al.	2019	Portugal	Renewable Energy Prosumers in Mediterranean Viticulture Social–Ecological Systems	Sustainability (Switzerland), 11(23), 6781.	Environmental Sustainability	Case study
García-Llorente et al.	2019	Spain	Agroecological Strategies for Reactivating the Agrarian Sector: The Case of Agrolab in Madrid	Sustainability (Switzerland), 11(4), 1181.	Innovation - agricultural practices	Case study
Plaisier et al.	2019	Nigeria	Approach for Designing Context-Specific, Locally Owned Interventions to Reduce Postharvest Losses: Case Study on Tomato Value Chains in Nigeria	Sustainability (Switzerland), 11(1), 247.	Innovation - agricultural practices	Case study

Gamache et al.	2020	France	Can living labs offer a pathway to support local agri-food sustainability transitions?	Environmental Innovation and Societal Transitions, 37, 93–107.	Policy	Conceptual
Ciaccia et al.	2021	Italy	Organic Agroforestry Long-Term Field Experiment Designing Trough Actors' Knowledge towards Food System Sustainability	Sustainability (Switzerland), 13(10), 5532.	Policy	Case study
Fèche et al.	2021	France	Building a transformative initiative for a territorialized agri-food system: constructing a living-lab and confronting norms? A case study from Mirecourt (Vosges, France)	Journal of Rural Studies, 88, 400–409.	Policy	Case study
McPhee et al.	2021	Canada	The Defining Characteristics of Agroecosystem Living Labs	Sustainability (Switzerland), 13(4), 1718.	Policy	Conceptual
Toffolini et al.	2021	France	Implementing agricultural living labs that renew actors' roles within existing innovation systems: A case study in France	Journal of Rural Studies, 88, 157–168.	Policy	Case study

Alamanos et al.	2022	Greece	Water for Tomorrow: A Living Lab on the Creation of the Science-Policy-Stakeholder Interface	Water (Switzerland), 14(18), 2879.	Environmental Sustainability	Case study
Amon et al.	2022	Germany	Regional opportunities to mitigate greenhouse gas emissions in the capital region Berlin-Brandenburg, Germany	2022 ASABE Annual International Meeting	Environmental Sustainability	Case study
Beaudoin et al.	2022	Canada	A research agenda for evaluating living labs as an open innovation model for environmental and agricultural sustainability	Environmental Challenges, 7, 100505.	Policy	Conceptual
Bouwma et al.	2022	Multinational	Sustainability Transitions and the Contribution of Living Labs: A Framework to Assess Collective Capabilities and Contextual Performance	Sustainability (Switzerland), 14(23), 15628.	Innovation - agricultural practices	Case study
Hebrard et al.	2022	Multinational	Towards Innovation-Driven and Smart Solutions in Short Food Supply Chains	International Journal of Food Studies, 11, 129–137.	Innovation - agricultural practices	Case study

Hvitsand et al.	2022	Norway	Establishing an Agri-food living lab for sustainability transitions: Methodological insight from a case of strengthening the niche of organic vegetables in the Vestfold region in Norway	Agricultural Systems, 199, 103403.	Environmental Sustainability	Case study
Majore and Majors	2022	Latvia	Digital Twin Modelling for Eco-Cyber-Physical Systems: In the Case of A Smart Agriculture Living Lab	PoEM Forum 22: Practice of Enterprise Modelling, 98-112.	Innovation - digitization	Case study
Metta et al.	2022	Multinational	An integrated socio-cyber-physical system framework to assess responsible in agriculture: A first application with Living Labs in Europe	Agricultural Systems, 203, 103533.	Innovation - digitization	Case study
Wieliczko and Floriańczyk	2022	Poland	Priorities for Research on Sustainable Agriculture: The Case of Poland	Energies, 15(1), 257.	Policy	Case study

Contribution II - A Living Lab approach for the construction of a Bio-district in an Inner Area of Sicily (Italy): the case of Calatino

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Abstract

Rural areas have historically been confronted with a multitude of challenges, including an ageing population, desertification, job losses and the decline of agricultural activities. In response to these challenges, several social, economic and environmentally sustainable initiatives have emerged with the objective of revitalising territories. It is noteworthy that the Bio-districts facilitate the implementation of agroecological practices through the utilisation of participatory methodologies. The design of an effective model for such territories remains a complex issue. In this context, the paper will analyse the potential of a Bio-district in Calatino, an inland area of Sicily within the National Strategy for Inner Areas (SNAI), a rural area with significant development challenges. As part of an innovation process, the Living Lab approach has been employed to engage several key stakeholders, including farmers, agronomists, distributors, environmental associations, public institutions and local administrators. Stakeholders were engaged in quadruple helix governance models with the objective of fostering innovation and cooperation. The most significant challenges encountered were those associated with the management of stakeholder motivations and the constraints imposed by time and resources.

The results demonstrate that the active involvement of all stakeholders has resulted in the formulation of proposals that are tailored to the specific characteristics of the territory, emphasising integrated and participatory approaches. Those participating in the Living Lab emphasised that the Bio-district would facilitate the more widespread implementation of agroecological practices by fostering collaboration and mutual support among local actors. Additionally, the proposal to establish a food hub, which could enhance efficiency within the food chain and reduce food waste, was met with considerable approval. This research is pivotal to the co-design and collaborative establishment of a Bio-district, providing insights to inform policymakers and other stakeholders engaged in analogous projects targeting sustainability and local economic development.

Keywords

Local development; Organic agriculture; Production-consumption models; Participatory development; Bio-region

1 Introduction

Inner areas are rural regions characterized by a low population density and a significant distance from major centers offering essential services such as education, healthcare, and transportation (Rossitti et al., 2021). These areas experience many challenges: socio-demographic and economic decline, environmental fragility, loss of opportunities otherwise associated with increased mobility and the use of information and communication technologies, and, more generally, technological innovations. As such, the development policies in Europe focus on social, political, and cultural agendas as a solution for reversing depopulation and marginalization through improved essential public services and triggering local development processes (De Toni et al., 2021). In Italy, the inner areas have huge development potentials given that they have unused environmental, economic, and social resources, which could help create new job opportunities (Barca et al., 2014). To counteract these processes, the National Strategy for Inner Areas (SNAI) was launched in 2012, considered one of the most advanced policies in the European Union regarding integrated rural development and institutional innovation (Carrosio, 2016). SNAI aims at combating marginalization and depopulation through sustainable development in planning policies (Rossitti and Torrieri, 2021).

Innovation is considered a key strategy for the realization of development objectives because it is only through this means that traditional agricultural and rural economies can be transformed (Peters et al., 2018). Farmers can generate value through new products and services (Timpanaro et al., 2023; Klerkx et al., 2012). Bottom-up approaches to disseminating innovation are increasingly gaining ground in rural contexts, being particularly effective in engaging local communities toward very specific issues: depopulation and land abandonment. In recent years, the growing interest in Social Innovation as a method has emphasized the importance of the social dimension in development processes (Moulaert et al., 2017) and the involvement of civil society (Moulaert et al., 2013; Neumeier, 2012; Polman et al., 2017). In rural areas, the SI initiatives in relation to organizational structures that are fostering new forms of food production and marketing are alternatives to the traditional large-scale models dominated by major producers (Neumeier, 2017). Such initiatives aim at the empowerment of small producers and the increasing bond between these producers and the consumer. One of the primary intentions of these initiatives is to promote consumer awareness of the alternative forms of food production and to improve working conditions as well as the general welfare of small rural producers. Many have pursued multifunctionality, that is, productive agricultural activities combined with services of a social character, namely education, care, and social inclusion of the most vulnerable groups. The agricultural hubs in such areas, hence, both in rural and urban, have long emerged to have consumers—for example, food hubs for exchanging knowledge/best practices of producers (Matson et al., 2013). Besides this, literature also explores the functioning of the role of SI in projects related to social farming (Borsotto et al., 2019; Dalla Torre et al., 2020) and agroecology (El Bilali, 2018; Marchetti et al., 2020).

In this perspective, characterized by rural areas with developmental problems and innovations that involve society and territories from the bottom up, Living Labs (LLs) emerge as spaces for innovative socio-technical research and experimentation. They are cooperative laboratories involving different public, private, and citizen stakeholders in collaboration for developing and assessing new technologies, services, and products under real-life conditions (Hossain et al., 2019). LLs promote a user-centered approach (Ballon and Schuurman, 2015) and are known for their ability to address complex issues in various environments (Mulder et al., 2008). As a result, they emphasize participant empowerment and the promotion of participatory involvement in problem-solving and the formulation of sustainable solutions for the agricultural and food sector (Cascone et al., 2024; Scuderi et al., 2023). In this regard, open innovation could center on technology, practices, and knowledge aimed at the sustainability and resilience of agricultural and agri-food systems (McPhee et al., 2021; García-Llorente et al., 2019).

In this study, we propose using LLs as an approach for creating a Bio-district to develop an inner area with high rural density and developmental challenges. Bio-district, Bio-region, and Organic District are concepts used interchangeably in the literature as a development model advocating for the sustainable transition of the territory through organic production, whereby local actors cooperate based on identifying organic farming or agroecology as a foundation for rural development (Lamine et al., 2023; Assiri et al., 2021). The strategic objectives of a Bio-district include internationalization, digitalization, enhancement of agricultural, cultural, and environmental heritage, integrated and synergistic poverty reduction, and the transition toward a greener economy more in line with EU strategies on circular economy, Green Deal, and Farm to Fork.

Specifically, a Bio-district develops along three main dimensions: social, economic, and environmental. The social dimension works toward social cohesion to develop strategies aimed at sustainable and inclusive territorial development, focusing on farmers (Dias et al., 2021). This approach will facilitate social aggregation through new job creation, revitalization of rural areas, and protection of the health of farmers and consumers. The economic dimension focuses on benefits for agricultural and tourism enterprises, as well as those related to culture and gastronomy, the reduction of costs for organic certification, and the development of innovative economic activities while increasing territorial value through marketing tools and opening new market channels. Finally, the environmental dimension refers to the protection of biodiversity, the use of regional seeds and traditional varieties, and agroecological principles and practices in safeguarding natural resources, improving soil fertility, and landscape conservation.

The effectiveness of this governance model derives from the synergistic collaboration of farmers, organizations, tourism entrepreneurs, and other sectors of the economy, among others, with schools. All these actors are bundled together under the leadership of the local authorities toward common goals, representing the territory as an entity with collective dedication to agroecology (Packer and Zanasi, 2023). LLs could serve as a key tool in this process of organizing the governance of the territory to co-produce necessary innovations for the creation and management of the Bio-district. LLs promote the experimentation and adoption of agro-ecological practices, network development between farmers, researchers, and institutions, and foster new participative forms of governance. These are key in realizing a Bio-district that seeks to combine agricultural productivity with environmental protection and the well-being of local communities, as it has been observed in different European contexts.

LL implementation in the Bio-district co-design was experimented in Sicily, a semi-arid Mediterranean territorial area, particularly in the inner area called "Calatino," which, according to the SNAI 2021-2027 strategy, is made up of a union of 9 municipalities. This area is part of the southeast of the former province of Catania; it covers 26% of the provincial area and 6.8% of the population of the metropolitan city. It is characterized by a marked agricultural and artisan vocation, low modernization of the productive processes of the area, and limited capacity to commercially enhance local products, not fully exploiting the true productive potential of the territory. There is fair diffusion of organic farming, a natural reserve called "Bosco di Santo Pietro," and plenty of cultural and tourist sites.

The following research questions have been formulated:

- Q1: How can innovation and co-construction practices, supported by a Living Lab, promote an effective agroecological transition in the Calatino Bio-district, contributing to the social, environmental, and economic development of the territory?
- Q2: How can a Living Lab support territorial governance in the Calatino Bio-district to enhance co-participation between administration, agricultural enterprises, processing sectors, and consumers to foster the social, environmental, and economic development of the territory?
- Q3: What will be the task of a Living Lab in promoting the agroecological transition and creating food hubs in the Calatino Bio-district, fostering cooperation among different actors to increase improvements in social, environmental, and economic development within the territory?

2 Materials and Methods

2.1 *The Living Lab Approach*

Living Labs create the ideal setting for evaluating experiences and conducting experiments in a true, familiar context for all stakeholders and users involved (Schuurman et al., 2016). They are open innovation ecosystems that facilitate technology and knowledge transfer among different actors (Hossain et al., 2019). Based on the principle of collaboration, they establish a "Living Lab network," which creates shared value among all stakeholders (Lehmann et al., 2015).

In a Living Lab, stakeholders and users form a Public-Private-People Partnership (PPPP) includes enterprises, public institutions, universities, institutes, and citizens who work together to innovate, create, prototype, validate, and test new technologies, services, products, and systems in real-life contexts (Leminen and Westerlund, 2019). The LLs approach is based on openness and collaboration among the actors, ensuring maximum benefits: flexibility and responsiveness of the private sector, observance by the public sector of legal and financial frameworks, and interchange of ideas with the population to adapt products or services to real needs.

Multi-stakeholder mobilization and participation as envisioned by the PPPP partnership is the key determinant in ensuring LL success. This approach includes all the quadruple helix sectors, meaning representatives from the public, private, academic, and general population (Figure 1). At the same time, stakeholders within an LL are organized regarding specific roles (Nyström et al., 2014).

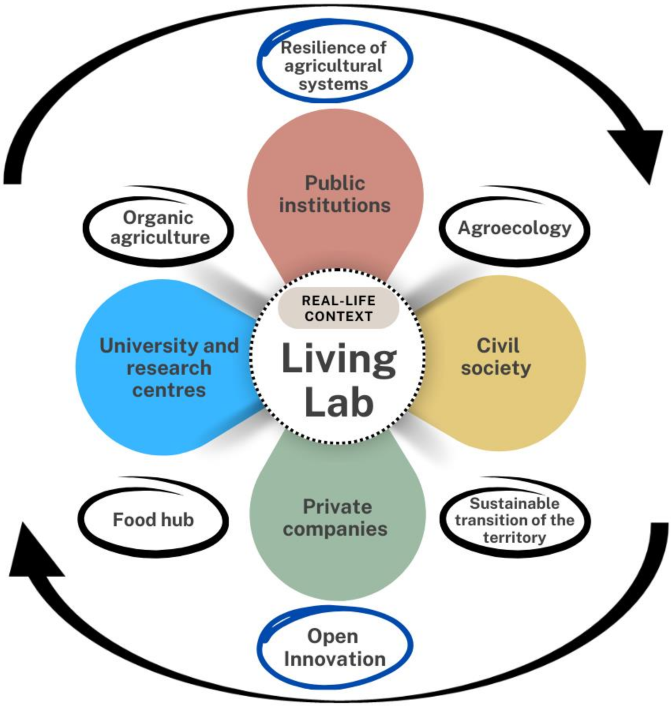

Figure 1 Participatory co-construction of the Bio-district as an innovative approach proposed by the Living Lab.

Living Labs combine and adapt various user-centered co-creation methods to best meet their goals. Studies indicate that LLs pilot, develop, and experiment with different methods based on the outcomes of innovation activities (Leminen, 2013). It is important to note that LLs encompass a wide range of methodologies; consequently, each project carried out in LL mode adopts a customized approach that can develop its own methodology to address the needs of a unique context (Dell'Era and Landoni, 2014).

Figure 2 illustrates the step-by-step procedure adopted to establish the LL. This process allowed the research team and the involved actors to progressively acquire an in-depth understanding of both the current and desired situations, as well as to identify the individuals who could contribute to the change initiative.

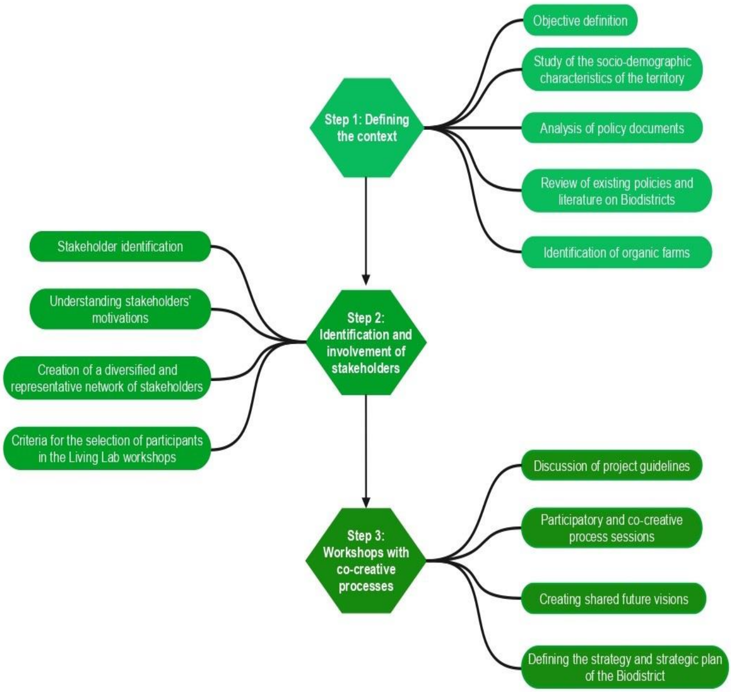

Figure 2 Theoretical framework: Steps of methodology.

Initially, a comprehensive understanding of the situation and the potential individuals to be involved was established and integrated into the process. Subsequently, we facilitated participatory processes for the co-creation of knowledge, conducting evaluations among participants and collecting researcher reflections based on observations. The following sub-chapters describe in detail the activities carried out, the data collected, and the analysis methods employed.

2.2 Context Definition

To identify the stakeholders at the start of the LL, it was crucial to clearly establish the problem (and the research questions), objectives, timelines, and the necessary resources (technical, human, etc.) appropriate to the real environment in which the LL was to operate. Initially, this step was carried out independently by the research group, then validated together with the LL participants.

Immersion in the real environment of the LL and understanding its stakeholders were essential to ensuring the initiative's success, as this allowed for an understanding of the political, economic, and social specificities of the territorial context. This step helped in identifying ongoing projects with which the Living Lab could interact and in comprehending the interests of stakeholders, including potential conflicts and collaborations. For this reason, a documentary analysis was conducted to delve into the operational context and identify the key stakeholders to be involved, as shown in Figure 3.

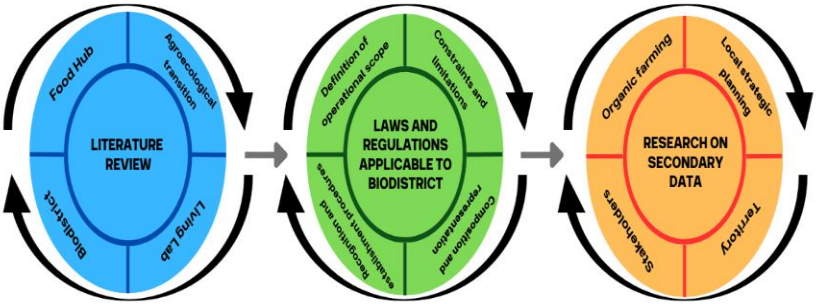

Figure 3 Preliminary steps in the constitution of the Calatino Bio-district through a living lab procedure.

Existing literature on the topic of Bio-districts was reviewed, including not only academic articles but also reports and other types of grey literature, to obtain a comprehensive view of the practices and challenges associated with the creation and management of a Bio-district. Additionally, the socio-demographic characteristics of the internal area of Calatino were examined in detail, analyzing data related to the population, demographic distribution, and local economic dynamics. Programmatic documents regarding the agri-food sector in the Calatino area were also studied to better understand the existing policies and ongoing initiatives.

To fully establish the Bio-district, an in-depth analysis of national (D.M. of December 28, 2022, No. 663273) and regional (Implementing Decree No. 32 of 2024, Sicily) regulations concerning recognition and constitution was conducted. This analysis aimed to thoroughly understand procedural aspects and other relevant elements such as sustainable local resource management, criteria for official recognition (e.g., area requirements, number of involved farms, presence of a sustainable strategic development plan), the formation of a committee or association to coordinate activities, stakeholder engagement procedures, forms of financial, technical, and logistical support, and monitoring systems to evaluate the effectiveness of undertaken initiatives. The specific conditions for the recognition of a Bio-district according to national and regional regulations are summarized in Table 1.

Table 1 Conditions for the recognition of Organic Districts according to National and Regional Legislation (*).

Conditions according to D.M. of December 28, 2022, No. 663273	Conditions according to Implementing Decree No. 32, 2024 Sicily
a) Name of the bio-district	a) The area of the district must fall entirely within the territory of the Sicilian Region; interregional district areas are an exception.
b) Territorial delimitation of the organic district, with an indication of the minimum area managed with organic methods, including the area in conversion to organic farming.	b) The area of the district must have at least a supra-municipal extension.
c) Proposal for a legal form, in accordance with the regulations on associative and corporate forms between public and private entities.	c) The administrative territory of each Municipality must be entirely included within the area of a single district.
d) List of participating entities and their respective roles and interactions.	d) The organic agricultural area pertaining to the district area must not be less than 300 hectares.
e) Proposal for administrative organization, with the indication of the board members, legal representative, and the methods of appointment and removal, as well as draft statutes and regulations.	e) The participating organic farmers, whether individuals or associations, must be at least 10.
f) Purpose of the district and activities to be carried out in line with the strategic objectives identified in the protocol by the promoting committee.	f) All entities listed in Article 4, paragraph 1 of D.M. of December 28, 2022, No. 663273 can participate in the organic districts where the organic agricultural area (SAU) is located.

g) Objectives, motivations, and expected results that define the development strategy, including the forecast of the percentage increase in the agricultural area used with organic methods.	g) Organic farmers, whether individuals or associations, must represent at least 51% of the members of the district's board of directors.
h) Promotional activities for the establishment of groups of operators to achieve forms of group certification.	h) All entities listed in Article 4, paragraph 3, letter a) of D.M. of December 28, 2022, No. 663273 can participate in only one organic district.
i) Forecast of the impact on environmental sustainability conditions, quality of life and work, as well as the economic vitality of the organic district.	

(*) Source: Our elaboration on D.M. of December 28, 2022, No. 663273 and Implementing Decree No. 32, 2024 Sicily

Finally, a detailed analysis of secondary data allowed us to identify the organic farms present in the area, using the Sian portal (National Agricultural Information System) (Ministry of Agricultural, Food and Forestry Policies, 2024) as the main source. This phase was crucial for subsequently identifying the relevant stakeholders for the project.

2.3 Stakeholder Engagement

Effective stakeholder engagement is essential to ensure the success of the Living Lab (Paskaleva et al., 2015). Consequently, a targeted methodological approach was adopted for this mobilization.

First, it was necessary to identify the stakeholders to be involved in the LL. This identification was facilitated by the study conducted in the previous phase, allowing us to outline a clear picture of the relevant actors.

Next, we sought to understand the motivations that might drive stakeholders to participate actively. Research indicates that both intrinsic and extrinsic motivations can positively influence stakeholder engagement (Ståhlbröst and Bergvall-Kåreborn, 2011). Therefore, it was important to communicate individually with each stakeholder, customizing the approach based on their specific motivations and interests.

Finally, creating a diversified and representative network of stakeholders was essential. This network comprised individuals with common interests but who brought heterogeneous perspectives in terms of age, gender, culture, ambitions, capabilities, and decision-making power. This network must adhere to the quadruple helix governance principle, involving representatives from the public, private, academic, and population sectors. Each stakeholder needed to contribute meaningfully to the problem at hand, ensuring effective collaboration aimed at achieving common goals.

