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Methods and tools to foster territorial approaches for the assessment of food supply chains

Presentata da

Francesco Cirone

Supervisore

Prof. Matteo Vittuari

Coordinatore Dottorato

Prof. Massimiliano Petracci

Co-Supervisore

Dr. Fabio De Menna

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Abstract

The challenges of the current global food systems are often framed around feeding the world's growing population while meeting sustainable development for future generations. Globalization has brought to a fragmentation of food spaces, leading to a flexible and mutable supply chain. This poses a major challenge to food and nutrition security, affecting also rural-urban dynamics in territories. It has only recently become clear what the cost of this process is. Not only in terms of environmental but also of societal and economic impacts which have long-term consequences for the planet and future generations. Furthermore, the recent crises have highlighted the vulnerability to shocks and disruptions of the food systems and the eco-system due to the intensive management of natural, human and economic capital.

Hence, a sustainable and resilient transition of the food systems is required through a multi-faceted approach that tackle the causes of unsustainability and promotes sustainable practices at all levels of the food system. In this respect, a territorial approaches become a relevant entry point of analysis for the food system's multifunctionality and can support the evaluation of sustainability by quantifying impacts associated with quantitative methods and understanding the territorial responsibility of different actors with qualitative ones.

Against this background the present research aims to i) investigate the environmental, costing and social indicators suitable for a scoring system able to measure integrated sustainability performance of food initiatives within the City/Region territorial context; ii) develop a territorial assessment framework to measure sustainability impacts of agricultural systems; and iii) define an integrated methodology to match production and consumption at territorial level to foster long-term vision of short food supply chains.

From a methodological perspective, the research proposes a mixed quantitative and qualitative research method. Quantitative methods are provided by the life cycle tools and statistical analysis, while the qualitative methods are based on focus groups, Delphi and backcasting. All methodologies are applied to selected case studies. The outcomes provide an in-depth view into the environmental and socio-economic impacts of food systems at territorial level, investigating possible indicators, framework, and business strategies to foster their future sustainable development.

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Overall introduction

The global production of food commodities

The urbanization trend which is shaping the current global food systems is bringing significant socio-economic changes in cities and region around the world (Tadros et al., 2021). This phenomenon poses a major challenge to food and nutrition security affecting also rural-urban dynamics (FAO & RUAF, 2015). The difficulties currently faced by global food systems are often described as a need to nourish the expanding population while also ensuring long-term sustainability for future generations. (FAO, 2017). Depending on national policies and economic structures, increased urbanization trends have impacted hunger and poverty in both positive and negative ways. To actively respond to these issues, the agricultural business sector dramatically boosted the cross-border movement of commodities and goods, therefore also increasing the complexity of global food systems. On the one hand to soften the high cost of raw materials, on the other hand to avoid high price volatility (Huchet-Bourdon, 2011). As a consequence of modern developments, the worldwide food systems have evolved into a disconnected, adaptable, and variable supply chain, in which food is primarily viewed as an intensively produced commodity. Nonetheless, the full extent of the ramifications of this progression has only recently come to light. These ramifications are not limited to economic considerations, but also encompass the societal and ecological repercussions resulting from the global supply chain.

The global value added generated by food systems is increased by 78% in real terms between 2000 and 2020, reaching USD 3.6 trillion in 2020 (European Commission, 2021). This economic added value has been produced by a reduction of 13% of global workforce employed in agriculture (FAO, 2020) and a major contribution to the intensive exploitation of non-renewable natural resources, soil erosion and biodiversity losses (Valencia et al., 2022), with ever greater responsibility for greenhouse gases (GHG) production due to livestock and crops activities within the farm gate (FAO, 2020). In addition, the vulnerability to shocks and disruptions of the food systems to wars and pandemics had severe impacts on food security and livelihoods. In fact, the recent COVID-19 pandemic has exacerbated vulnerabilities (O'Meara et al., 2022), while the current Ukraine war is intensifying the food crisis and accessibility to primary goods (McGreevy et al., 2022).

Hence, to address these global challenges, a sustainable and resilient transition of the food systems is required. A multi-faceted approach that addresses the root causes of unsustainability and promotes the adoption of sustainable practices at all territorial levels of the food system with all stakeholders, from production to consumption is still under discussion.

Food systems transition toward sustainability

Sustainability has become a crucial focus for nations, governments, and organizations around the world. The UN Sustainable Development Goals (SDGs) demonstrate a common agreement on target policy aims to achieve sustainable progress in various areas, including food systems. The overall aim is to ensures food security and nutrition for all, while also preserving the economic, social, and environmental resources needed to maintain food security for future generations. This transformation is also seen as a crucial part of achieving the other SDGs (ONU, 2022).

Indeed, the food sector plays a crucial role in sustainable development since it provides jobs and livelihoods for a large portion of the global population. It can ensure an adequate and nutritious food quality level for people, determining their health and well-being conditions. It can offer an important source of food security and nutrition for communities at the local level (Valentini, Sievenpiper, Antonelli, & Dembska, 2019). However, to fulfil the sustainable transition of the food system new paradigms able to overcome strict neoclassical interpretations of food system dynamics and new operative assessments to monitor it are required (McGreevy et al., 2022).