When inviting participants to the LL, creating a "protective space" to stimulate and support innovative and open thinking was crucial (Smith and Raven, 2012). This safe environment was designed to accommodate those who shared the need for change and was located within the municipality of Caltagirone.

2.4 Workshops with Participatory and Co-Creative Processes

Two preliminary workshops were organized, which were crucial for establishing a climate of trust and collaboration among the various actors involved (Figure 4).

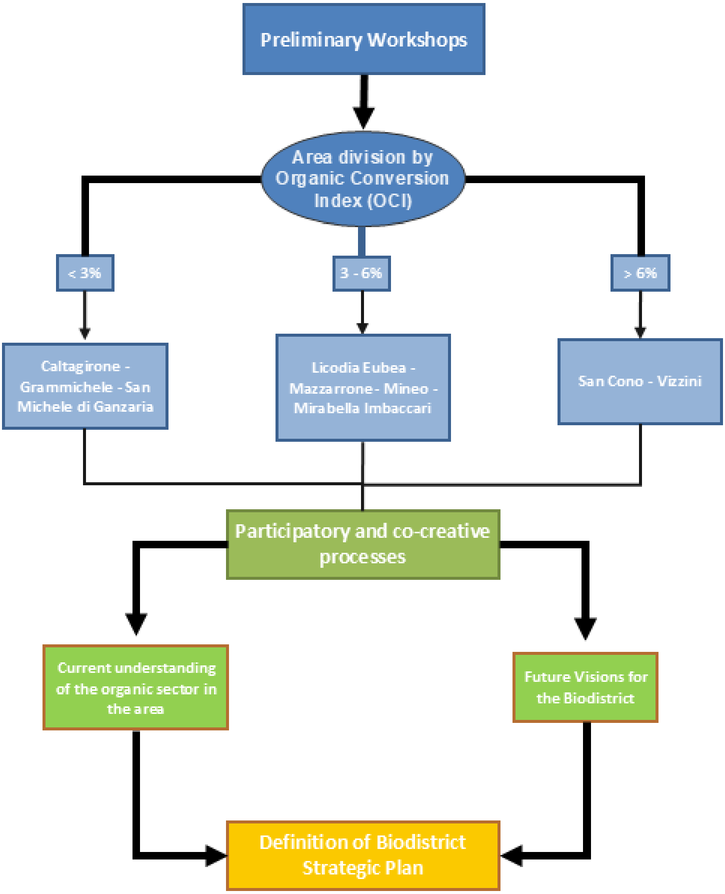

Figure 4 Participatory and Co-Creative Processes for Bio-district Strategic Planning.

The first workshop was conducted via telematics, having a marginally practical approach by discussing the lines of the project with the actors in force at that time and obtaining feedback for further collaboration agreements. The second took place at the premises of the Municipality of Caltagirone (lead partner for SNAI) and permitted more direct and involving comparison which facilitated sharing ideas and experiences between farmers who knew how to express needs and expectations regarding the Bio-district. These have allowed various subjects to participate and validate initial guidelines on which discussion is established for further participation.

Since, at the regulatory level, one of the criteria for the recognition of bio-districts is the surface area conducted organically (or in conversion), it was decided to use this criterion to constitute the discussion groups, and so the nine municipalities of the Calatino inland area were divided based on an Organic Conversion Index (OCI), calculated as:

$$OCI = {}^{N_{org}}\!/_{N_{tot}}$$

Where N_{org} represents the number of organic farms and N_{tot} represents the total number of farms per municipality. Subsequently, the municipalities were classified into three categories based on their OCI, with the threshold set at 3%, 3% to 6%, and above 6%. This approach permitted the organisation of a sufficient number of workshops to accommodate the number of groups, thereby ensuring a specific focus on the needs of the various stakeholders. Two sessions of participatory and co-creative processes were organized with stakeholders to make them understand in depth what is taking place and take part in the visions that are being created for the future of the Calatino Bio-district. The workshops have seen an in-depth discussion on the Bio-district project, focusing specifically on the benefits — from an environmental, social, and economic standpoint — brought about by organic agriculture and more in general by sustainable agriculture. The workshops facilitated an in-depth examination of both current issues and future potential, with active involvement of all participants.

3 Results

3.1 Characteristics of the area and its suitability for establishing a Bio-district

The inner area of Calatino, designated as part of the National Strategy for Inner Areas (Strategia Nazionale Aree Interne, SNAI) since 2014, encompasses eight municipalities: Caltagirone, Grammichele, Licodia Eubea, Mineo, Mirabella Imbaccari, San Cono, San Michele di Ganzaria, and Vizzini. Recently, with the programming of the National Agency for Territorial Cohesion 2021/2027, the municipality of Mazzarrone has also been included (Figure 5). These municipalities are part of the metropolitan city of Catania, with a total population of 70,606 inhabitants, representing 1.5% of the Sicilian population (Table 2).

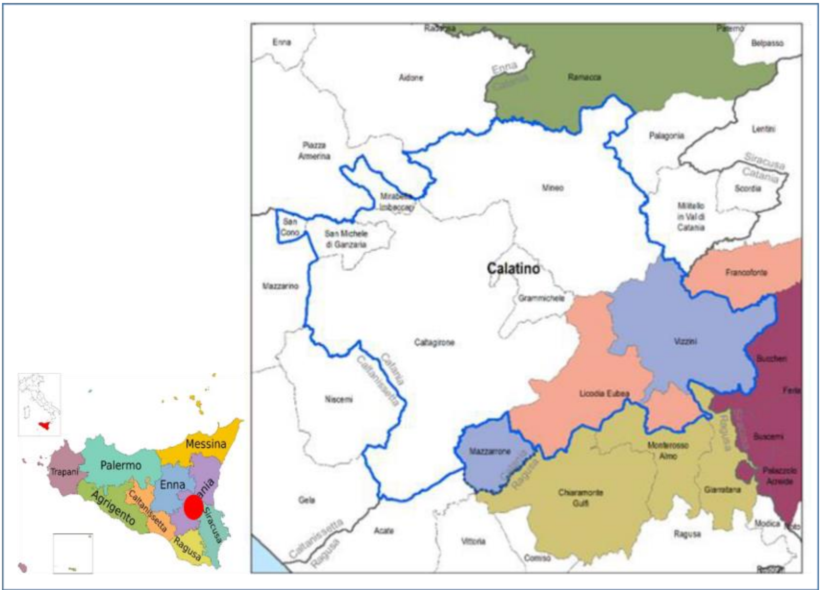

Figure 5 Territorial delimitation of Calatino area with highlighted inclusion of Mazzarrone in the SNAI strategy.

Table 2 Territorial and demographic data of the Calatino SNAI area.

Municipality	Resident population	Area Municipality (Km2)	Population density (n/km2)	Utilised Agricultural Area (SAU)	Number of farms
Caltagirone	35,765	383.37	93.29	20,437	2,368
Grammichele	12,407	32.07	386.87	1,698	511
Licodia Eubea	2,731	112.45	24.29	6,132	823
Mazzarrone	3.987	34.78	114.63	1,905	352
Mineo	4,486	245.27	18.29	15,423	1,859
Mirabella Imbaccari	4,217	15.3	275.62	990	214
San Cono	2,416	6.63	364.40	278	100
San Michele di Ganzaria	2,878	25.81	111.51	904	217
Vizzini	5,702	126.75	44.99	8,563	463
Total SNAI area	70,606	982	1,434	56,330	6,907

Calatino was included in the National Strategy for Inner Areas (SNAI) after experimenting with different models of local governance following previous local development experiences. A strong point for the area is that, as far as the definition and implementation of the SNAI is concerned, this took place in an experiential context, in which the municipalities of Calatino had already undertaken collaboration and development paths, in line with the current strategy for inner areas. Agriculture is the backbone of the economy in Calatino, offering a base for the sustenance of the livelihood and employment of its people. A rich tradition of agriculture has been dominant in this territory, facilitating cultivation of different quality products. Table 3 provides an overview of the agricultural crops in the different municipalities, tabulated herbaceous and woody crops. For herbaceous crops, the largest areas of cereals, dry legumes, and forage crops have been reported in the municipalities of Caltagirone and Mineo, thus suggesting a strong vocation for agriculture, whereas in municipalities like Mirabella Imbaccari and San Cono, the area for almost all categories is very limited. As for woody crops, citrus fruits are prevalent in Mineo, which is expressed by the highest average share of the area dedicated to this crop. In Caltagirone, there is more diversification among vines, olives, citrus fruits, and other fruits. The share of the vineyard area is quite significant in a few municipalities; hence, they specialize in viticulture: Licodia Eubea and Mazzarrone. Overall, the table shows considerable variability in the spread of agricultural areas across different municipalities: certain ones seem to specialize their production based on certain crops; the rest display a higher level of diversification.

Table 3 Distribution of agricultural areas by crop type in the municipalities of the SNAI area.

Municipality	Agricultural Crops								
	Herb crops (ha)				Woody crops (ha)				
	Cereals	Dried legumes	Potatoes and vegetables	Forage	Grapevine	Olive	Citrus	Fruit	Others
Caltagirone	6,596	379	739	3,344	892	1469	615	541	34
Grammichele	405	77	14	169	21	176	480	72	1
Licodia Eubea	1,463	209	78	888	956	342	68	196	
Mazzarrone	189	8	9	88	865	160	17	97	11
Mineo	4,574	532	335	132	30	952	3000	170	3
Mirabella Imbaccari	378	13	27	54	9	117	4	15	3
San Cono	30	2	2	26	4	33	1	117	
San Michele di Ganzaria	291	38	3	101	45	139	4	107	
Vizzini	1,944	182	33	1951	48	296	13	37	47

In the Calatino region, several factors are perceived as obstacles to the realisation of the sector's full potential, including farm fragmentation, difficulties in accessing the market, limited water resources and climate change problems. Nevertheless, the necessity to modernise and enhance the competitiveness of the sector persists, supported by the implementation of more sustainable and innovative practices. The distribution of organic farms in the municipalities of the Calatino inner area is summarised in Table 4.

Table 4 Percentage of Organic Farms in Municipalities of Calatino SNAI Area

Municipality	Organic farms (no.)	Total farms (no.)	% Bio/Tot
Caltagirone	70	2,368	3.0
Grammichele	14	511	2.7
Licodia Eubea	26	823	3.2
Mazzarrone	20	352	5.7
Mineo	76	1,859	4.1
Mirabella Imbaccari	9	214	4.2
San Cono	11	100	11.0
San Michele di Ganzaria	7	217	3.2
Vizzini	46	463	9.9
Total SNAI area	279	6,907	4.0

The Table shows that there is a serious presence of organic agriculture; however, the share of organic farms is very heterogeneous among the municipalities. For example, San Cono presents the highest percentage of organic units compared to the total number of farms, holding an 11% rate of the local total number of farms; this would sustain a strong orientation towards sustainable agricultural practices in this municipality. Followed are Vizzini, Mazzarrone, and Mirabella

Imbaccari with percentages of 9.9%, 5.7%, and 4.2%, respectively. These figures testify for organic interest in cultivation, and for good potential for further investment in these practices. Overall, in the Calatino area where SNAI is implemented, 4% of the farmlands are managed organically. The overall number demonstrates that some municipalities already register important percentages, but there is still space to enhance and develop the diffusion of organic practices throughout the territory. Figure 6 shows the distribution of the organic certifications among the different certifying bodies working in the Calatino area.

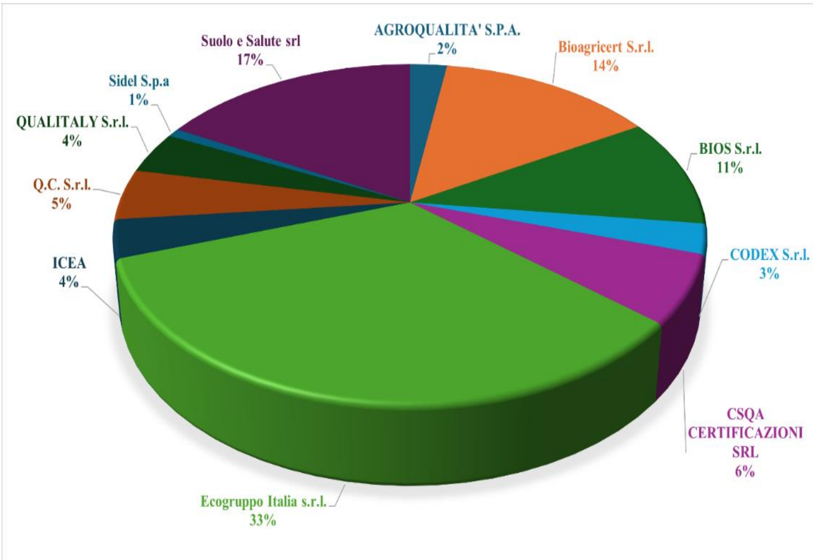

Figure 6 Distribution of Organic Certifications among the different Certifying Authorities in the Calatino SNAI Area.

The high level of certification concentration among very few large entities, including Ecogruppo Italia S.r.l. and Suolo e Salute Srl (who together cover almost 50 per cent of the market), indicated that close collaboration with these entities would have to ensure the success of the initiative and further support local farmers in switching to more sustainable practices. The overall distribution of organic operators in the Calatino region is then analysed through Figure 7. 71% of the agricultural activities are specialized in vegetable production—herbaceous and tree production—whereas 19% are specialized in livestock. The cultivation of plants and animals is spread throughout the entire territory; this importance is projected as a base and vital objective factor for the set-up of a Bio-district that can give a supporting boost to tackle the present difficulties and encourage the transition to a more sustainable and competitive agriculture. By promoting organic farming, the Bio-District could improve farmers' economic conditions, add value to local products, and contribute to harmonious and sustainable development of the territory.

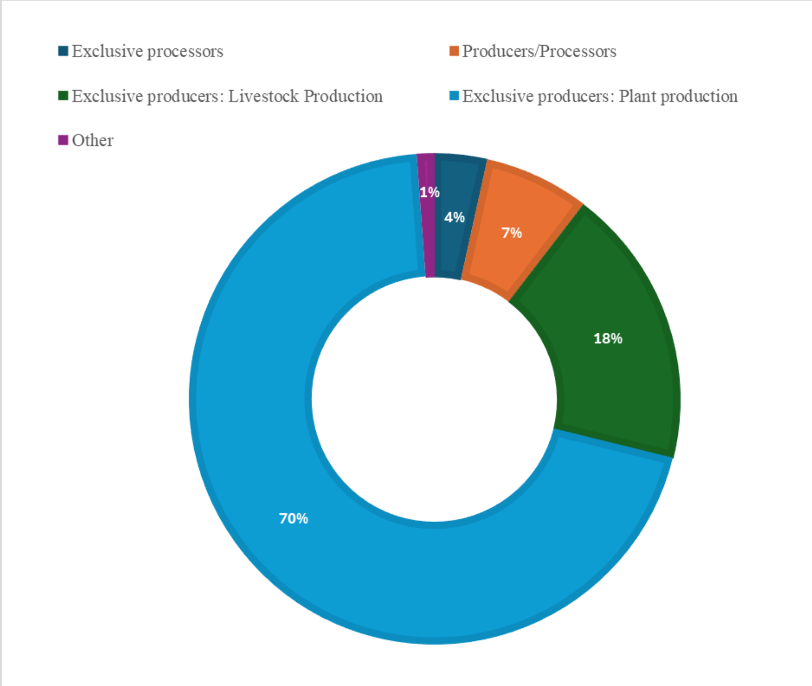

Figure 7 Distribution of different categories of organic operators in the Calatino SNAI Area.

3.2 Identification and Involvement of Stakeholders

The process of identifying the stakeholders was conducted in a systematic manner, in accordance with the findings of the preceding contextual analysis. For the Living Lab of the Calatino Bio-district, a few key groups of stakeholders have been identified, including farmers, processors, distributors, and traders; environmental and consumer associations; and delegates from public and private organisations. In particular, the number of farmers included in the list of certified organic or converting farmers as required by the DM of December 28, 2022, n. 663273, was of the essence to ensure compliance with the Bio-district guidelines. It was essential to gain insight into the underlying motives of the stakeholders to facilitate their active involvement in the project. Interviews and interpersonal contacts revealed that among the farmers and environmental associations, intrinsic motivations were more clearly expressed and felt. These included the desire to sustain agriculture and to improve the quality of life. Among the traders and distributors, motivations of an economic nature and the desire to access new markets were particularly prominent. To create a properly diverse and representative network of stakeholders, the quadruple helix model was employed to ensure involvement from a variety of sectors, including the public, private, and academic spheres, as well as the general population (Figure 8). Accordingly, a variety of perspectives and competencies were represented to facilitate a constructive and inclusive discourse.

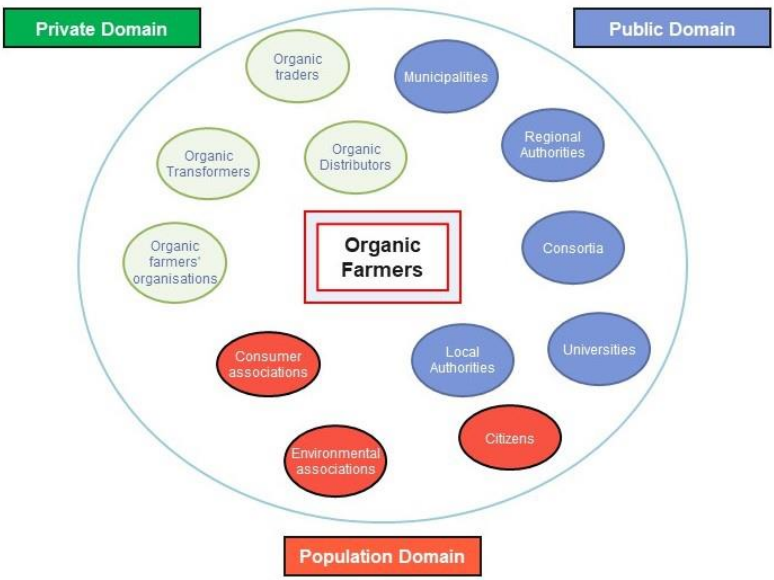

Figure 8 Key Stakeholders and their interests in the project.

The criteria for the selection of participants in the Living Lab are:

1. Belonging to the organic supply chain: participants should be part of the organic supply chain, as certified organic or converting farmers, whether individually or as a member of an association, processors, distributors, and traders, according to DM of December 28, 2022, n. 663273, for the constitution of a Bio-district in Italy. This even counted for entities and associations active in the field of environmental protection (environmental associations) and those that promoted the territory and its products (consumer associations).
2. Positive personal characteristics: participants had to have personal characteristics that would positively influence the collective process, such as an open mind, good communication skills, reflectivity, and being able to accept and agree upon frameworks for the collaborative processes.
3. Diversity of roles and skills: ensuring a diversity of formal roles, knowledge, perspectives, and decision-making processes was vital and well-aligned with the quadruple helix model including public, private, academic, and civic sectors.
4. Territorial belonging: participation is restricted to actors pertaining to the specific region where the project was getting implemented; in this case, the Calatino area.

The most significant key interest groups that participated in the stakeholder engagement process are presented in Figure 9.

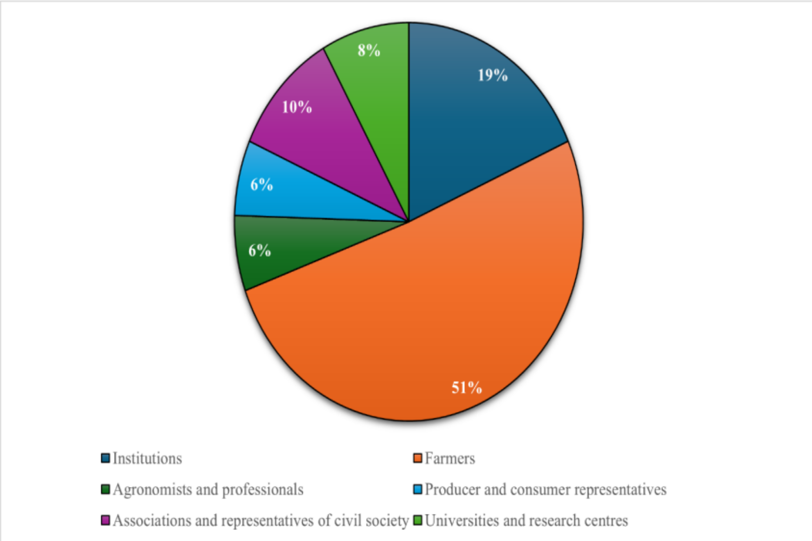

Figure 9 Stakeholders involved in the process of establishing the Calatino Bio-district through the Living Lab procedure.

3.3 Results on the Aggregation Process

The co-design process highlighted that the Calatino Bio-district intends to build its identity on two fundamental pillars:

1. A decisive orientation towards agroecology
2. Integrated and sustainable development throughout the entire agri-food supply chain

The goal is to create widespread, sustainable, and perceptible well-being that involves both the environment and the local populations. Therefore, the discussion focused on a potential strategy centered on agricultural practices that respect natural balances and the enhancement of local resources. This model of growth aims not only to protect biodiversity and local traditions but also to improve the quality of life and strengthen the socio-economic fabric of the territory.

The district strategy is fully integrated with the significant natural, environmental landscape, culture and history resources of the territory derived from the geographical position of Calatino at the center in the context of Mediterranean exchange flows. The area is well known for its historic center of Caltagirone, UNESCO World Heritage Site on Baroque architecture and for Bosco di Santo Pietro Nature Reserve, placed to the southeast of Caltagirone. It represents one of the largest natural reserves in Sicily; here biodiversity is very vast with numerous species of Mediterranean flora and fauna (mammals, birds, insects) and endemic plants vital to ensure recolonization mechanisms of native species as well as for faunistic components that maintain ecological equilibria within the region.

Other notable areas include Vizzini, the setting of Giovanni Verga's works, with its beautiful hilly and rural zones, baroque churches, and the Gattopardo castle; the inclusion in Val di Noto, among the UNESCO heritage sites; Grammichele, the only municipality with a hexagonal urban layout; Licodia Eubea, located among hills and wooded areas and home to an artificial basin offering opportunities for outdoor activities; Mineo, Mazzarrone, and San Cono characterized by extensive citrus, table grape, and prickly pear plantations; San Michele di Ganzaria and its proximity to the Rossomanno, Grottascura, and Bellia nature reserve. These municipalities offer a mix of history, culture, craftsmanship, and natural landscapes.

In this context, the Living Lab approach has enhanced the elaboration of an ideal space for conducting experiments in a collaborative manner to promote agroecological transition in the territory. It brings together farmers, researchers, institutions, and local communities that design and test new solutions for sustainable agriculture; opportunities that have uncovered solutions never before imaginable. The workshops open in nature and collaborative in practice created a safe place for participants to share their ideas and concerns, engendering a sense of community and working on common ground. As basically one of the main keys to success of the project, co-construction involving a local community in a real definition and performance of solutions, is usually seen. Stakeholders firmly believe that participation in the decision-making process provided them a channel to have a voice and bring in ideas that are directly attuned to their needs, and hence they will work more for the change.

Therefore, the Living Lab allowed discussions on agroecological practices that will be adopted in the Bio-district and how such practices will reduce the environmental impact of agricultural activities in Calatino hugely. The introduction of these practices will also see improved soil health and reduced usage of dangerous chemicals, a beneficial venture in the long term for the environment. This affirmatively answers research question Q1, which also agrees with what has been supported by the FAO, as shown in Figure 10.

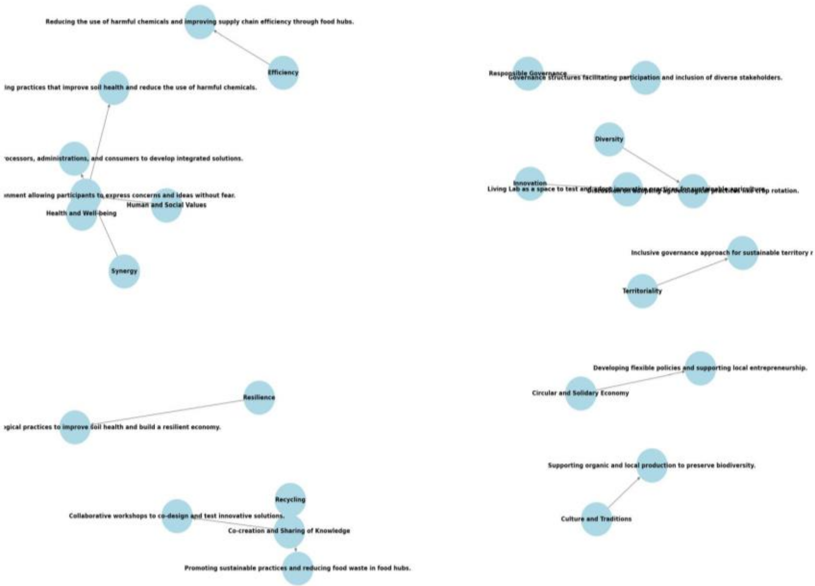

Figure 10 Connection between bio-district of Calatino and the 13 Agroecology Principles by FAO.

The figure illustrates the way the preferred agroecological principles and practices in the Calatino Bio-district can be closely aligned with the agroecological principles promoted by the FAO. These connections include the diversification of crops to enhance the resilience of agricultural ecosystems and provide a wider range of ecosystem services; the integrated management of pests by encouraging natural pest control through synergies within the agricultural ecosystem, thereby reducing reliance on chemical pesticides; organic fertilisation and soil management by promoting nutrient recycling within the agricultural system through the use of compost, manure, and other organic fertilisers, which improves soil health and productivity. The efficient utilisation of water resources through sustainable irrigation techniques and the conservation of rainwater; the conservation of local genetic resources to enhance the resilience of agricultural ecosystems to climate change and other stresses; agroforestry by co-creating and sharing knowledge on integrating trees and shrubs into agricultural practices; and the active participation of the community and the valorisation of local knowledge to support these practices. This approach serves to diminish the carbon footprint and augment the capacity of agricultural ecosystems to adapt to climate change.

Regarding question Q2, respondents emphasised that governance structures should ensure the involvement, and later the inclusion, of various stakeholders. The inclusive governance approach would support the consideration of all needs and concerns of each stakeholder to promote more equitable and sustained land management. Inclusive governance is an important component in building trust and collaboration between different communities in the area. It became clear that the formulation of policies based on the results and experiences of the Living Lab will be very helpful for the success of the Bio-district. Policies should be very flexible, so that they can be adapted to the specific needs of an area to ensure a rapid response to changes and emerging challenges. Clearly delineated support policies will promote an environment conducive to innovation and sustainability. It was argued that collaboration between farmers, processors, administrative bodies and consumers is crucial for creating synergies and developing integrated solutions for sustainable land management. Finally, in response to question Q3, the design of the bio-district shifted towards the possible establishment of a 'food hub' within the bio-district, described as a 'centre for aggregation and distribution of food, integrating research and innovation in a real and participatory context'. In this configuration, the food hub is more than an entity that simply collects and distributes local products. It is an experimental space where citizens, producers, researchers and institutions work together to develop new solutions for sustainability, food access and innovative promotion of agricultural practices. The LL provides a space to test these solutions and then scale them up in real practice to ensure knowledge transfer for the adoption of more sustainable practices within the community.

To achieve the following strategic objectives, it can be in an abandoned industrial area in the industrial zone of Caltagirone:

- Centralisation of distribution: in this case, the food hub is a centre for the collection, distribution and sale of local agricultural products, which can give small producers access to the market. Within the bio-district, this initiative allows organic producers to reach a wider audience (even from areas outside the Calatino), thus increasing the profitability and economic sustainability of agricultural enterprises.
- Support for organic production: it continues to manage the supply and demand of organic products - to avoid overproduction or undersupply. It is important to maintain the level of quality and certification required for a product within a bio-district, so that products meet the requirements to be valued as organic in the marketplace.
- Promotion of local consumption: through marketing, education, and awareness initiatives that encourage the consumption of local and organic products, the food hub increases consumer awareness of the bio-district's importance. This not only boosts local sales but also strengthens community identity and cohesion.
- Collaboration and innovation: The food hub can become a centre for innovation and collaboration between farmers, processors, distributors and passing consumers. It can offer knowledge exchange on sustainable practices and cooperate in supporting the development of new organic products and building solidarity networks that strengthen the whole bio-district.
- Access to funding and resources: Food hubs as part of the bio-district can have a cooperative model for sustainable development with resilient attractiveness for public and private funding.

4 Discussion

In the preparatory work for the creation of the Living Lab, much attention was paid to the definition of the system boundaries and the selection of those to be invited as participants. Within the Italian bio-district initiatives, farmers are recognised as primary stakeholders, based on a close integration with the local social and environmental context (Di Veroli et al., 2024). In addition, among other benefits, farmers can now sell their products within the territory and participate in a multifunctional tourist circuit at local level, hosting different bio-farms: bio-itineraries, educational bio-farms, social bio-farms - thus increasing their income (Belliggiano et al., 2020; Dara Guccione et al., 2024). The structured methodology used to identify the main stakeholders in an organic area allowed the involvement of farmers, processors, distributors, traders, environmental and consumer associations, as well as representatives of public institutions and private interests. Moreover, this inclusive approach was essential to ensure the representativeness and diversity necessary for constructive discussions and effective co-creation of solutions (Puerari et al., 2018; Dekker et al., 2020).

The development of a diverse network of actors, based on the quadruple helix model, has been shown to be effective in enhancing innovation and collaboration. The involvement of actors from the public, private, academic and civil society sectors ensured a spectrum of views and skills that enriched the decision-making process and contributed to the creation of innovative and joint solutions (Steen Van Bueren, 2017; Kronsell et al., 2018). A major challenge relates to the limited time available for smallholders and private institutions to participate in the workshops. This limitation may have temporarily reduced the innovative and informed input from these relevant actors. However, their appreciation of the participatory approach suggests that, with more appropriate support and less rigid planning, their future involvement could be increased, particularly in action planning and idea testing. Based on the experiences and lessons learned during the meetings, we describe the main contextual dimensions for Calatino (Figure 11).

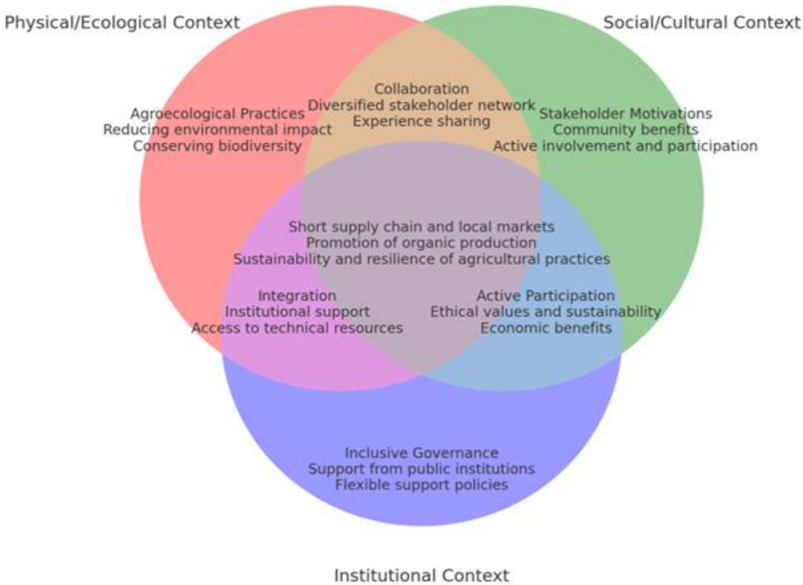

Figure 11 Interconnected Contexts and Influencing Factors in the Formation of the Calatino Bio-district.

One important aspect that emerged was the intrinsic and extrinsic motivations of stakeholders. Intrinsic motivations, such as the willingness to promote sustainable agricultural practices and quality of life in their communities, were very strong for farmers and environmental organisations. This helped them to engage proactively and contribute meaningfully to the project, as it was easily aligned with their own ethical values and sustainability goals. Traders and distributors, on the other hand, were more attracted by the economic benefits: the new markets they would access and the benefits of being part of a bio-district.

The adoption of agroecological practices in the Calatino Bio-district, as discussed in the Living Lab, is a fundamental step towards reducing the environmental impact of agriculture in the area. These practices promise not only to improve soil health, but also to reduce the use of harmful chemicals. In addition to these environmental benefits, agroecological farms: provide more employment per hectare (thus supporting the regional economy), require fewer fossil fuels, and contribute positively to landscape conservation and biodiversity (Van der Ploeg et al., 2019; Gargano et al., 2021). One of the most evident aspects that emerged from the workshops is the farmers' awareness, but again a paradigm shift is needed to adopt these practices. The most valuable part of the long-term benefits of agroecology will have to come from farmers, who should adopt an approach that values ecological processes and is also sustainable. The LL has proved to be an effective space for facilitating this change, providing a collaborative environment where farmers can share experiences and solutions. This participatory approach is important to overcome initial resistance and adapt agro-ecological practices to specific local conditions (López-García et al., 2021; Méndez et al., 2017). Access to scientific and technical knowledge is also needed to sustain the transition (HLPE, 2019). The bio-district as a collaborative environment allows the exchange of experiences between farmers, researchers and other stakeholders. Create synergies between organic and agroecological farming. These tools promote the spread of organic farming at territorial level. And facilitate the expansion towards agro-ecological practices (Guareschi et al., 2020). However, the presence of different stakeholders with different levels of interest and decision-making power can lead to uneven exchanges or even excessive bureaucracy. This underlines the importance of developing inclusive governance structures. An inclusive approach to governance is important to ensure that the needs and concerns of all stakeholders are considered, thereby facilitating more equitable and sustainable land management. Inclusive governance creates trust and cooperation between the different communities within the area, which are fundamental elements for ensuring the success of the bio-district in the long term. This is in line with best practice in the literature, which highlights how stakeholder participation can improve the adoption and effectiveness of both environmental and agricultural policies (Poponi et al., 2021; Favilli et al., 2018).

Farmers should be the foundation of this governance model, always supported by other actors, especially public bodies such as the municipality, to ensure collaborative governance that creates a positive environment for all stakeholders and the territory. Inclusive governance is essential to reduce the degree of information asymmetry and facilitate the definition of common principles that provide a clear path towards sustainability within an agroecological framework. This approach, combined with the quadruple helix model, allows for the consideration of a wide range of perspectives and skills, enriching the decision-making process and facilitating the creation of innovative and shared solutions (Engels et al., 2019). The workshop results emphasised that policy development based on lessons learned and results will be very critical for the success of the bio-district. However, the implementation of such policies is very challenging. The policy should reflect the uniqueness of each area in which it is implemented, developed and respond to a rapidly changing context and challenges (Knickel et al., 2023). While flexibility is essential to respond to local dynamics and environmental variables, it can also hinder the establishment of prescriptive, uniform guidelines, with possible implications for stakeholder uncertainty. In this case, the importance of clearly defined support policies cannot be overemphasised. Innovation and maintenance find their way to a favourable atmosphere through such policies, which also act as a channel for bridging the differences that could have led to disputes, by defining strategies to mitigate them and promote peaceful coexistence (Compagnucci et al., 2021).The experience of the LL provides a valuable basis for the development of these policies, but it is essential that the proposed solutions are adaptable and considerate of the diverse needs and contexts of stakeholders.

Small supply chains and neighbourhood markets within the bio-district will encourage farmers to adopt sustainable practices. This means that the monetary value remains at the local community. From a different perspective, this approach is also highly beneficial to biodiversity conservation. It encourages the cultivation of local and resilient varieties (Poponi et al., 2023; Guarnaccia et al., 2020). Through short supply chains, farmers can sell their products directly to consumers as end-users. In this way, middlemen are eliminated (Paciarotti and Torregiani, 2021). Consequently, Farmers' profit margin on sales increases. This fosters economic sustainability on one hand and high-quality product production that sustains local agricultural traditions on the other (Paciarotti et al., 2019). Furthermore, direct sales create closer ties between producers and consumers by increasing trust in food systems' transparency (Sellitto et al., 2018). Consumers can buy fresh, high-quality products. And often at very competitive prices. The availability of local products further enriches the diet in terms of health and diversification, while also raising awareness of food origins and production methods (Rico Mendez et al., 2021). In today's context, consumers not only demand, but also seek - with increasing quality and safety dimensions for the finalisation of their purchase process - products that are also accompanied by information on the origin of the raw materials (Timpanaro and Cascone, 2022). With this increased awareness, consumers (when informed) start to prefer organic and locally produced products; in this way they directly support their local economy while reducing the environmental impact generated by the transport/distribution of these goods (Scuderi et al., 2019). In this way, consumers become active actors in a sustainable production process, and they contribute to building more transparency between the different actors involved in a responsible food system.

Within this perspective, the proposal to create a food hub in the bio-district has generated a unanimous consensus among the partners, highlighting the strategic value of such structures to sustain their practices. Food hubs are an important way not only to increase efficiency within the supply chain, but also to reduce food waste, which is very important from a sustainability perspective (Shariatmadary et al., 20-23). However, the implementation of food hubs faces several challenges. The planning and management of this type of infrastructure requires significant investment, both in terms of financial and human resources (Morganti and Gonzalez-Feliu, 2015). This lack could affect their effectiveness and long-term sustainability.

Moreover, they can be used as educational points where consumers can understand the value of a sustainable and healthy diet, which improves the quality of life in localities (Berti Mulligan, 2016). These centres can hold workshops, events and training programmes to raise awareness of the environmental, economic and social benefits of consuming local and organic food. Education on sustainable consumption will strengthen the relationship between producers and consumers and lead to a conscious commitment to sustainability within the community.

The creation of a food hub within the bio-district is a great opportunity to promote a more sustainable and resilient model through local agricultural development. However, it is important that all stakeholders - from public institutions to local entrepreneurs and end consumers - integrate the challenges involved to maximise their potential in a collaborative way.

5 Conclusion

The aim of the study was to explore the possibility of creating a bio-district in Calatino through a participatory process involving different local stakeholders. The Living Lab methodology, with its tools and practices, is described, considering the quadruple helix model. Agroecological practices are indeed a valuable tool to promote the sustainability and resilience of territories. This approach has allowed the integration of perspectives from farmers or agronomists, but also from traders, environmental associations and public institutions.

An innovative process was developed to identify sectors and themes for change. The process has shown some adaptability and generalisability to other contexts. Therefore, it could help to improve Living Lab methodologies in different territorial situations.

The results showed that although the roles and contexts of the actors are diverse, they share a common understanding of the issues and can co-create a vision for the future. The difference between the way things are and the way they want them to be served as an indicator of where to focus future idea generation and innovation activities, as well as planning and testing specific actions.

A major limitation was that stakeholders had limited resources and time, which affected the level of participation and the depth of discussion. In addition, organising and running the Living Lab is a heavy process that requires a lot of effort, which may not be replicable in contexts with even scarcer resources.

This research contributes to the Bio-district and Living Lab literature by discussing a real-life application of the Quadruple helix model in a rural context. The results could be useful for further comparative studies and for the development of theoretical frameworks that could apply an integration of multiple and sustainability-oriented, innovation-based disciplinary approaches.

Both practically and politically, the project highlights the need for support policies that are flexible and adaptable to specific rural needs. Inclusive governance structures and schemes such as food hubs can play an important role in the dissemination of agroecological practices. Public institutions need to work very closely with local stakeholders to ensure that policies work well and that benefits are shared in every way.

The experience and lessons learned from the Calatino Living Lab project provide a solid foundation for future similar initiatives. For a bio-district to be successful in the long term, a participatory approach and inclusive governance need to be strongly promoted. This, especially in terms of support services, shows that it is possible to have sustainable and resilient agricultural systems that also improve the quality of rural life.

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Contribution III - Innovation in Inner Areas: how Living Labs support green transition and Bio-district success

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Abstract

Bio-districts represent an innovative governance tool that fosters cooperation among farmers, institutions, and other local actors to promote environmental sustainability, economic resilience, and social cohesion in rural areas. However their implementation requires the active engagement of farmers, whose willingness to participate is influenced by a range of psychological and institutional factors. This study investigates the factors influencing organic farmers' intention to join a potential Bio-district in the Calatino area (Sicily, Italy), applying an Extended Theory of Planned Behaviour (ETPB) framework that includes Perceived Utility and Trust in Government. A survey was conducted with 143 organic and transitioning farmers. Data were collected through a participatory Living Lab approach, which provided space for dialogue, knowledge exchange, and co-learning. The results show that Attitude ($\beta = 0.649$; $p < 0.001$) and Subjective Norms ($\beta = 0.231$; $p < 0.01$) positively influence the Intention to join the Bio-district, while Perceived Behavioural Control is not significant. Furthermore, Perceived Utility ($\beta = 0.410$; $p = 0.001$) and Trust in Government ($\beta = 0.173$; $p = 0.055$) indirectly influence Intention through Attitude. The participatory approach of the Living Lab facilitated data collection and encouraged farmer involvement, providing a shared learning environment and helping to build trust among local actors. The study offers concrete recommendations for public policy: strengthening institutional trust, communicating the tangible benefits of membership, and adopting participatory tools can promote the adoption of sustainable agricultural models in marginal rural contexts.

Keywords

Bio-district; Living Lab; Inner Areas; Theory of Planned Behaviour (TPB); Organic farming

1 Introduction

In recent years, the agricultural and agri-food sector has faced unprecedented challenges due to major global phenomena (Timpanaro and Foti, 2024). The COVID-19 pandemic has highlighted the vulnerability of globalized food supply chains, underscoring the need for more resilient and sustainable production models. At the same time, the war between Russia and Ukraine has further exacerbated the food crisis, generating instability in agricultural commodity markets and increasing Europe's dependence on external supplies (European Commission, 2025). These events have reinforced awareness of the importance of developing more autonomous, resilient, and sustainable agri-food systems capable of ensuring long-term food security.

In the European context, the transition toward more sustainable agricultural models has been formally outlined through the European Green Deal, and particularly the Farm to Fork strategy, which aims to reduce agriculture’s environmental impact and promote short and local supply chains (Colglazier, 2015; European Commission, 2025). This vision is embedded within the broader Vision on Agriculture and Food (2025), which emphasizes the role of innovation, digitalization, and agroecological practices in ensuring a fairer and more sustainable European agri-food system (Quaranta et al., 2020; European Parliament, 2022).

Within this framework, Bio-districts or Eco-Regions serve as fundamental tools for promoting an agricultural model that integrates economic, social, and environmental sustainability while enhancing local resources and strengthening connections among farmers, consumers, and institutions. Bio-districts are local networks made up of organic farmers, public institutions, civic associations and other local actors, aimed at promoting agroecological practices, short supply chains and shared value in the local area (Poponi et al., 2021). Recognized by national legislation in Italy (Ministerial Decree No. 47, 2022), Bio-districts are emblematic of policentric governance models that combine state support, market incentives, and community-based institutions (Kraljevic and Zanasi, 2023). The role of Bio-districts extends beyond fostering cooperation among rural stakeholders to encourage organic farming and sustainable development, as they also contribute to territorial regeneration and the creation of value in rural areas (Di Veroli et al., 2024). Moreover, Bio-districts facilitate the interconnections between agriculture and other economic sectors and local activities, such as eco-tourism, education, and culture, because of the synergies between agriculture, artisanal production, recreational activities, and tourism in different territories (Guareschi et al., 2020; Mazzocchi et al., 2021). From a political economy perspective, Bio-districts respond to multiple failures: the inability of conventional markets to reward environmental and social externalities, the fragmentation of public interventions, and the erosion of trust among actors in marginal rural areas. Therefore, the Bio-district approach enhances territorial multifunctionality by creating links between rural, urban, and peri-urban areas and engaging multiple actors in the local development process (Dias et al., 2021; Lamine et al., 2023; Packer and Zanasi, 2023).

Their role is particularly crucial in inner areas, which are characterized by increasing economic and social marginalization. Since 2014, these areas have been the focus of the National Strategy for Inner Areas (SNAI), which has played a key role in promoting local development policies, counteracting depopulation, and enhancing the endogenous resources of the territory (Barca et al., 2014). The promotion of short supply chains, the strengthening of local economies, and the adoption of agroecological practices can contribute to the revitalization of these territories by offering new income opportunities for farmers and ensuring an active presence in the area (Assiri et al., 2021; Poponi et al., 2021; Stefanovic, 2022; Stotten and Froning, 2023).

A concrete example of this dynamic is represented by the Calatino, an inner area of Sicily where a Living Lab has been established among various local stakeholders (University of Catania, Local Action Groups – GAL, municipalities, agricultural and consumer associations, etc.) to promote innovative and participatory solutions for agricultural sustainability and rural development. A Living Lab is a collaborative environment where farmers, institutions, businesses, and other local actors engage in discussions and co-create shared solutions (Cascone et al., 2024). This method facilitates knowledge exchange, collective learning, and the testing of new ideas (Hossain et al., 2019), making it particularly suitable for investigating the dynamics of farmers' participation in new initiatives such as the Bio-district.

This experimental lab allows for testing new forms of governance and collaboration among local actors, with the aim of enhancing organic production, fostering the transition toward a more sustainable economy and society, and encouraging farmers to join a potential Bio-district of Calatino (Dara Guccione et al., 2024; Sturla et al., 2024). The Living Lab functions as an experimental and participatory platform for testing agroecological practices, digital technologies, and new governance arrangements aimed at supporting the establishment of a Bio-district.

While the literature recognises the potential of Bio-districts to promote multifunctional rural development and territorial regeneration, no studies provide empirical analyses of the factors that influence producers' intentions to participate in such networks and how market, regulatory and collective action conditions intersect in this process. This lack of empirical evidence hinders the design of effective policies to encourage local cooperation.

This paper aims to fill this gap by applying the Theory of Planned Behavior (TPB) – a widely used framework in behavioral research – to analyze the intention of organic farmers in the Calatino area to join a Bio-district. The TPB is extended to include two key constructs: Perceived Utility, representing expected economic, social, and ecological benefits; and Government Trust, capturing the role of institutional credibility and political support. These additions reflect the need to better capture farmers' reasoning in contexts of high uncertainty, weak markets, and evolving governance.

Accordingly, the central research question is: Which psychological, economic, and institutional factors influence the willingness of organic farmers in marginal rural areas to join a Bio-district?

In addressing this question, the study contributes to the literature on sustainable food governance, collective action, and rural transformation, and offers practical recommendations for policymakers, civil society actors, and local administrators engaged in ecological transitions.

2 Theoretical Background

2.1 TPB and Extended Version

Several theoretical models have been used in studies of farmer behaviour to explain individual intentions and decisions, including the Technology Acceptance Model (TAM), the Diffusion of Innovation Theory (DOI), the Social Cognitive Theory (SCT) and the Theory of Planned Behaviour (TPB). The choice to adopt TPB in this study is based on its ability to capture the cognitive, social and perceived components that influence behavioural intention (Damalas, 2021). Furthermore, the modular and open structure of TPB makes it particularly suitable for extension with constructs relevant to the specific context, thus providing a solid yet flexible theoretical basis for investigating decision-making dynamics in complex rural areas (Sapkota et al., 2025; Gowda et al., 2021). These characteristics are particularly consistent with the objective of this study, which aims to explore the intentions of organic farmers in the Calatino area regarding adherence to an agroecological model of local development.

The TPB is an extension of the Theory of Reasoned Action (TRA) (Ajzen, 1991). It is one of the most widely used cognitive frameworks in the social sciences to examine individual decision-making processes, and its effectiveness in understanding farmers' choices has been demonstrated in several studies (Adnan et al., 2019; Despotovic et al., 2019).

The theory states that behaviour arises from the intention to perform a certain action. The stronger the intention, the more likely an individual is to engage in the behavior (De Groot and Steg, 2007; Gallagher et al., 2022; Timpanaro and Cascone, 2022). The proposed TPB postulates three constructs for analysis: Attitudes, Subjective Norms, and Perceived Behavioral Control (Ajzen, 1991; Ajzen and Madden, 1986). These constructs refer to unobservable variables that cannot be directly measured or observed and are estimated through the analysis of observable variables. The constructs for the TPB are defined as follows:

1. Attitude (ATT): reflects the extent to which engaging in a behavior is evaluated positively or negatively (Ataei et al., 2021; Rezaei et al., 2020).

2. Subjective Norm (SN): reflects the extent to which a person believes there are expectations or pressures on them to perform or not perform a certain behavior. Subjective Norms evaluate the importance of approval or disapproval of the behavior by relevant groups (Castillo et al., 2021; Savari and Gharechaee, 2020).

3. Perceived Behavioral Control (PBC): reflects the extent to which a person perceives ease or difficulty in performing a behavior (i.e., resources, knowledge, and opportunities available to a person, which to some extent determine the

likelihood of performing the behavior) (Tama et al., 2021; Farani et al., 2019; Bagheri et al., 2019).

The literature distinguishes between injunctive norms (perception of what others expect) and descriptive norms (what others do) (White et al., 2009). In the present study, items related to subjective norms tend to reflect mainly the injunctive dimension, linked to the judgement of colleagues and family members. Similarly, Perceived Behavioural Control can be decomposed into self-efficacy (personal ability) and controllability (presence of external constraints) (Castanier et al., 2013). Although both aspects are present in the scale used, it is recognised that a further distinction between these two components could improve the understanding of the results.

The TPB has been applied in various areas of agriculture to analyze how farmers make decisions. It has been used to explore, how farmers respond to agro-environmental policy initiatives (Daxini et al., 2019; Irwin et al., 2023). Additionally, it has been used to investigate motivations behind the adoption of practices for the conservation of farm biodiversity (Maleksaeidi and Keshavarz, 2019), the adoption of sustainable agricultural innovations (Timpanaro et al., 2023a), agricultural diversification (Senger et al., 2017), and water management in agriculture (Rezaei et al., 2019). Despite the general usefulness of the TPB model for identifying and understanding the various behaviors of farmers and rural inhabitants (Lalani et al., 2016; van Dijk et al., 2016; Adnan et al., 2017), several researchers have suggested that the explanatory power of the TPB is low in some situations (Ahmmadi et al., 2021, Arunrat et al., 2017). Ajzen also proposed that the TPB, with some flexibility, should be adjusted and extended according to the specific situation during use (Ajzen, 1991; Sok et al., 2021; Chen, 2017).

The decision to participate in a Bio-district is not a simple individual choice, but a complex collective decision rooted in the socio-institutional context and personal assessments of potential benefits. In this scenario, the TPB has been extended with two additional constructs: Perceived Utility (PU) and Government Trust (GT), selected based on the specificity of the case study and supported by previous empirical evidence. The inclusion of PU reflects the importance of considering multidimensional assessments that integrate the economic, environmental and social benefits expected from participation in the Bio-district. PU does not directly influence intention but contributes to forming a positive assessment of the action itself (i.e. attitude), in line with the findings of Adnan et al. (2017) and Lemus et al. (2024), according to whom perceived benefits are a key antecedent in building attitudes towards sustainable practices. Similarly, Trust in Government (GT) was included to capture farmers' perceptions of institutional support and the consistency of public policies in promoting innovative agricultural models. In inner areas, often characterised by mistrust of institutions and low social capital, GT can be an important factor shaping attitudinal predisposition towards collective initiatives (Li et al., 2023; Zhang and Wu, 2018). For this reason, the effect of GT is hypothesised to be mediated by attitude, as the perception of reliable public support can influence how farmers evaluate the action, rather than directly affecting their intention.

2.1.1 Perceived Utility as additional construct

The decision of farmers to participate in participatory initiatives such as bio-districts involves navigating through economic uncertainties and environmental considerations, like when adopting conservation practices (Lemus et al., 2024). Participation in a bio-district not only reflects a commitment to sustainability but could also influence agricultural productivity and, consequently, the economic objectives of farmers (Smol, 2021; Tur-Cardona et al., 2018). Therefore, it is essential to examine how farmers integrate psychological and economic assessments in their decision to join a bio-district, in line with the principles of the Theory of Planned Behavior (TPB). Previous studies have suggested the importance of incorporating economic assessments within the TPB to better understand sustainable agricultural decisions (Adnan et al., 2017; Rossi-Borges et al., 2015). These approaches highlight how Perceived Utility significantly influences intention. Perceived Utility refers to the subjective perception of the benefits, utility, and satisfaction individuals believe they will gain from a product (Adnan et al., 2019; Rossi-Borges et al., 2015; Wang et al., 2018). In the case of the decision to join a bio-district, it includes not only the evaluation of direct economic benefits but also the value attributed to environmental conservation and the improvement of the farming community. Incorporating this multidimensional understanding of Perceived Utility into the TPB helps explain how economic motivations, along with environmental and social evaluations, guide farmers toward adopting sustainable practices like participating in bio-districts.

2.1.2 Government Trust as additional construct

The adoption of sustainable agricultural practices is significantly influenced by farmers' perceptions of government support. Tien et al. (2022) and Yanakittkul and Aungvaravong (2019) confirmed that policy tools are effective in promoting sustainability in agri-food production. This support manifests in various forms, including the redistribution of resources, financial subsidies, market oversight, and greater external protection, which are perceived by farmers as a positive evaluation of political support. According to Li et al. (2023), government support is essential for farmers' self-efficacy and for helping them mitigate risks associated with their activities. Bhatt and John (2023) further demonstrated how financial assistance and institutional support are crucial for minimizing income risks, especially for small-scale farmers who rely heavily on agricultural income. Moreover, the government plays a unique role in promoting agricultural innovation, facilitating collaboration between farmers and key external stakeholders to establish and maintain innovation platforms (Zhang and Wu, 2018). Trust in government not only reflects the perception of the direct benefits of political actions but also the value and respect farmers perceive from incentive policies. This dynamic plays a crucial role in the specific context of a bio-district, such as the one proposed for the Calatino. Strong trust in the government's ability and willingness to support agricultural initiatives can be decisive, as a positive perception can catalyze enthusiasm for actively participating in this new model of agricultural governance. The adoption of the bio-district model requires substantial collaboration between farmers and the government, implying a paradigm shift towards more sustainable and integrated practices. Therefore, if farmers perceive a genuine governmental commitment to ensuring adequate support, resources, and incentives, their willingness to participate and adopt innovative practices will be significantly influenced. This trust in government support can become a key element for the success of the bio-district initiative, encouraging broader and deeper involvement from the local farming community.

2.2 Research Hypothesis

The aim of this research is to investigate the influence of the TPB constructs on the intentions of farmers in the Calatino region to join a bio-district. To achieve this goal, we have formulated the following hypotheses, based on the key constructs of the TPB and the additional constructs of 'Perceived Utility' and 'Government Trust.'

Hypothesis 1 (H1): Farmers' attitudes (ATT) have a positive and significant relationship with their intention (INT) to participate in the bio-district.

Hypothesis 2 (H2): Subjective norms (SN) significantly influence farmers' intentions (INT) to participate in the bio-district.

Hypothesis 3 (H3): Perceived behavioral control (PBC) has a significant impact on farmers' intentions (INT) to participate in the bio-district.

To explore further the factors that may influence the decision-making process of farmers, we extended the traditional TPB model by including Perceived Utility and Government Trust as mediating constructs on intentions.

Hypothesis 4 and 5 (H4 and H5): Perceived Utility (PU) and Government Trust (GT) positively influence farmers' attitudes (ATT) toward participating in the bio-district, acting as mediating variables. Hypothesis 6 and 7 (H6 and H7): Attitude (ATT) mediates the effect of Perceived Utility (PU) and Government Trust (GT) on farmers' INT to participate in the bio-district.

The inclusion of mediations through Attitude for the PU and GT constructs is based on theoretical and practical considerations related to the evaluative nature of farmers' decision-making processes. Both variables are conceived as cognitive antecedents that act upstream of the formation of farmers' attitudes towards participation in the Bio-district. In the case of PU, the subjective assessment of the economic, environmental and social benefits of joining the Bio-district tends to directly influence the value that farmers attribute to this behaviour, thus modulating their attitude. Similarly, the perception of reliable and consistent institutional support (GT) helps to reinforce a positive judgement towards participation, contributing to the construction of a favourable attitude. From this perspective, PU and GT do not directly influence intention, but shape the attitude that, in turn, guides behavioural intention. The choice to test these effects as mediations allows us to evaluate the psychological structure underlying the decision-making process, in line with established extensions of the TPB.

To test these hypotheses, we propose two models:

- Model 1: Based on the traditional TPB structure, this model will be used to test hypotheses H1, H2, and H3.
- Model 2: An extension of the TPB model that includes Perceived Utility and Government Trust as variables that indirectly influence INT through Attitude, as illustrated in Figure 1.

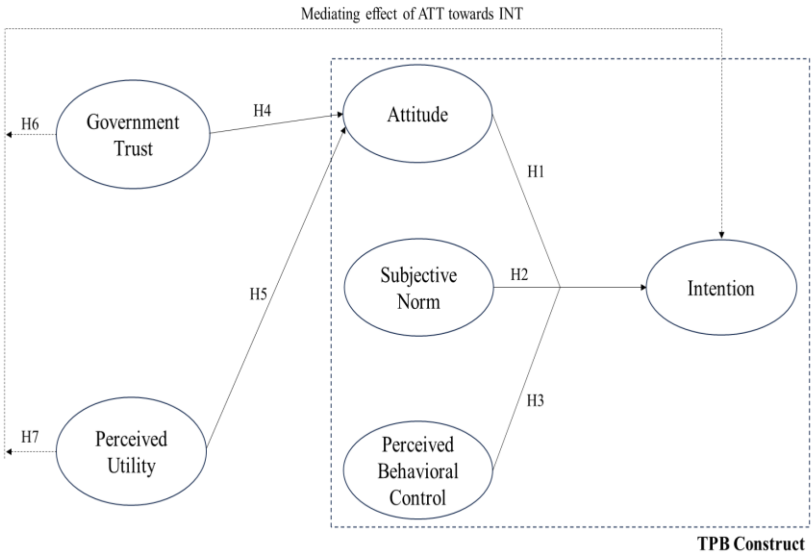

Figure 1 Extended theory of planned behavior and research hypothesis

3 Methods

3.1 Data Collection

The sample of the study consists of organic farmers from the Calatino area in Sicily, one of the regions included in the National Strategy for Inner Areas (SNAI), which encompasses nine municipalities: Caltagirone, Grammichele, Licodia Eubea, Mazzarrone, Mineo, Mirabella Imbaccari, San Cono, San Michele di

Ganzaria, and Vizzini. This strategy aims to promote the development of territories characterized by depopulation, geographical isolation, and limited access to essential services, through targeted policies to foster economic and social sustainability. In the context of the Calatino, this involves the need for interventions that support the growth of the agricultural sector, encouraging sustainable practices and innovations such as the bio-district. To limit potential sampling bias, a combination of direct access through agricultural associations and public consultation during local events was used, to also involve non-affiliated farmers.

Participants were selected using mailing lists provided by the University of Catania and major agricultural associations operating in the area, such as Confagricoltura and the Confederazione Italiana Agricoltori Sicilia. The target population consists of all certified organic farmers operating in the municipalities of the Calatino SNAI. According to official data from the SIAN (National Agricultural Information System), there are 279 such farms. The sampling strategy adopted is non-probabilistic convenience sampling, but it has been structured to achieve balanced geographical coverage across municipalities and maximise the response rate through the direct involvement of trade associations. During the meetings, approximately 168 farmers were initially contacted, of which 143 were found to be valid after a cleaning process based on criteria of completeness, internal consistency and minimum completion time, with a response rate of 86.7%. The final sample represents 51.2% of the reference population of 279 organic farms in the area (SIAN). Although the sample size may appear small, it represents a significant fraction of the reference population, helping to ensure the internal validity of the survey. Furthermore, the sample size was determined using the "10-times rule" method, a widely adopted approach for estimating the minimum sample size in PLS-SEM (Hair et al., 2011; Peng and Lai, 2012). According to this rule, the recommended sample size must exceed the total number of paths pointing to a latent variable (or the total number of paths starting from a latent variable towards its indicators, if greater), multiplied by 10. In our case, five constructs (ATT, SN, PBC, PU, GT) influence intention (INT), so the minimum recommended number is 50. Our sample of 143 respondents meets this requirement, making it adequate for the planned structural analyses. However, we recognise that further comparative studies would be needed to generalise the results beyond the Calatino area.

Data collection, conducted between March and December 2024 by a group composed of researchers from the University of Catania, affiliated with the Department of Agriculture, Food and Environment, and trained facilitators. The meetings were mainly held in person, in municipal halls or association headquarters. Before the actual survey, a pilot study was conducted with 10 local organic farmers to test the clarity of the constructs, the understanding of the questions and the structure of the questionnaire. The observations that emerged made it possible to improve the wording of some questions to adapt them to the local context, especially those relating to more abstract concepts such as Government Trust and Perceived Utility.

During the events, in addition to administering the questionnaire, an interactive Living Lab session was conducted. In this phase, participants were introduced to the concept of the Bio-district, including its key features, potential benefits for the region, and concrete examples from other Italian territories.

The Living Lab facilitated direct dialogue and open discussion among farmers and other supply chain actors, transforming data collection into an opportunity for collective learning and networking. Furthermore, detailed information on the study’s objectives, procedures, and participants' rights was provided, ensuring transparency and anonymity. This approach actively engaged stakeholders and contributed to gathering richer and more context-specific data on the potential for Bio-district participation. Through the Living Lab, farmers were involved in a collective learning process that made the questionnaire not only a data collection tool, but also an opportunity to stimulate active participation and networking among operators in the organic supply chain. The Living Lab played a dual role: methodological, as an environment for engagement and co-creation, and instrumental, in the participatory construction of part of the survey.

During each session, researchers were present to provide direct and contextual clarification in case of doubts, thus ensuring correct understanding by participants.

The survey was structured in two sections. The first section aimed to collect information about the farm's characteristics (municipality of the farm center, size, years in organic farming) and the socio-demographic details of the participants, including gender, age of the operator, and their level of education. The second section focused on analyzing the influence of latent psychological constructs on the farmers’ intentions to participate in the bio-district. The constructs were assessed using a 5-point Likert scale, with values ranging from 1 (strongly disagree) to 5 (strongly agree) (Table 1).

Table 1 Statements, scales, means, standard deviations and references for the socio-psychological constructs.

Item	Statement	Scale (1–5)	Mean (score)	Standard Deviation	References
INT_1	I intend to participate in a Bio-district in my territory in the future	Strongly disagree/strongly agree	3.86	0.64	(Cammarata et al., 2024; Savari et al., 2025; Rossi-Borges et al., 2015)
INT_2	I am willing to participate in a Bio-district in my territory in the future	Strongly disagree/strongly agree	3.80	0.67	
INT_3	I will actively advise other farmers to participate in Bio-district initiatives in our community	Strongly disagree/strongly agree	3.79	0.66	
ATT_1	I believe that participation in a Bio-district in my area would	Strongly disagree/strongly agree	3.72	0.67	(Ataei et al., 2021; Rezaei et al., 2020)

	have a positive impact on my reputation as a sustainable farmer				
ATT_2	I see participation in a Bio-district in my area as an effective way to improve my market position	Strongly disagree/strongly agree	3.71	0.67	
ATT_3	If I were to join a Bio-district, I would be able to access additional financial resources more easily for my company	Strongly disagree/strongly agree	3.62	0.70	
SN_1	My organic farmer colleagues would approve of my participation in a Bio-district in my area	Strongly disagree/strongly agree	3.16	0.60	(Castillo et al., 2021; Savari and Gharechaee, 2020)

SN_2	My family would approve my participation in a Bio-district in my territory	Strongly disagree/strongly agree	3.02	0.73	
SN_3	The expectations of others regarding my participation in a Bio-district in my area influence my decisions	Strongly disagree/strongly agree	3.04	0.67	
PBC_1	I have a clear understanding of how to participate in a Bio-district	Strongly disagree/strongly agree	2.79	0.69	
PBC_2	I believe I have sufficient skills to face the challenges that could arise from participating in a Bio-district in my area	Strongly disagree/strongly agree	2.93	0.70	(Tama et al., 2021; Farani et al., 2019; Bagheri et al., 2019)

PBC_3	I am confident in my ability to conform to the expectations and guidelines set by a possible Bio-district in my area	Strongly disagree/strongly agree	2.99	0.73	
PBC_4	For me it would be accessible to participate in a Bio-district in my area	Strongly disagree/strongly agree	2.90	0.69	
PU_1	I believe that participation in a Bio-district in my area would offer marketing opportunities that would improve the visibility of my products	Strongly disagree/strongly agree	3.86	0.68	(Lemus et al., 2024; Laksono et al., 2022)
PU_2	I expect that participation in a Bio-district in my area will contribute to the	Strongly disagree/strongly agree	3.74	0.75	

	improvement of my farm income				
PU_3	I believe that a Bio-district in my area would favour the creation of new job opportunities	Strongly disagree/strongly agree	3.59	0.77	
GT_1	I believe that the government will consider the interests of my area in the promotion of Bio-districts	Strongly disagree/strongly agree	2.67	0.71	
GT_2	I believe the government would be fully committed to supporting the development of Bio-districts in my agricultural area	Strongly disagree/strongly agree	2.61	0.72	(Tien et al., 2022; Li et al., 2023; Lin and Guan, 2021)
GT_3	I trust the government's ability to make	Strongly disagree/strongly agree	2.62	0.74	

decisions that would benefit my community through the implementation of Bio-districts	

After collecting the responses, a thorough data cleaning process was carried out to exclude incomplete or potentially manipulated responses. At the end of this process, 143 valid responses were collected from organic farmers in the Calatino area. This number represents a significant portion of the total number of organic farms in the SNAI Calatino area, which currently amounts to 279 (Sian), and is considered an adequate sample for the subsequent analyses.

3.2 Data analysis

The classic relationships hypothesized by the TPB model and the specific research hypotheses of the study were estimated using Partial Least Squares Structural Equation Modeling (PLS-SEM) (Lohmöller, 1989). The PLS-SEM approach has been widely used to estimate complex models with numerous constructs that are relevant when using a conceptual model such as the TPB (Jony and Serradell-Lopez, 2021; Sarstedt et al., 2021). Additionally, PLS-SEM analyzes the entire model rather than breaking it down into pieces (Goodhue et al., 2012) and provides concurrent analysis for both the measurement and structural models, which in turn leads to more accurate estimates (Al-Emran, 2020). To ensure the reliability and overall validity of the indicators in accurately representing their respective constructs, several parameters were calculated, including factor loadings (> 0.5), Cronbach's alpha coefficient ($\alpha > 0.7$), and indicator reliability (Rho A > 0.7). Furthermore, the convergent and discriminant validity of the constructs were examined. Convergent validity is satisfied when the AVE (Average Variance Extracted) of the constructs is equal to or greater than 0.5. As for discriminant validity, the Fornell-Larcker criterion was used, which involves comparing the square root of the AVE and the correlations between latent constructs (Cammarata et al., 2024).

4 Results

4.1 Descriptive statistics

The final sample consisted of 143 respondents, representing 51% of the organic farms in the area. The majority of the interviewed farm operators were male, representing 84.6% of the sample. Regarding age, the largest group was composed of individuals aged 55 or older (44.7%), followed by those aged between 40 and 55 years (39.9%), while 15.4% were younger than 40 years. In terms of education level, over half of the respondents hold a degree (58.7%), 31.5% completed high school, and 9.8% have only elementary school education. In relation to farm size, 41.2% of farms are under 10 hectares, another 41.2% are between 11 and 20 hectares, and only 17.6% exceed 20 hectares. Finally, regarding experience in organic farming, 52.4% of operators have been practicing it for 6 to 10 years, 40.6% for over 10 years, while a minority of 6.3% has less than 5 years of experience (Table 2).

Regarding the measured constructs, overall average scores were relatively high (Table 1). Specifically, the mean values ranged from 2.61 (GT2) to 3.86 (INT1 and PU1), reflecting a variety of perceptions among participants regarding the elements of the TPB model applied to the Bio-district case. In general, the construct related to government trust (GT) showed the lowest average scores, indicating a certain skepticism towards the role of institutions in supporting Bio-districts.

Table 2 Demographic characteristics of the sample.

Variable	Variable Description	Absolute frequency	Percentage Frequence (%)
Conductor gender	Male	121	84.6
	Female	22	15.4
Age of the conductor	< 40 years	22	15.4
	40 - 55 years	57	39.9
	55 years and above	64	44.7
Education	Middle school	14	9.8
	High school	45	31.5
	Degree	84	58.7
Farm size (ha)	< 10 ha	59	41.2
	11 - 20 ha	59	41.2
	> 20 ha	25	17.6
Years in organic farming	In conversion	1	0.7
	< 5 years	9	6.3
	6 - 10 years	75	52.4
	> 10 years	58	40.6

4.2 PLS-SEM output

4.2.1 Measurement model

Measurement model results highlighting strong associations between latent constructs and indicators, with factor loadings greater than 0.5 and ranging from 0.7 to 0.9. All Cronbach's alpha values exceed the critical threshold of 0.7, indicating high internal consistency of the measured constructs in the model. Moreover, the indicator reliability values (rho A) are greater than 0.7 for all constructs, and the convergent validity values (AVE) are all above 0.5, confirming the overall robustness of the measurement model (Table S1 in the Supplementary materials). The Fornell-Larcker criterion results (Table S2, SM) confirm the discriminant validity of the constructs, demonstrating that the square root of the AVE for each construct is greater than the correlations with other latent constructs. Finally, the variance inflation factors (Table S3, SM) indicate no issues of multicollinearity among the constructs.

4.2.2 Structural model

The research hypotheses were tested through the PLS-SEM structural model. Figure 2 shows the direct paths between the considered constructs and their respective standardized coefficients. The value of R^2 increased from 0.52 in the original TPB model to 0.56 in the extended model, indicating an improvement in the model's predictive power. This increase, although moderate, supports the validity of the proposed theoretical extension, confirming that PU and GT contribute to explaining an additional amount of variance in farmers' intention to participate in the Bio-district. The results indicate that attitude ($\beta = 0.649$, $p < 0.001$) is the strongest predictor of farmers' intention to participate in the Calatino Bio-district, confirming its central role in the TPB model. Subjective norms show a positive and significant effect on intention ($\beta = 0.231$, $p < 0.01$), although with a smaller effect than attitude. In contrast, perceived behavioral control (PBC) does not show a statistically significant direct effect on intention ($\beta = 0.013$, $p > 0.05$), thus not supporting hypothesis H3. Moreover, attitudes toward the potential Calatino Bio-district were significantly influenced by the additional constructs, perceived utility (ß = 0.632; $p < 0.001$) and trust in government (ß = 0.184; $p < 0.01$), confirming H4 and H5. Regarding the indirect effects between the constructs, the hypothesized relationships are statistically significant, supporting hypotheses H6 and H7. Among these, the main indirect effect is that between Perceived Utility and Intention ($\beta = 0.410$, $p < 0.001$), mediated by Attitude. Furthermore, PU also has a significant direct effect on intention ($\beta = 0.253$, $p = 0.001$), suggesting partial mediation, in which attitude acts as a mediator, but PU also directly influences intention. In contrast, GT shows a non-significant direct effect on INT (β = –0.020, p = 0.744) but it has a significant indirect effect via ATT (β = 0.124, p = 0.055), thus confirming complete mediation. The mediation analysis thus confirms that both additional constructs indirectly influence the intention to join the Bio-district, highlighting the importance of the role played by attitude as a key mediator in the model.

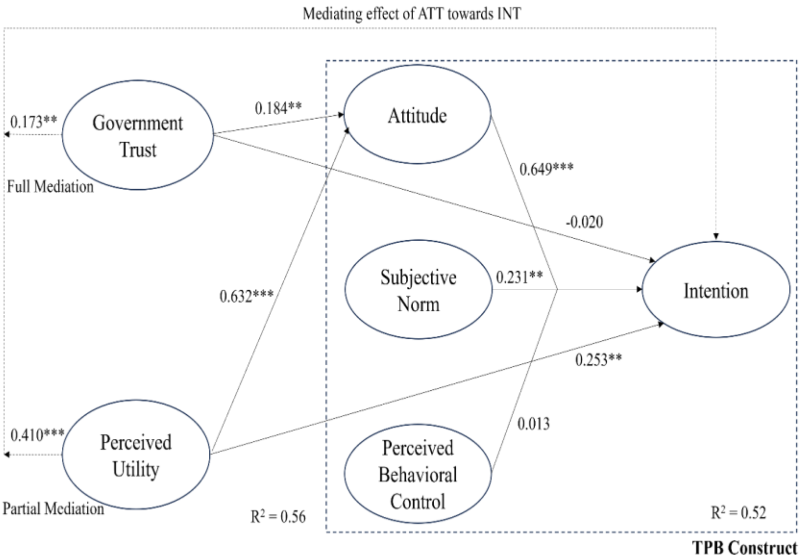

Figure 2 Graphical representation of the structural model results. Note: *p < 0.05; **p < 0.01; ***p < 0.001.

5 Discussion

This study analyzes the various factors that influence farmers' intention to join a potential Bio-district in the Calatino area, using psychological indicators based on the Extended Theory of Planned Behavior (ETPB). Referring to previous studies that have expanded behavioral models with socio-demographic variables and other contextual dimensions (Poponi et al., 2024; Sciurano et al., 2024), this work aims to provide a deeper understanding of the factors that drive the decisions of organic farmers in rural Italian contexts. The application of ETPB to investigate farmers' intention to participate in a territorial development initiative such as the Bio-district represents, to the best of our knowledge, an innovation in the Italian context, especially for the inner areas of Sicily. The results of this study offer new evidence supporting the effectiveness of the TPB as a theoretical framework for explaining farmers' behavior.

An innovative element that enriched our approach was the use of the Living Lab method. This tool, conceived as an environment of co-creation and shared learning, facilitated a direct dialogue between the actors in the organic supply chain, i.e. producers, processors, distributors and consumers (Compagnucci et al., 2021). In this context, farmers were not only able to gain a deeper understanding of the potential economic and environmental benefits of joining the Bio-district but also had the opportunity to actively discuss ways to overcome barriers to transition to more sustainable production models.

The Living Lab facilitated the construction of collaborative networks and the sharing of good practices, strengthening the sense of community and mutual trust, essential aspects for successful collective initiatives (Timpanaro et al., 2024).

These participatory processes underline how the creation of favourable contexts and collaborative networks can be a key element for the success of the Bio-district, thus offering a concrete tool for the revitalisation of marginal rural areas.

According to the results of the structural model, ATT had a highly significant effect on farmers' intention to participate in a potential Bio-district ($\beta = 0.649$, $p < 0.001$), confirming hypothesis H1. This result aligns with what Ajzen and Cote (2008) stated, identifying attitude as one of the best predictors of intention. Previous studies applying the TPB as a theoretical framework have highlighted the key role of attitude in various behavioral contexts, including biodiversity protection (Maleksaeidi and Keshavarz, 2019), agricultural diversification (Senger et al., 2017), participation in agri-environmental schemes (Van Dijk et al., 2015), pesticide use (Bagheri et al., 2019; Sok et al., 2024), and adoption of agricultural insurance (Timpanaro et al., 2023b). In our study, farmers with more favorable attitudes towards the Bio-district seem mentally more prepared to engage in sustainable initiatives, as they perceive such participation as useful, valuable, and reasonable. In this context, the crucial role of attitude has important implications. Public policies should emphasise the values of sustainability, community and agricultural innovation, promoting educational and communication strategies that highlight the long-term benefits of sustainable agriculture, both environmentally and economically. Furthermore, these strategies should be co-designed with local stakeholders to strengthen the sense of belonging and make farmers active protagonists of change. Fostering a cultural shift towards sustainability can contribute not only to increasing the intention to adhere to it, but also to supporting the effective transition to more sustainable practices in the long term.

SN emerged as a significant predictor of farmers' intention to participate in the potential Bio-district ($\beta = 0.231$, $p < 0.01$), supporting hypothesis H2. This result emphasizes that farmers' intention is influenced by social pressure, an element that has been extensively documented in the literature. For example, Li et al. (2021) highlighted the role of SN in the adoption of improved farming systems, and it has been found to be a relevant determinant of farmers' intention to adopt agroforestry (Felton et al., 2023) and conservation practices (Thapa et al., 2024). In the case of the Bio-district of Calatino, the relevance of SN highlights how the support and approval from farmers' social networks – including colleagues, trade associations, and local stakeholders – represent crucial factors for promoting their participation. In the context of Calatino, this means that the perceived support and approval of relevant social networks – colleagues, trade associations, cooperatives and local stakeholders – are a key lever for promoting membership of the Bio-district. This evidence suggests that it would be beneficial to strengthen local networks and create a sense of belonging to a sustainability-oriented agricultural community. Public policies should encourage cooperation between farmers and actors in the supply chain through participatory initiatives such as thematic working groups, platforms for the exchange of good practices or co-design processes. These tools can foster a shared cultural transformation, stimulating dynamics of mutual recognition, emulation and positive social pressure within the local agricultural system.

The results related to PBC show that it does not emerge as a significant determinant in directly influencing farmers' intention to participate in the Bio-district of Calatino. This finding contrasts with the existing literature, which frequently identifies PBC as a key predictor in behavioral decisions (Laksono et al., 2022; Savari and Khaleghi, 2023). However, this result is consistent with the conclusions of Maleksaeidi and Keshavarz (2019). A possible explanation for this discrepancy may lie in the structural and socioeconomic characteristics of the context in which the study was conducted. In the Calatino area, factors such as the limited availability of technical and financial resources and the perceived complexity of joining the Bio-district may have attenuated the influence of perceived behavioral control. Although PBC has not shown a direct influence, its role should not be overlooked in policy strategies. The lack of effect could signal the presence of structural or psychological barriers that limit farmers' confidence in their ability to join complex initiatives such as a Bio-district. Consequently, public policies should intervene to remove these obstacles, providing concrete tools – such as technical support, access to subsidised credit or administrative simplification – that can increase the perception of self-efficacy and facilitate participation. Strengthening PBC through targeted measures can not only improve future intentions but also contribute to the sustainability of the project itself, making farmers more confident in their operational choices.

The results of our study highlight the significant mediating role of Perceived Utility in influencing farmers' intention to join the Bio-district of Calatino. PU emerges as a key variable, capable of synthesizing individual perceptions of the tangible and intangible benefits derived from participation in the Bio-district. This finding aligns with existing literature, which emphasizes that the perception of both economic and environmental benefits represents a fundamental driver for behavioral change (Tur-Cardona et al., 2018; Yazdanpanah et al., 2022). In our case, farmers value membership in the Bio-district for two main reasons: on one hand, the possibility of improving the perceived quality of their products through recognized certification; on the other hand, the expectation of accessing more lucrative markets or support networks for logistics and commercial purposes (Belligiano et al., 2024). This observation is consistent with studies that highlight how farmers are more likely to modify their agricultural practices when they perceive direct economic benefits or improvements in product reputation (Tennhardt et al., 2024; Sharifuddin et al., 2019). The practical implications of this result are significant: the role of the PU suggests that public policies should aim to communicate clearly and concretely the tangible benefits of joining a Bio-district. Initiatives such as information campaigns, demonstration workshops, field trials and cost-benefit analyses could reinforce the perception of usefulness, reduce uncertainties and strengthen farmers' confidence in collective sustainability pathways. In addition, actions that increase the visibility and recognisability of products linked to the Bio-district, perhaps through collective brands or territorial marketing strategies, can further strengthen this motivational lever.

Government Trust emerged as an important construct in influencing farmers' intention to participate in the Bio-district of Calatino, not only as a direct determinant but also as a mediator through which positive attitudes towards the project are reinforced. This result is consistent with other studies that highlight how contextual factors can mediate the relationship between attitude and behavior (Tien et al., 2022). GT seems to act as a stabilizing factor, reducing uncertainty and mitigating concerns about economic risks or transition costs to organic practices. In our case, perceived support from institutions governs both the level of trust in the feasibility of the project and farmers' willingness to see it as an economically and socially sustainable solution (Guareschi et al., 2023). This indirect effect is particularly significant in rural contexts such as Calatino, where farmers are often exposed to conditions of economic and structural vulnerability. However, it is interesting to note that, GT may not always automatically translate into concrete behaviors, especially in the presence of structural barriers such as lack of access to credit or difficulty in reaching lucrative markets (Tien et al., 2022). Strengthening trust in institutions is a strategic priority for promoting sustainable agricultural policies. This implies the need to ensure consistency, transparency and continuity in policy implementation – for example, by maintaining economic incentives for conversion to organic farming over time, providing qualified technical assistance services and reducing bureaucratic barriers to participation. Personalised support measures, especially in the early stages of participation, can help to consolidate trust in institutional support and make the transition to more resilient and sustainable agricultural models more effective.

This study contributes to scientific literature in at least three ways. Firstly, it extends the application of the Theory of Planned Behaviour to the specific case of farmers' adherence to a Bio-district in an inland area of Southern Italy, a context that has been little explored in the literature to date. Although this study focuses on a specific inland area of Sicily, the results obtained may also offer relevant insights for other rural contexts with similar characteristics. Many of the dynamics observed in Calatino are frequently found in marginal areas subject to depopulation, fragmentation of the agricultural supply chain and lack of infrastructure. Consequently, the evidence that has emerged can contribute to a broader understanding of the factors that favour or hinder the agroecological transition in other disadvantaged territories, both in Italy and in the Mediterranean. Secondly, the inclusion of the constructs of Perceived Utility and Government Trust strengthens the explanatory power of the model, highlighting how contextual, economic and institutional variables can mediate attitudes and influence intentions. This suggests that the TPB can be effectively adapted and integrated to study complex decision-making processes in the field of agroecology and territorial development. Finally, the results enrich scientific reflection on the role of trust and the perception of collective benefits in bottom-up participatory processes.

The study presents some limitations that open the door for future research. One of the main limitations is the relatively small sample size, which is exclusively focused on the Calatino area in Sicily. This may limit the generalizability of the results, as the intentions and behaviors of farmers in other regions or contexts could differ. Therefore, the results should be interpreted with some caution. Additionally, the theoretical model applied focuses on the intention of farmers to join a potential Bio-district, rather than actual behavior, since the Bio-district has not yet been officially established in the study area. Examining actual behavior in the presence of an operational Bio-district could provide a deeper understanding of decision-making dynamics. Another limitation concerns the focus on selected constructs. While these are fundamental within the TPB framework, the inclusion of other external factors, such as moral norms, economic barriers, or policy changes, could provide a more comprehensive view of farmers' intentions and decisions. Finally, although the PLS-SEM method offers advantages in analyzing complex models with small samples and does not require a normal distribution of data, non-normality may still affect the accuracy of estimates and the overall robustness of the model. Future studies could expand the sample to other geographic areas or adopt alternative methodological approaches to further improve the validity and reliability of the results.

6 Conclusions

This study applied an extension of the Theory of Planned Behaviour to analyse the factors influencing the intention of farmers in the Calatino area to join a possible Bio-district, offering an original contribution in a rural Italian context that has been little explored to date. The inclusion of two contextual variables – Perceived Utility and Government Trust – made it possible to better capture the socio-institutional specificities of inland areas, improving the predictive capacity of the model and providing new theoretical and practical evidence.

The results of this study highlight the crucial role of favourable attitudes, shared social norms and the perception of concrete benefits in shaping farmers' intentions to join a Bio-district. These elements underscore the importance of public policies that go beyond economic incentives, promoting a sense of belonging to a sustainable agricultural community, access to more profitable markets, and confidence in the ability of institutions to ensure continuity and support over time. To strengthen the propensity to join, it is essential to invest in strategies that consolidate farmers' trust in policies favouring organic farming, facilitate the creation of collaborative networks between local actors and increase the perception of the usefulness of the Bio-district through concrete communication, training and demonstration initiatives in the field. Only through an integrated approach, capable of activating both cognitive and structural levers, will it be possible to promote an effective transition towards sustainable agroecological models that can be replicated in other territorial contexts.

The key message emerging from this study is that, to encourage adherence to sustainable practices in rural areas, it is essential to integrate psychological dimensions and contextual factors into a participatory and systemic approach. In this sense, the proposed model can be a useful tool that can be replicated in other similar contexts.

Among the limitations of the study are the small sample size and the analysis limited to intention, in the absence of observable behaviour. Future research could extend the analysis to other territorial contexts, comparing territories with different levels of organic development, and explore the role of structural variables (such as access to credit or commercial supply chains). Furthermore, it would be interesting to investigate the role of Living Labs not only as tools for participatory governance, but also as spaces for social learning capable of transforming intentions into concrete behaviour, promoting resilience and cohesion in rural areas.

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Supplementary Materials

Table S1 Factor loadings, Cronbach's a, Rho A and average variance extracted (AVE) of the measurement model.

Item / Construct	INT	ATT	SN	PBC	PU	GT
INT_1	0.954					
INT_2	0.935					
INT_3	0.943					
ATT_1		0.920				
ATT_2		0.880				
ATT_3		0.898				
SN_1			0.879			
SN_2			0.881			
SN_3			0.765			
PBC_1				0.768		
PBC_2				0.871		
PBC_3				0.871		
PBC_4				0.874		
PU_1					0.876	

PU_2					0.885	
PU_3					0.766	
GT_1						0.927
GT_2						0.784
GT_3						0.936
Cronbach α	0.939	0.882	0.802	0.869	0.800	0.864
rho_A	0.940	0.883	0.848	0.894	0.832	0.924
AVE	0.891	0.809	0.711	0.717	0.712	0.784

Table S2 Discriminant validity with the Fornell-Larcker criterion.

	INT	ATT	SN	PBC	PU	GT
INT	1.000					
ATT	0.516	1.000				
SN	0.207	0.236	1.000			
PBC	0.152	0.194	0.490	1.000		
PU	0.373	0.436	0.086	0.067	1.000	
GT	0.044	0.071	0.077	0.091	0.051	1.000
AVE	0.891	0.809	0.711	0.717	0.712	0.784

Notes. The square root of AVE (last row) for each latent construct should be higher than the other correlation values among the latent variables.

Table S3 Structural model - Multicollinearity check (Variance Inflated Factors -VIFs)

	INT	ATT
ATT	1.343	
SN	2.122	
PBC	2.011	
PU		1.054
GT		1.054

Notes. Values below 3.3 indicate an acceptable level of correlation among constructs.

Contribution IV - Social Identity in Consumer Preference Elicitation for Bio-District and Agroecological Certification

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Abstract

This study investigates how consumers' preferences for sustainability-related food attributes can contribute to the establishment of a Bio-District in the inner area of Calatino (Sicily). A discrete choice experiment was conducted on two products of the local Mediterranean diet—extra virgin olive oil and bread—each characterized by three sustainability attributes: Bio-District certification, agroecological production, and a technical quality feature (cold extraction for oil, ancient wheat flours for bread). A between-subject design was implemented to test the additional effect of a Social Identity Label, aimed to strengthen the link between consumption, territory, and community belonging. Results reveal a significant willingness to pay for all sustainability attributes, with positive effects associated with the identity-based label. These findings highlight the potential of consumer choices to support agroecological transitions in marginal areas and suggest that identity-driven narratives can enhance the effectiveness of territorial certification systems in promoting rural development.

Keywords

Discrete choice experiment; Willingness to pay; Rural areas; Sustainability labelling; Territorial development

1 Introduction

Inner areas represent marginal territories characterized by significant distance from essential services such as healthcare, education, and transportation, and are often affected by structural phenomena of demographic decline, economic isolation, and social vulnerability (Vendemmia et al., 2021). Although disadvantaged by limited accessibility, these areas possess valuable environmental, cultural, and agricultural resources that can serve as a foundation for sustainable development strategies centered on the valorization of local specificities. In this context, several countries have launched targeted policies aimed at reversing marginalization processes through territorial regeneration models that promote inclusion, resilience, and social innovation (Cotella and Brovarone, 2020; De Toni et al., 2021).

In the Italian context, the National Strategy for Inner Areas (SNAI) functions as the main framework for designing integrated interventions aimed at revitalizing these territories (Carrosio, 2016). Within this framework, increasing attention has been devoted to local development strategies that focus on the valorization of endogenous resources and are based on the active involvement of local stakeholders. In marginal and rural areas, this approach often translates into participatory planning processes aimed at strengthening territorial cohesion and promoting sustainable production models (Basile and Cavallo, 2020; Menconi et al., 2017). Moreover, in these territories, the agricultural sector represents a key driver for triggering processes of economic and environmental regeneration (Cascone et al., 2024).

The Bio-District model fits within this perspective: it was designed as a territorial governance tool based on cooperation among organic farmers, citizens, local authorities, and other stakeholders, with the aim of promoting sustainable agri-food systems embedded in the territory and aligned with the principles of agroecology and the circular economy (Poponi et al., 2024). By enhancing ecological practices, short supply chains, and local identities, Bio-Districts position themselves as engines of integrated and participatory development, capable of combining environmental sustainability, collective well-being, and local competitiveness. In Italy, the Bio-District model has experienced growing diffusion supported by its official recognition under Ministerial Decree No. 663273 of 28 December 2022, which defines the requirements and conditions for the establishment of Bio-Districts. The decree sets minimum criteria for territorial delimitation, the composition of the promoting committee, and the procedures for regional recognition, establishing the Bio-District as a structured and acknowledged form of territorial governance. According to this definition, a Bio-District is a geographical area in which organic farmers, public institutions, citizens, and other local actors coordinate for the sustainable management of resources, promoting the ecological transition of production practices and consumption patterns (Dias et al., 2021; Poponi et al., 2021). Currently, more than forty Bio-Districts are active across the country, with a strong concentration in southern and island regions (Dara Guccione et al., 2024).

Within this collaborative governance model, consumers also play a fundamental role, not only as the end users of organic and local products, but also as co-protagonists in supporting the entire territorial ecosystem of the Bio-District through their purchasing choices. From this perspective, the consumer is no longer merely the endpoint of the agri-food supply chain but becomes an active agent in the co-construction of sustainable production systems, capable of influencing the economic and value dynamics of the territory (Sacchi et al., 2024). Their purchasing decisions go beyond individual preferences and can help guide demand towards local production, short supply chains and agroecological practices, thus contributing to the legitimisation and consolidation of models such as the Bio-District. Numerous studies confirm that local food consumption today represents a powerful tool for both economic and identity-based support to rural communities. Small-scale production has become an integral part of community and economic development strategies (Deller et al., 2017; Vochozka et al., 2018). The purchase of local products has been associated not only with a greater sense of food security and perceived quality, but also with a clear willingness to support the local economy and local farmers (Cvijanović et al., 2020). According to the findings of Grebitus et al. (2013), the belief that buying short supply chain food contributes to supporting the local economy has a positive effect both on consumers' willingness to pay and on their qualitative perception of the product. This preference is not only based on environmental or health-related motivations, but on a relational and territorial dimension that emphasizes proximity, trust, and the social impact of consumption (Aprile et al., 2016; Rossi et al., 2024).

Especially in rural areas, conscious consumption can directly contribute to local resilience by strengthening the ties between cultural identity and social cohesion. Through their choices, consumers can become co-authors of an integrated development project, contributing not only to the economic survival of local production but also to its social and cultural legitimacy. Within this framework, Bio-Districts represent privileged laboratories for observing and facilitating such dynamics, thanks to their territorial embeddedness, multi-actor logic, and emphasis on the interconnections between production, consumption, and community.

Despite the growing diffusion of environmental certifications, empirical evidence suggests that consumers do not always recognize their value or translate this awareness into concrete purchasing preferences (Piracci et al., 2024). To bridge this communication gap, the literature has explored various strategies aimed at making the sustainability characteristics of products more visible and understandable, including the introduction of environmental labels, the use of explicit claims, and the application of nudging tools (Jäger and Weber, 2020). Within this context, an especially promising approach is one that leverages the sense of social belonging. According to Social Identity Theory (Tajfel and Turner, 1986), individuals tend to adopt behaviors that are consistent with the norms and values of the group with which they identify. Recent studies have applied this principle to food consumption through the introduction of identity-based labels that highlight a product's affiliation with an ecological or ethical community (Ortega et al., 2022; Lin and Nayga, 2022). In this way, the consumer's choice becomes not only an economic act but also a symbolic expression of alignment with a shared system of values.

Considering these premises, the present study aims to investigate how consumer preferences can support the establishment of a Bio-District in the inner area of Calatino, in Sicily, where the University of Catania has launched a multi-actor participatory process. The analysis focuses on two emblematic products of the Mediterranean diet and local agri-food heritage—extra virgin olive oil and bread—selected for their cultural and productive relevance within the territorial context. A choice experiment was implemented using a between-subject design, in which participants were randomly assigned to two experimental conditions: one in which product attributes were accompanied by a Social Identity Label, and a control condition in which this element was absent.

The aim of this study is threefold: (i) to estimate the willingness to pay (WTP) of Sicilian consumers for attributes related to systemic sustainability—such as Bio-District certification, agroecological production methods, cold extraction (for olive oil), and the use of ancient grain flours (for bread); (ii) to assess the effect of activating a pro-sustainability social identity through the introduction of a Social Identity Label, understood as a tool to strengthen the link between consumption, territory, and community belonging; and (iii) to analyze the extent to which consumers' socio-demographic characteristics influence their WTP for these attributes and their interaction with the activated social identity.

This study introduces an innovative approach to consumer behavior analysis, addressing the topic of Bio-Districts from the demand-side perspective for the first time. Literature has focused primarily on the institutional and productive dimensions of these territorial models, largely overlooking the strategic role of consumer preferences in their emergence and legitimation. In this regard, this research fills a significant gap by investigating the WTP for a Bio-District certification that is not yet available on the market but is currently being developed in several rural areas in Italy. Furthermore, the inclusion of agroecological practices and a social identity label allows for the extension of existing models, exploring the relationship between individual values, systemic sustainability, and collective identification. Applying this experimental design in a marginal inner area such as the Calatino further enhances the theoretical scope of the study, offering insights into sustainable consumption dynamics in often overlooked contexts.

The structure of the article is as follows: Section 2 describes the experimental design and data analysis procedure; Section 3 presents the main results; Section 4 critically discusses these findings considering the existing literature; and finally, Section 5 draws conclusions, highlighting the limitations of the study and suggesting avenues for future research.

2 Materials and Methods

2.1 Survey Design

The survey was structured into three main sections. The first part provided respondents with a clear explanation of the concept of

Bio-districts and agroecological production. This section also introduced the two food products used in the study – bread and olive oil – highlighting their relevance to the rural area under consideration. The second section consisted of a discrete choice experiment (DCE), in which participants were asked to choose between different hypothetical product profiles based on combinations of attributes. The final part included a series of socio-demographic questions (age, gender, education, household income).

The survey was conducted via the Qualtrics platform and distributed online to a sample of Sicilian consumers, with a particular focus on food shoppers. To ensure data quality and mitigate hypothetical bias, the survey included a short "cheap talk" text, which encouraged respondents to treat the choices as if they were real. Participants were also asked to commit to providing thoughtful and honest answers at the beginning of the questionnaire. Data collection took place between May and July 2025 and the final sample consisted of 422 complete observations.

2.2 Choice Experiment Design

This study uses a Discrete Choice Experiment (DCE) to estimate consumers' WTP for two typical products from the Calatino area: extra virgin olive oil and bread. These products were selected because they are widely consumed by all demographic groups, making them ideal for exploring consumer preferences and their willingness to support local and sustainable production systems (Latino et al., 2022; Wongprawmas et al., 2016). Furthermore, both products have strong cultural and symbolic value in the Mediterranean diet and are commonly produced in the region, reinforcing their representativeness of local practices (De Boni et al., 2019; Perito et al., 2019). Both products were presented as potentially certified by a future Calatino Bio-district. The aim is to assess preferences and willingness to pay for specific attributes associated with sustainability, quality and territorial identity.

The attributes selected for extra virgin olive oil were Bio-district certification (present or absent), extraction method (conventional or cold), agroecological production (present or absent) and price, which had four levels: €5.00, €9.00, €13.00 and €17.00 for a 1-litre bottle. For bread, the attributes considered were Bio-district certification (present or absent), the type of flour used (common or from local ancient wheat varieties), agroecological production (present or absent) and price, with levels of €2.50, €3.50, €4.50 and €5.50 for a 1 kg loaf. Table 1 details the attributes and attribute levels used in the experimental design. Attributes not related to price were modelled as dummy variables, which take the value 1 when the product has that characteristic and 0 otherwise. The selection of attributes and levels was supported by consultation with local organic producers and a review of market dynamics relating to the short supply chain in the area.

Table 1 Attributes and attribute levels in the choice set design.

Attribute	Levels (Olive Oil)	Levels (Bread)
Bio-district certification	Yes / No	Yes / No
Agroecology production	Yes / No	Yes / No
Extraction process	Conventional / Cold extraction	—
Flour type	—	Common wheat / Ancient wheat varieties
Price	€5.00 / €9.00 / €13.00 / €17.00	€2.50 / €3.50 / €4.50 / €5.50

Both experimental designs were developed using the Ngene software, implementing separate D-efficient designs for each product. In a preliminary phase, a pilot survey (n = 53) was conducted with null priors, from which a multinomial logit (MNL) model were estimated (one for each product). These coefficients were then used as informed priors to generate the final designs, constructed according to an efficient Bayesian approach (Scarpa et al., 2007a; Ferrini and Scarpa, 2007). It has been shown that experimental designs constructed from multinomial logit (MNL) model probabilities can also be effectively applied in the context of random parameter logit (RPL) models (Bliemer & Rose, 2010). Furthermore, the use of an efficient Bayesian design allows the statistical precision of the estimates to be maintained, even with a limited number of observations (Cerjak et al., 2025). Each design included 24 choice tasks, divided into 3 blocks of 8 tasks each. Each respondent was randomly assigned to one of the blocks and each respondent was assigned to one block of choice tasks for bread and one block of choice tasks for olive oil. In each choice task, two product alternatives plus an opt-out option ("None of these") were presented to simulate a real-life purchasing situation. See Figure 1a and Figure 1b for examples of the choice tasks presented for extra virgin olive oil and bread.

Figure 1 Example of a choice task for olive oil.

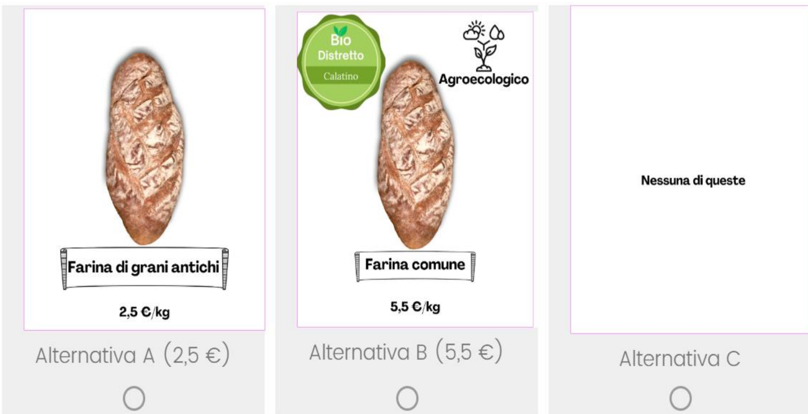

Figure 2 Example of a choice task for bread

Respondents were randomly assigned to two different versions of the questionnaire, identical in terms of structure and content, but differing in the presence or absence of a social identity label. One of the two versions featured a Calatino Bio-district label accompanied by a statement emphasising its identity and territorial value ('This product is destined for consumers who choose to support sustainable agriculture and local development.'). This label was applied to both bread and oil, in line with the hypothesis that a reference to social identity could positively influence consumer preference for local and sustainable products.

This manipulation is inspired by previous studies on the effectiveness of social identity labels in sustainable consumption contexts (Eby et al., 2019; Schwartz et al., 2020) but differs in its emphasis on the connection between consumption, territory and sense of belonging, consistent with the agroecological and participatory approach of Bio-districts.

To mitigate "hypothetical bias", a cheap talk script was included at the beginning of the experimental section, inviting participants to consider the choices as if they were real and considering their spending constraints (Silva et al., 2011; Tonsor and Shupp, 2011). In addition, a detailed and visual description of the attributes and their meanings was provided to facilitate a correct understanding of the tasks proposed. The order of the blocks within each task were randomised to avoid order effects.

2.3 Econometric analysis

2.3.1 Choice Experiment Analysis

To analyse the preferences expressed by respondents and estimate their willingness to pay (WTP), an approach based on discrete choice models was adopted. This type of methodology is based on two fundamental economic theories. The first is Lancaster's consumer theory (1966), according to which the value that a consumer attributes to a good does not depend on the product, but on the specific characteristics that compose it. The total perceived utility is the result of the sum of the utilities generated by each attribute of the good.

The second is the Random Utility Theory (McFadden, 1974), which introduces a probabilistic component into the choice. According to this theory, the utility that an individual obtains by selecting a given alternative in each decision-making context can be broken down into two parts: a systematic component, which depends on the observable attributes of the alternative and the individual's preferences, and a non-observable component, which is stochastic. This utility can be represented as follows:

$U_{njt} = \beta' \; x_{njt} + \varepsilon_{njt}$ (1)

Where x_{njt} represents a column vector of dimension *M*, containing the explanatory variables associated with alternative j for individual n. The vector β, also of dimension *M*, collects the coefficients that express the individual's systematic preferences with respect to the attributes considered and which are common to all choice situations.

The deterministic part of utility ($\beta' x_{njt}$,) reflects the individual's observable assessment based on the characteristics of the alternative. Conversely, ε_{njt} represents the error term, i.e. the unobservable component, which encompasses the latent effects and preferences not captured by the model (Bazzani et al., 2017).

In our study, we adopted a Mixed Logit model with error component (MXL-EC). This specification allows us to overcome the limitations of standard discrete choice models, in particular the homogeneity of preferences and the assumption of independence from irrelevant alternatives (IIA) (Train, 2009). The MXL-EC model allows for a random distribution of taste parameters, enabling each consumer to express differentiated and flexible individual preferences. The additional error term also allows the correlation between repeated choices to be modelled, while the option not to purchase (opt out) remains constant throughout the choice tasks (Scarpa et al., 2005; Scarpa et al., 2007b).

According to Lancaster's theory (1966), the overall utility that consumer n associates with alternative j in task t is broken down into a deterministic component, linked to observable attributes, and a non-observable stochastic component. Considering that the experimental design involves two distinct sets of choice tasks – one for bread and one for oil – two separate utility equations have been specified, which share a common theoretical structure but differ according to a specific attribute of the product.

For olive oil, the utility function is as follows:

$$U_{njt} = NoBuy + \beta_1 Price_{njt} + \beta_{2n} BioDistrict_{njt} + \beta_{3n} Agroecology_{njt} + \beta_{4n} Extraction\ process_{njt} + \beta_{5n} BioDistrict_{njt} \times SocialIdentity_n + \beta_{6n} Agroecology_{njt} \times SocialIdentity_n + \beta_{6n} Extraction\ process_{njt} \times SocialIdentity_n + \varepsilon_{njt} \quad (2)$$

For bread, the utility function takes the form:

$$U_{njt} = NoBuy + \beta_1 Price_{njt} + \beta_{2n} BioDistrict_{njt} + \beta_{3n} Agroecology_{njt} + \beta_{4n} Flour\ type_{njt} + \beta_{5n} BioDistrict_{njt} \times SocialIdentity_n + \beta_{6n} Agroecology_{njt} \times SocialIdentity_n + \beta_{6n} Flour\ type_{njt} \times SocialIdentity_n + \varepsilon_{njt} \quad (3)$$

In both specifications, NoBuy represents the specific constant of the alternative associated with not choosing, i.e. the opt-out option; Price is a continuous variable that reflects the three retail price levels considered for the products; BioDistrict and Agroecology are dummy variables common to both products, which take the value 1 when, respectively, the product is certified by the Calatino Bio-district or obtained following agroecological practices, and 0 otherwise. The Extraction process attribute is specific to oil and takes the value 1 if the oil has been processed using cold extraction, while Flour type is specific to bread and takes the value 1 if flour from local ancient wheat varieties has been used. In both cases, the value is 0 if the characteristic is absent.

The model also includes interactions between each of these attributes and the SocialIdentity variable, a dummy variable that takes the value 1 in choice tasks where there was a territorial label evoking social identity, and 0 otherwise. These interactions allow us to analyse whether and how perceived belonging to a particular territorial community influences preference for sustainable and local products. Finally, ε_{njt} represents the unobserved error term, independent both between alternatives and with respect to the model parameters.

All attributes, except for price and the NoBuy constant, are treated as random parameters. It is assumed that these parameters follow a normal distribution, to account for the heterogeneity of individual preferences. Furthermore, it is assumed that there is a complete correlation between the random coefficients. This assumption is made so that any links between attributes can be captured in the model structure (Mariel and Artabe, 2020).

The estimates obtained from the model specifications, separated by oil and bread, were used to calculate consumers' marginal willingness to pay (WTP) for each product attribute. The WTP is defined as the negative ratio between the coefficient of the attribute of interest and the price coefficient, under the assumption of linearity of the utility function in relation to price. For instance, the WTP for the cold extraction method is calculated as $-\beta_{4n}/\beta_1$, representing the additional amount a consumer is willing to pay for a bottle of olive oil produced using this method, in comparison to an equivalent bottle obtained using the conventional method.

In addition to the primary effects, the WTP for interactions between each attribute and the Social Identity variable for both products was also estimated. These interactions enable the assessment of the influence of the territorial label on the willingness to pay for sustainable and local attributes. To illustrate this point, consider the example of the WTP for the interaction between Agroecology and Social Identity. This interaction is reflected in the variation in WTP for agroecological practices, which is induced by the presence of the social identity label.

Starting from estimates of willingness to pay, a further analysis was carried out to examine the heterogeneity of consumer preferences in relation to the presence or absence of the social identity label. Individual distributions of WTP were calculated for each attribute of the two products, distinguishing between the two experimental subgroups (social identity label present vs. absent), to observe how the identity narrative of the territory could influence willingness to pay for the sustainable and local characteristics of the product.

WTP distributions were estimated using the kernel density function (kdensity) in Stata and then graphically represented for each attribute of each product. The graphs obtained allow a visual comparison between the two groups, highlighting any variations in the shape, position and dispersion of the distributions. To support the visual analysis, the Kolmogorov–Smirnov test was used to verify the statistical significance of the differences between the WTP distributions in the two groups. In addition, an independent samples t-test was applied to compare the WTP means in the presence and absence of the social identity label.

2.3.2 Analysis of the effects of socio-demographic variables

After deriving a specific WTP for each attribute and for everyone in the sample, a more in-depth analysis of the effects of individual characteristics on the preferences expressed was carried out. To investigate how individual characteristics influence willingness to pay (WTP) for sustainable and local attributes, a Seemingly Unrelated Regression Equations (SURE) model (Zellner, 1962) was estimated. This approach allows for the simultaneous modelling of multiple equations, considering the possible correlation between the error terms associated with each WTP, thus improving the efficiency of the estimates compared to separate regressions.

In our study, the SURE model was estimated separately for the two products analysed (oil and bread), including individual WTPs for each main attribute and, in addition, WTPs relating to the interactions between these attributes and the Social Identity Label variable. The aim is to understand whether and to what extent socio-demographic variables such as age, gender, level of education and income influence the willingness to pay for sustainable products, and whether this effect changes in the presence of a territorial identity narrative.

The estimated equations therefore take the following form:

$$WTP_{Biodistrict,i} = \alpha_0 + \sum_{k=1}^{K} \alpha_k s_{ki} + \varepsilon_{1i} \quad (4)$$

$$WTP_{Agroecology,i} = \gamma_0 + \sum_{k=1}^{K} \gamma_k s_{ki} + \varepsilon_{2i} \quad (5)$$

$$WTP_{ExtractionProcess,i} = \delta_0 + \sum_{k=1}^{K} \delta_k s_{ki} + \varepsilon_{3i} \quad (6)$$

$$WTP_{FlourType,i} = \zeta_0 + \sum_{k=1}^{K} \zeta_k s_{ki} + \varepsilon_{4i} \quad (7)$$

$$WTP_{Biodistrict \times SocialIdentity,i} = \theta_0 + \sum_{k=1}^{K} \theta_k s_{ki} + \varepsilon_{5i} \quad (8)$$

$$WTP_{Agroecology \times SocialIdentity,i} = \lambda_0 + \sum_{k=1}^{K} \lambda_k s_{ki} + \varepsilon_{6i} \quad (9)$$

$$WTP_{ExtractionProcess \times SocialIdentity,i} = \mu_0 + \sum_{k=1}^{K} \mu_k s_{ki} + \varepsilon_{7i} \quad (10)$$

$$WTP_{FlourType \times SocialIdentity,i} = \nu_0 + \sum_{k=1}^{K} \nu_k s_{ki} + \varepsilon_{8i}$$

(11)

where the dependent variables represent individual WTP for each attribute — Biodistrict, Agroecology, Extraction Method (for oil), Type of Flour (for bread) — as well as for the related interactions with the social identity label. The explanatory variables s_{ki} indicate the *k*-th socio-demographic characteristics of individual *i*. The coefficients α_k, γ_k, δ_k, ζ_k, θ_k, λ_k, μ_k and ν_k represent the marginal effects of these explanatory variables on the willingness to pay for each attribute. The error terms ε are assumed to have zero mean, to be homoscedastic and independent between individuals, but may be correlated between different equations.

3 Results

3.1 Preference and WTP for Attributes

The estimates of the MXL-EC model for extra virgin olive oil are presented in Table 2. The price and No-buy coefficients are negative and statistically significant, thus confirming consumers' aversion to price increases and their willingness to forego purchases. Conversely, all the attributes of interest – Bio-District certification, agroecological production and extraction method – show positive and highly significant average coefficients, indicating that their presence increases the utility associated with the choice of product.

Interaction with social identity is significant for the attributes of Bio-District certification and extraction method. In the first case the coefficient is positive, suggesting that consumers who identify with a sustainability-related identity attribute additional value to territorial certification. For the extraction process the coefficient is negative, indicating that the presence of social identity reduces the perceived usefulness associated with cold extraction. For the agroecology attribute, on the other hand, interaction with social identity is not significant. The high and significant standard deviations for all attributes indicate marked heterogeneity in consumer preferences.

Table 2 Estimates from Mixed Logit Model with Error Component for extra virgin olive oil.

Variable	Mean	S.E.
Price	-0.197***	0.018
Bio-district	2.726***	0.228
Agroecology	1.547***	0.143
Extraction Process	1.426***	0.127
Bio-district x SocialIdentity	0.812**	0.236
Agroecology x SocialIdentity	0.267	0.163
Extraction Process x SocialIdentity	-0.529***	0.144
No-buy	-1.070***	0.197
	S.D.	
Bio-district	2.107***	0.224
Agroecology	1.093***	0.146
Extraction Process	1.029***	0.178
Bio-district x SocialIdentity	2.150***	0.254
Agroecology x SocialIdentity	1.720***	0.206
Extraction Process x SocialIdentity	1.028***	0.210
Error Component	2.084***	0.196
N	10,128	
Log-Likelihood	-2015.669	
AIC	4103.337	
BIC	4363.367	

*p<0.05, **p<0.01, ***p<0.001.

Table 3 presents the estimates of the MXL-EC model for bread. As expected, the coefficients associated with price and the No-buy option are negative and statistically significant. This suggests that an increase in price reduces the perceived utility for consumers, while the idea of not purchasing any of the proposed alternatives is evaluated less favourably than choosing a product. The attributes Bio-District certification, agroecology and type of flour have positive and significant coefficients, suggesting that their presence increases the utility associated with the choice. As regards interactions with social identity label, only that relating to the Bio-District is statistically significant and positive. This finding suggests that social identity serves to reinforce the importance attributed to territorial certification. Interactions with agroecology and type of flour are not significant, suggesting that the activation of sustainable identity has not substantially changed the economic evaluation of these two attributes. In this model too, significant values are observed for the standard deviations of various attributes, confirming a certain heterogeneity of preferences among participants, especially for flour and certification.

Table 3 Estimates from Mixed Logit Model with Error Component for bread.

Variable	Mean	S.E.
Price	-0.892***	0.065
Bio-district	1.467***	0.169
Agroecology	0.450***	0.087
Flour Type	1.199***	0.174
Bio-district x SocialIdentity	0.506*	0.200
Agroecology x SocialIdentity	0.115	0.118
Flour Type x SocialIdentity	-0.069	0.213
No-buy	-6.470***	0.450
	S.D.	
Bio-district	1.141***	
Agroecology	0.258	
Flour Type	1.485***	
Bio-district x SocialIdentity	1.202***	
Agroecology x SocialIdentity	0.396**	
Flour Type x SocialIdentity	1.951***	
Error Component	2.611***	
N	10,128	
Log-Likelihood	-1676.73	
AIC	3425.461	
BIC	3685.491	

*p<0.05, **p<0.01, ***p<0.001.

To assign a monetary value to consumers' preferences with respect to the attributes considered, estimates of willingness to pay (WTP) were calculated based on the coefficients of the MXL-EC model. The results, presented in Table 4 for oil, demonstrate that for most of the variables examined, the mean WTP values are statistically different from zero, as indicated by the Wald test. The exception to this is the interaction between agroecology and social identity, which was found to be non-significant. This suggests that social identity did not produce an economically relevant variation in willingness to pay in this case. It has been estimated that consumers are willing to pay an average of €13.80 more for Bio-District certification, €7.83 more for agroecological production, and €7.22 more for cold extraction methods. The introduction of social identity has a differentiated impact: for Bio-District certification, there is an increase in WTP of up to €17.91, while for agroecology there is an increase (€9.19), which is not, however, statistically significant. Conversely, the extraction method exhibited a substantial decrease in WTP, reaching €4.54.

Table 4 WTP for extra virgin olive oil.

Variable	Mean	S.E.	95 Conf. Intervals	
Bio-district	13.803***	1.223	[11.405	16.201]
Agroecology	7.834***	0.762	[6.340	9.327]
Extraction Process	7.223***	0.755	[5.743	8.703]
Bio-district x SocialIdentity	17.915***	1.248	[15.469	20.362]
Agroecology x SocialIdentity	9.189	0.774	[7.672	10.705]
Extraction Process x SocialIdentity	4.543***	0.640	[3.289	5.797]
No-buy	-5.418***	1.057	[-7.489	-3.346]

*p<0.05, **p<0.01, ***p<0.001.

Table 5 presents the WTP estimates for bread. Once more, the mean WTP values are considerably different from zero based on the Wald test, thereby confirming that each attribute exerts a significant economic influence on the stated choices. Consumers show a willingness to pay €1.64 for the Bio-District attribute, €0.50 for agroecology and €1.34 for the type of flour. Social identity contributes to increasing WTP for Bio-district certification, which rises to €2.21, and for agroecology, which rises to €0.63. Conversely, for the flour type attribute, there is a slight reduction in WTP in the social identity group, which falls to €1.27.

Table 5 WTP for bread.

Variable	Mean	S.E.	95 Conf. Intervals	
Bio-district	1.643***	0.170	[1.308	1.978]
Agroecology	0.504***	0.087	[0.334	0.673]
Flour Type	1.343***	0.197	[0.956	1.729]
Bio-district x SocialIdentity	2.211***	0.159	[1.898	2.523]
Agroecology x SocialIdentity	0.633***	0.100	[0.437	0.829]
Flour Type x SocialIdentity	1.265***	0.159	[0.951	1.578]
No-buy	-7.246***	0.601	[-8.425	-6.067]

*p<0.05, **p<0.01, ***p<0.001.

Figures 2–7 illustrate the individual distributions of WTP for each attribute, distinguishing between consumers exposed to the social identity treatment and those in the control group. Overall, social identity appears to significantly influence the economic valuation of the attributes under study, although the effect varies across products and characteristics.

For the olive oil, the impact of social identity is particularly pronounced for the Bio-District certification (Figure 2). The WTP distribution for the "With Social Identity" group is clearly shifted to the right, with a higher density between €15 and €25, whereas the control group exhibits a more concentrated distribution centered on lower values. The t-test confirms a statistically significant difference in mean WTP between the two groups ($p < 0.001$), and the Kolmogorov-Smirnov test also indicates significant differences in the overall distribution ($p < 0.001$).

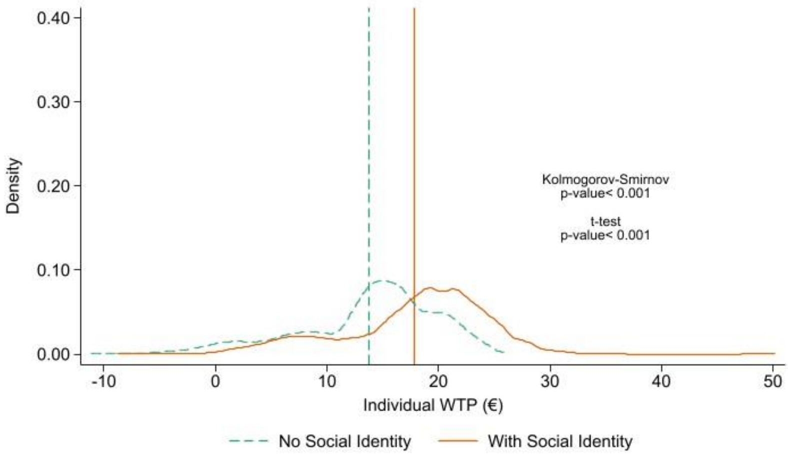

Figure 3 Comparison between experimental groups in WTP for Bio-District certification of extra virgin olive oil. The vertical lines indicate the average WTP values for each group.

For the Agroecology attribute (Figure 3), the differences are more subtle yet still noticeable: the treated group displays a taller curve centered around €10, suggesting a moderate increase in mean WTP and a higher concentration of values. Once again, both the t-test and the Kolmogorov-Smirnov test confirm that these differences are statistically significant.

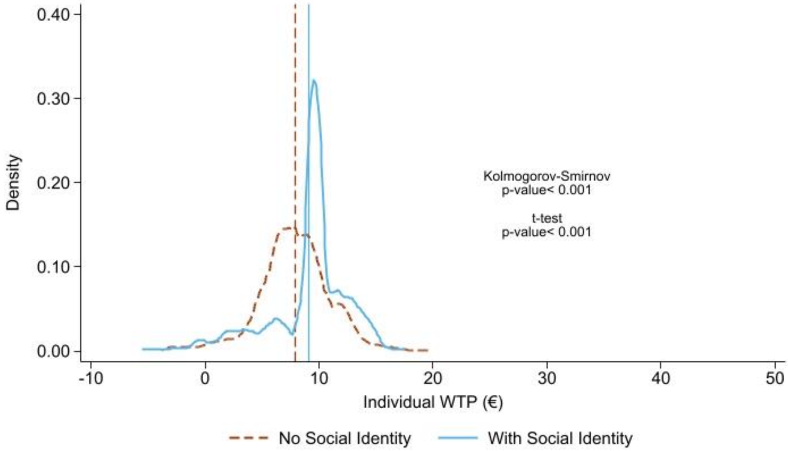

Figure 4 Comparison between experimental groups in WTP for Agroecology production of extra virgin olive oil. The vertical lines indicate the average WTP values for each group.

The case of the extraction process (Figure 4) stands out as an exception compared to the other attributes. Here, the curve for the "With Social Identity" group is shifted to the left, indicating a systematic reduction in willingness to pay relative to the control group. This result aligns with the findings from both the MXL-EC model and the aggregated WTP estimates, where the interaction with social identity yields a negative and statistically significant effect. Once again, both the t-test and the Kolmogorov-Smirnov test confirm the presence of significant differences.

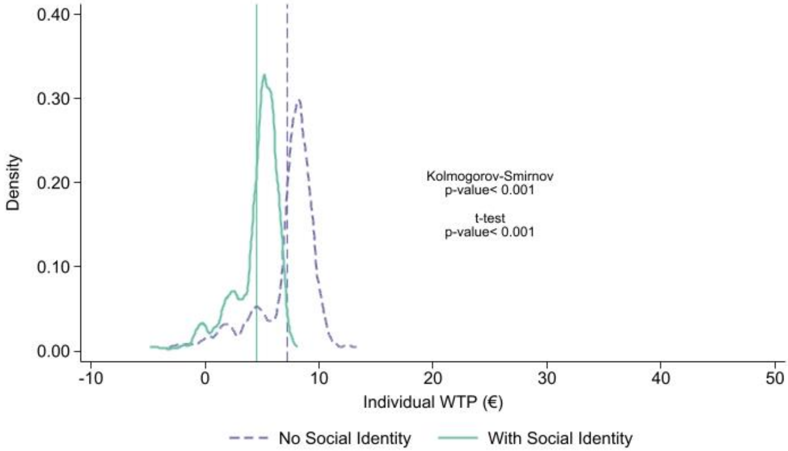

Figure 5 Comparison between experimental groups in WTP for Extraction process of extra virgin olive oil. The vertical lines indicate the average WTP values for each group.

Regarding bread, the effect of social identity remains pronounced for the Bio-District attribute (Figure 5), with the distribution clearly shifted to the right and a higher average WTP observed in the treated group. Both statistical tests are significant ($p < 0.001$), confirming that not only the mean values but also the entire cumulative distributions of WTP differ between the two groups.

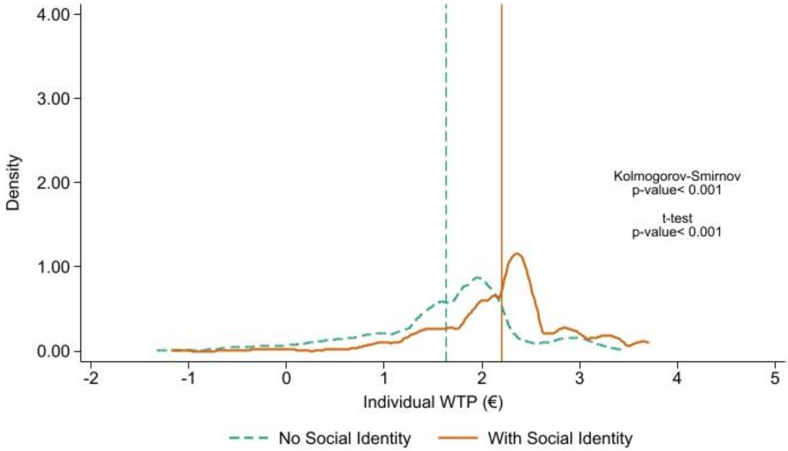

Figure 6 Comparison between experimental groups in WTP for Bio-District certification of bread. The vertical lines indicate the average WTP values for each group.

For the Agroecology attribute (Figure 6), a visual gap between the two curves is also evident. The curve for the group with social identity appears wider and more skewed, with a higher density shifted toward greater values compared to the control group, whose distribution is more concentrated and symmetric around values close to zero. Once again, both tests confirm the statistical significance of differences in both the mean values and the overall distributions ($p < 0.001$).

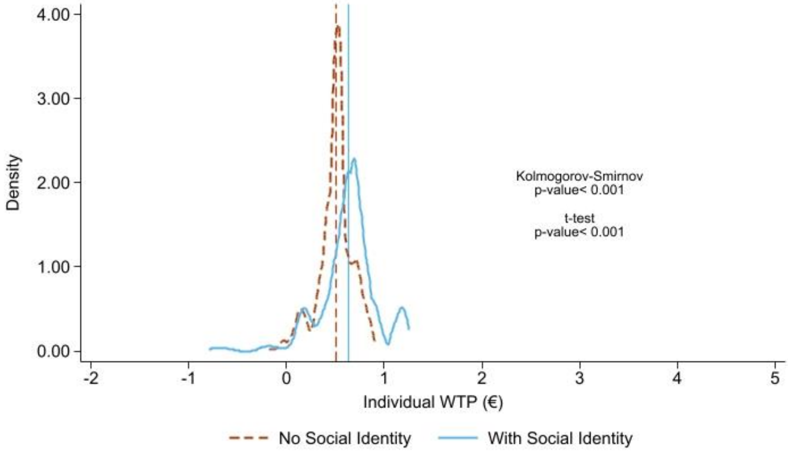

Figure 7 Comparison between experimental groups in WTP for Agroecology production of bread. The vertical lines indicate the average WTP values for each group.

Finally, for the Flour Type attribute (Figure 7), the two distributions appear visually very similar, and indeed the t-test does not detect a statistically significant difference in mean WTP between the two groups ($p = 0.175$). However, the Kolmogorov-Smirnov test is significant, indicating that, despite the absence of a difference in means, there is a difference in the overall shape of the cumulative distributions.

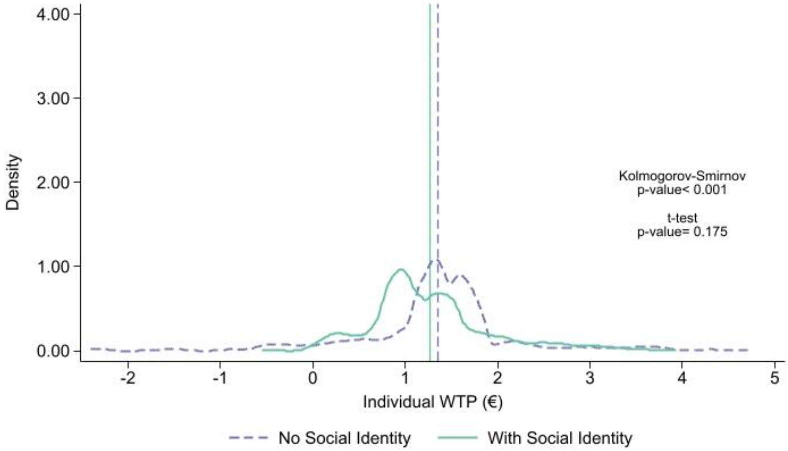

Figure 8 Comparison between experimental groups in WTP for Flour type of bread. The vertical lines indicate the average WTP values for each group.

3.2 Effect of socio-demographic variables on WTP for the attributes

To investigate the socio-demographic factors influencing WTP for the different attributes of extra virgin olive oil, a Seemingly Unrelated Regression (SUR) model was estimated. The results are presented in Table 6. The dependent variables are the individual WTP values for each attribute, both with and without interaction with social identity.

Among the most influential variables, education level stands out. Individuals with a bachelor's degree show a higher WTP for the Bio-District attribute, while those holding a master's degree exhibit a greater willingness to pay for all three main attributes, as well as for the interactions Bio-District × social identity and Extraction process × social identity. Participants with a PhD also demonstrate significantly higher WTP values for all non-interacted attributes.

Perceived income has an opposite effect. Consumers who report being in “good” or “very good” economic conditions exhibit a lower willingness to pay for the Extraction process attribute and for the Agroecology × social identity interaction. Finally, household size has a positive influence on WTP for both Bio-District and Extraction process, while age is negatively associated only with the Extraction process × social identity interaction, suggesting that older consumers are less responsive to this technical-identity combination.

Table 6 SUR Estimates for extra virgin olive oil.

	Bio-district		Agroecology		Extraction Process		Bio-district x SocialIdentity		Agroecology x SocialIdentity		Extraction Process x SocialIdentity	
Constant	10.310**	(3.059)	5.043**	(1.583)	8.343***	(1.345)	20.502***	(3.354)	11.817***	(1.768)	4.245***	(1.019)
Gender: female	-0.652	(0.576)	-0.002	(0.298)	-0.046	(0.253)	-0.953	(0.632)	-0.144	(0.333)	-0.281	(0.192)
Age	-0.030	(0.024)	0.010	(0.012)	-0.009	(0.010)	-0.044	(0.026)	-0.009	(0.013)	-0.016*	(0.008)
Education												
Up to Banchelor's Degree	3.637**	(1.276)	0.638	(0.660)	0.850	(0.561)	1.736	(1.399)	0.662	(0.737)	0.892*	(0.425)
Up to Master's Degree	4.711***	(0.905)	1.678***	(0.468)	1.340**	(0.398)	3.054**	(0.992)	0.965	(0.523)	0.728*	(0.301)
PhD	3.507**	(1.271)	1.493*	(0.658)	1.755**	(0.559)	1.782	(1.393)	1.087	(0.734)	0.348	(0.423)
Income level												
Bad	2.533	(2.789)	1.024	(1.444)	-1.604	(1.226)	-0.621	(3.058)	-2.558	(1.612)	0.996	(0.929)
Neither bad or good	0.459	(2.738)	1.005	(1.417)	-2.280	(1.204)	-3.378	(3.001)	-3.534*	(1.582)	0.394	(0.912)

Good	-1.666	(2.740)	0.304	(1.418)	-3.307**	(1.205)	-5.064	(3.004)	-4.416**	(1.583)	-0.007	(0.912)
Very good	-2.306	(2.875)	0.974	(1.488)	-2.676*	(1.264)	-5.759	(3.152)	-4.026*	(1.661)	-0.461	(0.957)
Household size	0.472*	(0.226)	0.095	(0.116)	0.209*	(0.099)	0.342	(0.247)	0.206	(0.130)	0.074	(0.075)

Standard errors in parentheses. *p<0.05, **p<0.01, ***p<0.001

Table 7 reports the results of the SUR model estimated to investigate the effect of socio-demographic variables on WTP for bread attributes and their respective interactions with social identity. Age is negatively associated with WTP for the Bio-District and Agroecology attributes, suggesting a lower inclination to value these aspects as age increases. However, a positive effect emerges for the interaction Flour Type × social identity, indicating that among older consumers, the identity component may enhance the perceived value of flour type.

Education level emerges once again as one of the strongest determinants. Individuals holding a bachelor's or master's degree exhibit higher WTP for the Bio-District and Agroecology attributes. A similar pattern is observed for the interactions with social identity, particularly for Bio-District × social identity and Agroecology × social identity. Conversely, for the Flour Type attribute, social identity exerts a negative effect: the interaction coefficients are significantly negative among those with a master's or PhD, indicating a reduced WTP when the identity component is involved. Finally, female gender shows a slight positive influence only for the interaction Flour Type × social identity, suggesting that women may assign greater identity-related value to the type of flour used in bread production.

Table 7 SUR Estimates for bread.

	Bio-district		Agroecology		Flour Type		Bio-district x SocialIdentity		Agroecology x SocialIdentity		Flour Type x SocialIdentity	
Constant	1.447***	(0.383)	0.469***	(0.087)	1.635***	(0.448)	2.085***	(0.335)	0.582***	(0.147)	1.635***	(0.330)
Gender: female	-0.135	(0.072)	-0.038*	(0.016)	0.120	(0.084)	-0.116	(0.063)	-0.040	(0.027)	0.127*	(0.062)
Age	-0.006*	(0.003)	-0.001*	(0.0006)	0.0004	(0.003)	-0.005*	(0.002)	-0.002	(0.001)	0.005*	(0.002)
Education												
Up to Banchelor's Degree	0.322*	(0.160)	0.093*	(0.036)	-0.154	(0.187)	0.332*	(0.139)	0.128*	(0.061)	-0.230	(0.137)
Up to Master's Degree	0.377**	(0.113)	0.094***	(0.025)	-0.041	(0.132)	0.428***	(0.099)	0.179***	(0.043)	-0.351***	(0.097)
PhD	0.397*	(0.159)	0.120**	(0.036)	-0.178	(0.186)	0.482**	(0.139)	0.203**	(0.061)	-0.298*	(0.137)
Income level												

Bad	0.179	(0.350)	0.033	(0.079)	-0.363	(0.408)	0.102	(0.305)	0.047	(0.134)	-0.341	(0.301)
Neither bad or good	0.116	(0.343)	0.012	(0.078)	-0.272	(0.401)	0.024	(0.299)	0.013	(0.131)	-0.275	(0.295)
Good	0.073	(0.343)	-0.007	(0.078)	-0.191	(0.401)	-0.014	(0.300)	0.003	(0.131)	-0.280	(0.295)
Very good	-0.394	(0.360)	-0.096	(0.082)	-0.240	(0.421)	-0.407	(0.315)	-0.142	(0.138)	0.214	(0.310)
Household size	0.051	(0.028)	0.009	(0.006)	-0.017	(0.033)	0.018	(0.024)	0.001	(0.010)	-0.042	(0.024)

Standard errors in parentheses. *p<0.05, **p<0.01, ***p<0.001

4 Discussion

The results of the estimated MXL-EC and SUR models for the two products analyzed—extra virgin olive oil and bread—offer valuable insights into the structure of Sicilian consumers' preferences for sustainability-related attributes. In line with the extensive literature on discrete choice modeling, the negative coefficients associated with price and the "no-buy" option confirm the central role of economic constraints in purchase decisions. As price increases, the likelihood of a product being chosen decreases (Krovetz, 2016; Hoek et al., 2017), and the "no-buy" option results in a reduction in perceived utility, indicating that participants, when presented with clearly defined sustainable options, tend to prefer purchasing over abstaining (Barreiro-Hurlé et al., 2010).

The Bio-District certification emerges as the attribute with the greatest impact on perceived utility and willingness to pay (WTP), with an estimated premium price of approximately €13.80 for olive oil and €1.64 for bread. This result suggests that consumers assign high value to labels capable of encapsulating multiple dimensions of sustainability, including geographical proximity, short supply chains, agroecological management, and territorial embeddedness. The Bio-District label functions not only as an informational tool but also as a symbolic and systemic marker, capable of linking the product to a shared set of values (Franco and Cicatiello, 2018). Although the literature has not yet provided direct estimates of WTP for Bio-Districts, these findings are consistent with previous studies on local and sustainable labels, which highlight the ability of such certifications to generate trust and activate preference mechanisms related to territorial identity and social responsibility (Guillaumie et al., 2024; Paffarini et al., 2021; Giannoccaro et al., 2019; Rizzo et al., 2024).

The agroecology attribute is also appreciated by consumers, albeit with slightly lower intensity. The WTP estimates indicate an average premium price of approximately €7.83 for olive oil and €0.50 for bread, suggesting that participants perceive agroecological production as offering added value in terms of healthiness, environmental protection, and the sustainability of production processes. Although the term "agroecology" is less familiar to consumers compared to other sustainability labels (Walthall et al., 2024), the positive response aligns with previous studies showing a higher willingness to pay for sustainable farming practices such as crop rotation or the adoption of environmentally friendly production techniques (Tapsoba et al., 2022; Kliem and Sagebiel, 2023).

Finally, the technical-functional attributes—the cold extraction method for olive oil and the type of flour for bread—elicit a positive response from consumers. In the case of olive oil, the preference for cold extraction suggests that participants perceive added value in techniques regarded as more natural, capable of preserving the product's organoleptic and nutritional properties. This finding is consistent with previous research by Perito et al. (2019) and Tempesta and Vecchiato (2019), which reported a significant preference for cold-pressed oils, often associated with superior quality and greater health benefits. Regarding bread, the appreciation for flours derived from ancient wheat varieties reflects a growing consumer interest in genuineness, digestibility, and the revival of traditional practices. The econometric estimates confirm a positive preference and willingness to pay (WTP) for this attribute, aligning with the findings of Teuber et al. (2016) and Morey et al. (2025), who observed that products made with ancient grains or wholemeal flours are perceived as healthier and more authentic. However, this evidence diverges from the findings of Nazzaro et al. (2025), who reported that, in the context of pasta, the flour type was the least influential attribute among those analyzed, with marginal utilities being nearly identical between conventional and ancient grain flours.

The inclusion of a Social Identity Label in the experimental design allowed for an investigation into whether—and to what extent—recognition of a shared sustainable identity could influence consumers' economic valuation of the different attributes. In line with social identity theory (Tajfel and Turner, 1986; Reed et al., 2012), it was expected that activating an identity dimension oriented toward sustainability would strengthen the value alignment between the product and the consumer, thereby increasing WTP for attributes consistent with that identity.

Among the attributes considered, the Bio-District certification is the one that most clearly responds to the activation of social identity. The effect is particularly pronounced in the case of olive oil, where the average willingness to pay increases from €13.80 in the control group to €17.91 in the treatment group, indicating an additional premium of over €4. A smaller increase is also observed for bread, from €1.64 to €2.21. This pattern suggests that the territorial and systemic dimension conveyed by the Bio-District label can be readily associated with a collective and sustainable identity, thereby reinforcing the role of the label as a signal of values and identity. These findings are consistent with recent empirical evidence highlighting the positive role of identity-based labels in strengthening the connection between products and consumer values (Ortega et al., 2022). For the cold extraction method in olive oil and the flour type in bread, reductions in willingness to pay are observed in the treatment group. Although the change is not statistically significant in the latter case, both variations suggest a potential perceptual misalignment between techno-functional signals and the value-based narrative activated by the identity label. These findings are in line with observations by Lin and Nayga (2022), who argue that the inclusion of identity labels in experimental tasks may induce cognitive overload or informational competition, thereby weakening the persuasive effectiveness of individual attributes.

The analysis conducted through SUR models allowed for a deeper examination of the role of socio-demographic variables in explaining individual WTP values. In line with previous studies emphasizing the importance of human capital in pro-environmental choices (Meyer, 2015; Panzone et al., 2016), education level emerges as the most relevant determinant in both models: individuals with medium to high academic qualifications exhibit a higher WTP for the Bio-District and agroecology attributes, as well as for their interactions with social identity. This finding suggests that understanding and appreciating complex concepts related to systemic sustainability may require a certain degree of cultural and environmental literacy (Aoki et al., 2017). Age also plays a non-negligible role in the case of bread: estimates show a negative correlation with WTP for agroecology and Bio-District attributes, consistent with the literature indicating greater engagement of younger individuals with environmental issues and sustainable diets (McFadden and Huffman, 2017; Ricci et al., 2018). Finally, medium- to high-income groups express lower WTP for cold extraction and for the Agroecology × Social Identity interaction. This result may be explained by a lower sensitivity to efficiency-related messages or a stronger focus on status-related variables over ecological ones.

While this study offers innovative and relevant findings, it also presents several limitations that should be acknowledged. First, the experimental design is based on hypothetical scenarios through an online choice experiment. As a result, the preferences expressed by participants may not fully reflect actual purchasing behavior, due to the so-called hypothetical bias. Although measures were taken to mitigate this effect—such as randomization of scenarios and control for social identity—the possibility of an overestimation of WTP cannot be entirely ruled out. Second, the sample consists exclusively of consumers residing in Sicily. While this reflects the territorial relevance of the Calatino Bio-District, it limits the generalizability of the findings to other socio-cultural and geographical contexts. The preferences expressed may be influenced by local cultural factors, familiarity with typical products, or the regional agricultural landscape. A further limitation concerns the fact that some of the tested attributes are not yet available on the market, such as the specific Bio-District certification for the Calatino. Consequently, responses may have been influenced by subjective interpretations or partial understanding of the attributes' meaning, despite the inclusion of explanatory descriptions within the questionnaire.

The findings of this study offer theoretical, managerial, and policy implications. From a theoretical standpoint, the study stands out for the originality of its experimental design, which incorporates both a market-absent attribute—the Bio-District certification—and a relatively underexplored production method such as agroecology. In doing so, it contributes to an emerging field of research that moves beyond the traditional dichotomies of “organic” versus “conventional.” These attributes were recognized and appreciated by consumers, demonstrating the theoretical and empirical relevance of systemic forms of sustainability that integrate ecological, economic, and socio-territorial dimensions in food choice processes. Moreover, the results show that the social identity label can either strengthen or weaken WTP for sustainable attributes, depending on the type of signal and the informational context. This supports the hypothesis that social identity does not operate in a uniform manner, but rather as a mechanism modulated by message content and perceptual coherence (Yuan et al., 2024). This contributes to the theoretical debate on identity-based labeling, suggesting that not all signals activate the same motivational drivers among consumers.

From a managerial perspective, the results highlight the existence of a significant willingness to pay for attributes related to environmental, social, and territorial sustainability, suggesting substantial opportunities for value creation for local businesses and agricultural producers. The Bio-District certification proves to be an effective tool for product differentiation, allowing for a distinctive market positioning compared to more traditional labels. Moreover, the positive effect observed for the Bio-District attribute in the presence of the Social Identity Label suggests that communication strategies capable of activating a sense of belonging and territorial identification can enhance the perceived value of products. Businesses can therefore benefit from territorial branding strategies that integrate identity-based and narrative elements aligned with values such as proximity, traceability, and short supply chains.

The findings of this study strongly support the hypothesis that consumers are willing to financially support forms of sustainable and territorial certification such as the Bio-District. This provides empirical backing for public policies aimed at promoting and formalizing Bio-Districts as tools for sustainable rural development. Furthermore, the evidence that the Social Identity Label can increase WTP for specific attributes suggests that promotional policies should also include communication campaigns capable of fostering citizens' identification with their territory. In this perspective, the adoption of narrative and participatory tools can contribute to strengthening community engagement, thereby facilitating the transition toward more sustainable and inclusive agri-food models.

5 Conclusions

This study analyzed the preferences and WTP of Sicilian consumers for sustainable attributes related to the production of bread and olive oil—two symbolic products of the Mediterranean diet—using a choice experiment enriched with a social identity label, while also exploring the effect of socio-demographic variables.

The results reveal a positive and significant evaluation by consumers for all the attributes considered, with a particularly strong preference for the Bio-District certification, which received the highest economic premium across both products. Agroecology and techno-functional characteristics were also appreciated, though to a lesser extent. The inclusion of the social identity label increased WTP in certain cases—especially for the Bio-District attribute—but showed mixed effects in others, suggesting that the effectiveness of such signals depends on the type of attribute and the perceptual context. Finally, the SUR models indicated that age, education, and income influence WTP in a non-uniform way, highlighting that sustainable preferences are not evenly distributed across the population.

From a theoretical perspective, this study offers an innovative contribution by exploring under-researched or market-absent attributes—such as the Bio-District certification and agroecological production—and by testing the effect of social identity on traditional food products. These findings expand the literature on the identity-based and symbolic mechanisms of sustainable consumption, contributing to the emerging debate on the alignment between personal values and market signals. The practical implications are also significant: for policymakers and local stakeholders, the existence of latent demand for sustainable and local supply chains may justify policy support for the establishment of Bio-Districts, particularly in inner areas, where integrated territorial valorization initiatives can promote both rural development and social cohesion. For businesses, the effectiveness of the Bio-District label as a differentiation tool suggests the opportunity to invest in certifications that convey territorial and environmental values—while avoiding excessive informational overload.

However, this study presents several limitations: the hypothetical nature of the choice experiment may introduce self-reporting bias; the sample, composed of Sicilian consumers, limits the generalizability of the results to other geographical contexts; finally, the tested attributes were introduced through standardized descriptions, whose interpretation may vary across individuals.

Future research could expand and deepen these findings along multiple dimensions. From a methodological perspective, it would be valuable to conduct experimental auctions to assess the consistency between stated preferences and actual purchasing behavior, evaluating the real-world reception of sustainability labels in everyday consumption contexts. Variants of the Social Identity Label could also be tested, using alternative formulations, different types of value-based messages, or presentation formats (e.g., images, storytelling, testimonials), to identify the most persuasive components. Further studies could extend the investigation to new territorial contexts, comparing rural and urban areas or established Bio-Districts versus those still in development, to assess how the communicative effectiveness of identity-based attributes varies with levels of territorial familiarity and embeddedness. From a theoretical standpoint, it would be interesting to explore the mediating or moderating role of variables such as territorial identity, environmental engagement, risk perception, or social awareness, to better understand the conditions under which identity-based labels are most effective.

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General Discussion and Conclusions

In recent years, the need to achieve sustainable development has become a pressing challenge for rural and marginal areas across Europe. These territories, often affected by depopulation, aging population, abandonment of agricultural land and insufficient public services, are called to respond to the objectives of the 2030 Agenda and the European Green Deal through place-based and inclusive strategies (Gallo and Pagliacci, 2020). Within this framework, agriculture is not only an economic activity, but also a social and environmental asset that can contribute to the regeneration of local communities and the ecological transition (Scheel, 2016). New participatory and territorial governance models are thus emerging to reconnect production, environment, and society, supporting agroecological innovation and strengthening the relationship between farmers, citizens, and institutions.

This thesis investigated the potential of Living Labs and Bio-districts as tools for promoting sustainable transitions in rural areas, through an in-depth case study of the Calatino, a SNAI area in inner Sicily. Through four interconnected scientific contributions, this work explored the different dimensions of territorial innovation—from stakeholder engagement to farmer participation and consumer behavior—framing them within the broader discourse of agroecology and territorial sustainability.

The first contribution provided a comprehensive review of the scientific literature on Living Labs applied to the agri-food sector. This systematic analysis highlighted the increasing diffusion of Living Labs as experimental environments to co-create innovation in agriculture, while also revealing a lack of common definitions and methodological coherence. Although Living Labs are widely recognized for their ability to involve multiple stakeholders and promote bottom-up processes, their application in rural contexts is still limited and fragmented. The review identified three main areas where Living Labs may play a transformative role: the ecological transition of food systems, the development of territorial food governance, and the enhancement of community-based innovation. These findings offer a conceptual foundation to frame the empirical work developed in the following contributions.

Building on the conceptual framework derived from the review, the second contribution focused on the empirical implementation of a Living Lab in the Calatino area. This phase aimed to explore the territorial context and co-design a shared vision for the establishment of a Bio-district. The Calatino, a marginal inner area in central-eastern Sicily, has experienced deep structural and demographic challenges over the past decades. However, it still retains a rich network of organic farms, local knowledge, and civic associations that can serve as a foundation for territorial regeneration.

Through a series of participatory workshops and field activities, the Living Lab brought together a diverse group of actors—organic and in-conversion farmers, public institutions, civil society organizations, researchers, and citizens—according to the quadruple helix model. The participatory process supported a collaborative analysis of the territorial assets, challenges, and opportunities for the creation of a Bio-district rooted in agroecological principles. Notably, the research identified a widespread willingness among stakeholders to co-design new forms of governance and value creation, provided that the initiative remains inclusive, transparent, and adapted to local needs.

The Living Lab approach also proved effective in fostering mutual learning and trust among actors who had never interacted before, highlighting the transformative potential of such methodologies in fragmented rural areas. However, the process revealed several challenges, including the difficulty of maintaining continuous engagement over time, the presence of asymmetries in knowledge and power among participants, and the need for institutional support to ensure the continuity and institutionalization of the initiative. Despite these limitations, the results provide valuable insights into the design and facilitation of participatory processes for territorial sustainability and the activation of place-based governance mechanisms.

The third contribution addressed a crucial dimension of Bio-district development: the willingness of organic and in-conversion farmers to engage in such a collective initiative. To this end, an extended Theory of Planned Behavior (ETPB) framework was employed to investigate the psychological, normative, and contextual drivers that influence farmers' intention to join the future Calatino Bio-district.

The empirical analysis, conducted on a sample of certified organic farms in the area, revealed that Attitude, Perceived Utility, Government Trust, and Subjective Norms were the main determinants of farmers' intention to adhere to the Bio-district initiative. Farmers were more likely to express a strong intention to participate when they perceived the Bio-district as a beneficial opportunity (economically, environmentally, or socially), and when they felt encouraged by relevant social referents, such as fellow farmers and local organizations. On the contrary, Perceived Behavioral Control did not show a significant effect, suggesting that practical constraints (e.g., time, resources, bureaucracy) might be less influential than expected—possibly due to the early stage of the initiative or the profile of the sample.

The findings also highlighted a crucial role played by institutional trust, underlining the importance of credible, transparent, and inclusive governance structures to ensure farmers' engagement. These results align with previous literature emphasizing that trust and perceived collective benefits are essential conditions for the success of agroecological transitions and community-based development models (Prost et al., 2023; Polge and Pagès, 2022; McKay et al., 2025).

The study filled a significant gap in the empirical application of behavioral theories to the context of Bio-districts and offered actionable insights for local policymakers and practitioners. By identifying the psychological and relational factors that shape farmers' intentions, this contribution provides a roadmap for designing targeted communication and support strategies aimed at increasing farmer participation and commitment in the early stages of Bio-district creation.

The fourth contribution explored the demand-side perspective of sustainable territorial development, by investigating consumers' preferences for products certified by the future Bio-district. A discrete choice experiment was designed to estimate the Willingness to Pay (WTP) for selected sustainability-related attributes on two typical products from the Calatino area: extra-virgin olive oil and bread. The attributes included agroecological production methods, traditional processing techniques (e.g., cold extraction or ancient wheat varieties), and a territorial certification label issued by the Bio-district.

The experimental design incorporated a between-subject manipulation of Social Identity Activation, through an identity-based label aiming to foster a sense of territorial belonging and pro-sustainability orientation. The results from mixed logit models showed that consumers positively valued the presence of the Bio-district label, agroecological attributes, and traditional production methods—confirming the existence of a market segment sensitive to the ethical and territorial dimensions of food.

The introduction of the Social Identity Label significantly increased the WTP for most sustainability attributes, particularly for those directly linked to the territory and the values of the community. This finding suggests that activating social identity mechanisms can effectively enhance consumers' valuation of sustainable food products, reinforcing the idea that individual choices are not only shaped by product characteristics, but also by symbolic meanings and identity-related cues.

In addition, Seemingly Unrelated Regression (SUR) models were used to analyse the influence of socio-demographic and attitudinal variables on individual WTP estimates. The results revealed that factors such as young age and higher education were associated with a higher valuation of Bio-district certified products. These insights underline the importance of communication strategies that not only inform but also resonate with consumers' values and social identities (Papaoikonomou et al., 2016).

Overall, this contribution highlights the potential of Bio-districts to promote more sustainable consumption patterns, if certification schemes can convey collective values and local embeddedness. It also offers innovative evidence on how behavioral levers such as identity-based cues can be mobilized to support agroecological transitions from the demand side.

The four contributions of this thesis offer a comprehensive and multi-actor view of how sustainable territorial development can be activated in marginal rural areas through the integrated use of Living Labs and Bio-districts. The Calatino case study, embedded in the Italian National Strategy for Inner Areas (SNAI), provided a concrete testing ground for exploring how participatory processes, institutional frameworks, farmer engagement, and consumer behavior converge in shaping a bottom-up agroecological transition.

From a theoretical point of view, the thesis contributes to bridging disciplinary gaps between agricultural economics, rural sociology, and behavioral science. The Living Lab approach proved valuable not only as a context-sensitive method for stakeholder engagement but also as a governance tool for co-designing development pathways in areas characterized by structural and demographic decline (Lupp et al., 2020). In particular, the first two contributions showed that institutional innovation and local leadership are key to overcoming inertia and activating cooperation among heterogeneous actors—confirming and extending previous insights from the literature on territorial governance and innovation systems.

From the farmers' side, the application of the Theory of Planned Behavior to the intention to join the Bio-district revealed the importance of internal drivers, rather than social norms or economic convenience alone. This suggests that policy instruments aiming to foster collective action should not only address material constraints but also work on the symbolic and motivational dimensions of change. The inclusion of psychological constructs such as perceived utility and government trust expands the explanatory power of the TPB and provides a more accurate understanding of farmers' decision-making in uncertain and complex contexts.

On the demand side, the final contribution demonstrated that consumers are willing to reward sustainability attributes related to territory, tradition, and agroecology—especially when these are framed within a shared social identity. The experimental evidence showed that identity-based communication can enhance the perceived value of certification schemes, activating motivations beyond individual utility maximization. This finding opens up new perspectives on how Bio-districts can act not only as production clusters but also as relational platforms where values, narratives, and social bonds are co-produced and expressed through food.

From a political perspective, the thesis highlights the need for a more integrated and participatory approach to rural development—one that aligns place-based strategies, multi-level governance, and market mechanisms. The findings suggest that Bio-districts should not be conceived merely as labels or administrative constructs, but as evolving socio-ecological systems that require continuous interaction between public institutions, producers, and consumers (Herrera et al., 2025). In this sense, investing in collective certification, identity-building, and stakeholder engagement becomes essential to sustain the long-term viability and legitimacy of such initiatives.

Future research could explore the dynamics of institutionalization of Bio-districts over time, investigate the scalability of Living Lab models in other marginal regions, and delve deeper into the interplay between social identity and sustainable consumption. Moreover, more attention should be paid to how digital tools and data governance can support participatory planning and monitoring in territorial development processes.

In conclusion, this thesis provides novel empirical and conceptual contributions to the field of sustainable rural development, offering actionable insights for scholars, practitioners, and policymakers. By showing how co-creation, behavioral drivers, and territorial identity can be strategically mobilized, it proposes an integrated vision for fostering agroecological transitions in rural Europe.

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Annexes

1 List of published papers

Timpanaro, G., **Cascone, G.***, Foti, V. T. (2025). Enabling Technologies in Citrus Farming: A Living Lab Approach to Agroecology and Sustainable Water Resource Management. *Bio-based and Applied Economics*.

Cascone, G.*, Tuccio, G., Timpanaro, G. (2025). Analysis of Italian craft beer consumers: preferences and purchasing behaviour. *British Food Journal*, *127*(3), 914-935.

Timpanaro, G., **Cascone, G.*** (2025). Consumer behavior and sustainability: Exploring Italy's green cosmetics market with prickly pear seed oil. *Heliyon*, *11*(3).

Timpanaro, G., Foti, V. T., **Cascone, G.**, Trovato, M., Grasso, A., Vindigni, G. (2024). Living Lab for the Diffusion of Enabling Technologies in Agriculture: The Case of Sicily in the Mediterranean Context. *Agriculture*, *14*(12), 2347.

Cammarata, M., Scuderi, A., Timpanaro, G., **Cascone, G.** (2024). Factors influencing farmers' intention to participate in the voluntary carbon market: An extended theory of planned behavior. *Journal of Environmental Management*, *369*, 122367.

Cascone, G.*, Scuderi, A., Guarnaccia, P., Timpanaro, G. (2024). Promoting innovations in agriculture: Living labs in the development of rural areas. *Journal of Cleaner Production*, 141247.

Timpanaro, G., Chinnici, G., Selvaggi, R., **Cascone, G.**, Foti, V. T., Scuderi, A. (2023). Farmer's adoption of agricultural insurance for Mediterranean crops as an innovative behavior. *Economia agro-alimentare*, *25*(2).

Timpanaro, G., Pecorino, B., Chinnici, G., Bellia, C., Cammarata, M., **Cascone, G.**, Scuderi, A. (2023). Exploring innovation adoption behavior for sustainable development of Mediterranean tree crops. *Frontiers in Sustainable Food Systems*, *7*, 1092942.

Timpanaro, G., **Cascone, G.** (2022). Food consumption and the Covid-19 pandemic: The role of sustainability in purchasing choices. *Journal of Agriculture and Food Research*, *10*, 100385.

2 List of submitted papers

Cascone, G.*, Guarnaccia, P., Timpanaro, G. Innovation in Inner Areas: How Living Labs Support Green Transition and Bio-District Success. *Environmental and Sustainability Indicators*. Current status: under review.

Cascone, G.*, Guarnaccia, P., Timpanaro, G. A Living Lab Approach for the Construction of a Bio-District in an Inner Area of Sicily (Italy): The Case of Calatino. *Environmental Development*. Current status: under review.

Timpanaro, G., Bissanti, G., **Cascone, G.**, Guarnaccia, P., Foti, V. T. Regulatory Frameworks and Policy Innovations for Agroecology in the Mediterranean: Comparative Insights, Challenges, and Global Prospects for Sustainable Transition. *Environmental Development*. Current status: with editor.

3 Conference Proceedings

Scuderi, A., Timpanaro, G., **Cascone, G.**, Continella, A., Cammarata, M. (2024). Voluntary Carbon Market and Implications for Agriculture in the European Union. In *INTERNATIONAL SYMPOSIUM: New Metropolitan Perspectives* (pp. 34-42). Cham: Springer Nature Switzerland.

Scuderi, A., Timpanaro, G., Sturiale, L., Cammarata, M., **Cascone, G.*** (2024). Evaluation of the "Silvestri Craters on Etna" Living Lab for Knowledge Value Transfer. In *INTERNATIONAL SYMPOSIUM: New Metropolitan Perspectives* (pp. 127-136). Cham: Springer Nature Switzerland.

Scuderi, A., **Cascone, G.**, Timpanaro, G., Sturiale, L., La Via, G., Guarnaccia, P. (2023). Living labs as a method of knowledge value transfer in a natural area. In *International Conference on Computational Science and Its Applications* (pp. 537-550). Cham: Springer Nature Switzerland.

4 Attendance to seminars and courses

- Participation as an auditor with a positive result in the final examination of the course: "**Microeconometrics applications for agricultural economics".** Prof. Luigi Cembalo, 22 March – 5 May 2023 (48 hours). As part of the Advanced Master in Agricultural Economics and Policy held at the Department of Agriculture of the University of Naples Federico II

- Participation as an auditor with a positive result in the final examination of the course: **"Applied econometrics for**

agricultural economics". Prof. Francesco Caracciolo, 16 May – 15 June 2023 (48 hours). As part of the Advanced Master in Agricultural Economics and Policy held at the Department of Agriculture of the University of Naples Federico II

- Course organised by the PhD coordinator:
  - Writing a scientific review article, Prof. Daniela Spina and Prof. Gaetano Chinnici - 6 and 9 June 2023 (6 hours)
  - Scientific publishing in the peer review era, Prof. Antonio Biondi – 27 June 2023 (3 hours)
  - CAD and GIS for sustainable agriculture, Prof. Claudia Arcidiacono and Prof. Provvidenza D'Urso – 4-5-6 July 2023 (9 hours)
  - ICT for participatory methods, citizen science and disseminating research, Prof. Teresa Graziano – 10-11-12 July 2023 (9 hours)
  - Agricultural policies in the UE: from the past to the future, Prof. Giovanni La Via – 18, 19, 22 December 2023 (10 hours)
  - Managing biological data with R: applications for plants and fruit tree species, Prof. Mario di Guardo – 22 - 26 January 2024 (20 hours)
  - General and Multivariate Statistical Analysis: application with the R software, Prof. Maria Raimondo – 7, 11, 14 and 18 March 2024 (20 hours)

- Participation to the International Summer School program: **"Experimental Auctions: Theory and Applications in Food Marketing and Consumer Preferences Analysis",** Prof. Maurizio Canavari, Prof. Andreas Drichoutis, Prof. Jayson L. Lusk and Prof. Rodolfo M. Nayga Jr. (42 hours). Organized by the Department of Agricultural and Food Sciences Alma Mater Studiorum-University of Bologna, Bologna, July 1-6, 2024

5 Scientific and educational activities

- Year 2023: **Student exercise on useful statistical sources in politics, business, and labour:** Subjects-POLITICA AGRARIA (L-25), Di3A University of Catania; Chair holder: Giuseppe Timpanaro

- Year 2023: **Achievement of the 1°Level Master in Viticulture, Oenology and Enomarketing.** Final project work titled "Development and Promotion of Etna DOC: The Role of the Consortium for the Protection and Promotion of Etna DOC Wines"**.** Department of Agriculture, Food and Environment (Di3A) **-** University of Catania, Supervisor: Prof.ssa Vera Teresa Foti. Received a final grade of 106/110.

- Year 2024: **Student exercise on Economic data search via FAOSTAT and subsequent data elaboration via database (4 hours):** Subjects **-** AGRIFOOD ECONOMY, Di3A University of Catania; Chair holder: Prof. Alessandro Scuderi

- Year 2024: **The wine chain: from production to nutrition (3 hours):** Subjects **-** Human Nutrition Sciences, Di3A University of Catania; Chair holder: Prof. Alessandro Scuderi

- Year 2024: **The marketing of wine (3 hours):** Subjects **-** Agri-food Markets and Marketing, Di3A University of Catania; Chair holder: Prof. Giuseppe Timpanaro

- Year 2024: **Legislation in wine (3 hours):** Subjects **-** QUALITY PRODUCTS ECONOMY, Di3A University of Catania; Chair holder: Prof.ssa Vera Teresa Foti

- Tutoring of thesis:
  - Consumer preferences for craft beer: marketing analysis using conjoint analysis.
    Student: Giancarlo Tuccio.
    Master's Degree in Agricultural Science and Technology;
  - Quality certification for agri-food products: the case of nickel-free products.
    Student: Chiara Cicciarello.
    Bachelor's degree in Food Science and Technology;
  - The ecological transition of agri-food systems: the case study of the Calatino territory.
    Student: Debora Anastasi.
    Bachelor's degree in Food Science and Technology;
  - Innovations in the agri-food system in support of made in Italy: the case of blockchain.
    Student: Giulia Branciforti.
    Bachelor's degree in Food Science and Technology
  - Sustainable food choices: an analysis of the factors underlying the purchasing behaviour of low-carbon products through the Theory of Planned Behaviour.
    Student: Veronica Maria Oddo.
    Master's Degree in Food Science and Technology.

6 Education and Research Experience

- 2022-2025: Ph.D. in Agricultural, Food, and Environmental Science. Department of Agriculture, Food and Environment. University of Catania. Supervisors: Prof. Giuseppe Timpanaro and Prof. Paolo Guarnaccia.
- January 2025 – July 2025: Visiting Scholar. Agricultural University of Athens – Department of Agricultural Economics &

Rural Development, Athens, Greece. Supervisor: Prof. Andreas C. Drichoutis

- May 2022 – November 2022: Research grant. BRESOV Project: Breeding for Resilient, Efficient and Sustainable Organic Vegetable Production (HORIZON 2020- SFS-07-2017). Department of Agriculture, Food and Environment. University of Catania. Supervisor: Prof. Ferdinando Branca.
- 2022 - 2023: Completion of a first-level Master's Degree in Viticulture, Oenology and Wine Marketing for the 2021/2022 academic year at the University of Catania. Final project work ‘Development and promotion of Etna DOC: the role of the Consortium for the Protection and Promotion of Etna DOC Wines’ supervisor Prof. V.T Foti.
- 2019 – 2021: Master's Degree in Agricultural Science and Technology (LM-69) from the University of Catania. Thesis: ‘Food consumption and the COVID-19 pandemic: the role of sustainability in purchasing decisions,’ supervisor Prof. G. Timpanaro.
- 2016 – 2019: Bachelor's degree in Agricultural Science and Technology (L-25) from the University of Catania. Thesis: ‘Multifunctionality in Sicilian wineries: the case of the Etna Wine Route,’ supervisor Prof. G. Timpanaro.