Territorial approaches

The need for territorial approaches in regional and territorial development came up as a proactive response to weaknesses of traditional approaches from the 1960s and 1970s, such as the modernization or the sectorial approach which did not take into account multiple sectoral issues in their models. Thus, it did not allow for considering the interdependence of different sectors and also the site-specific territorial characteristics of regions and places in addressing sustainable development. Territorial approaches, in contrast, emphasize the importance of understanding and addressing the unique characteristics and context of a region or area, and advocates for a holistic approach that considers the sustainability issue and the interdependence of different sectors. It also prioritizes the engagement and participation of local actors and stakeholders, recognizing that their knowledge and skills are essential for the success of any development initiative. Furthermore, traditional approaches to development and planning were criticized for their narrow focus on economic growth and development, while underestimating social and environmental considerations. Territorial approaches address these shortcomings by promoting sustainable and inclusive development, taking into account the economic, social, environmental, and territorial dimensions of a region or area. As highlighted by Marcel Mazoyer (1988) multiple production systems and their interactions defined the agrarian systems described as a complex and multifaceted territorial development. Hence, the need for an interdisciplinary approach to understand the dynamics of territories and their evolution. Territory can be understood as a complex system comprising a geographic area, a network of stakeholders, and a system of representations (Moine, 2006). This territorial complexity is captured by the interplay between land cover and land use, respectively the natural layers such as vegetation, crops, and structures that cover the land surface, and the observable human activities of land exploitation and structural elements in the landscape. Their interactions constitute a land use system, which includes socioeconomic information and governance issues and approaches the concept of territory. In the context of sustainable food systems, territorial approaches would involve assessing the unique food production and consumption patterns of a specific region, as well as the resources and infrastructures available to support sustainable food systems. In this context goods and services provided by the land use systems are categorized as land functions (Verburg et al., 2009). Those represent the multifunctionality of the territorial system by providing goods and services based on material, capital and social functions.

Methods and tools for analysing territorial development

To analyse and understand the sustainability impacts of such complex food systems at the territorial level requires a combination of mixed (qualitative and quantitative) methods research (MMR) to gather in-depth information (Timans, Wouters, & Heilbron, 2019). Mixed methods research, as outlined by Tashakkori and Creswell (2007), involved the "*use of both qualitative and quantitative approaches or methods in a single study or program of inquiry*". Adopting MMR can provide a complete and nuanced understanding of sustainability (Scerri and James, 2010).

Within the quantitative approaches, Life Cycle Thinking (LCT) are widely established sustainability evaluation methodologies, involving the analysis of the life cycle-generated impacts of a product, process or service and identifying ways to minimize these impacts (Luján-Ornelas et al., 2020). Avoiding burden shifting is one of the major contributions of life cycle analysis, which refers to ensuring that improvements in one stage of the life cycle are not achieved at the expense of another stage (Life Cycle Initiative, 2022). LCT framework is composed by:

- Life Cycle Assessment (LCA), which is a tool for evaluating the environmental impacts of a product or process throughout its entire life cycle, from raw material extraction to disposal (ISO, 2006, 2002).
- Life Cycle Costing (LCC), which is a methodology for identifying the full costs of a product or process throughout its entire life cycle, with the goal of optimizing cost-effectiveness (Hunkeler et al., 2008).

- Social Life Cycle Assessment (S-LCA), which is a tool for measuring both positive and negative social impacts of a product or process throughout its entire life cycle (UNEP Life Cycle Initiative & Social LC Alliance, 2020).

Strongly connected with the assessment framework, indicators are characterized by their specificity, observability, and measurability. These characteristics enable indicators to serve as means of demonstrating progress or changes towards specific outcomes (Moldan, Janoušková, and Hák, 2012). However, as is often pointed out in scientific literature, their selection can affect the results of the studied system and can be largely unsuitable for getting an insight into the multifunctionality in territorial context, since they often focus on agricultural and production activities and fail to consider non-agricultural activities (Barbier and Lopez-Ridaura, 2010). Beyond assessment framework and indicators, qualitative research can support the analysis of production and consumption patterns by involving stakeholders and local actors in the definition of sustainable supply chain strategies at the territorial level.

Objectives of the research

The scope of the research is to contribute to the development of territorial approaches with three main specific objectives:

1) to investigate environmental, cost and social indicators suitable for a scoring system able to measure integrated sustainability performance of food initiatives within the City/Region territorial context;

2) to develop a territorial assessment framework to measure the sustainability impacts of agricultural systems;

3) to propose a mixed methods approach to meet production-consumption patterns at the territorial level.

All objectives as well as methodologies adopted are applied to different selected case studies. For the first objective, the investigation is applied at food initiatives level. For the second objective, an integrated crop-livestock system is analysed, while for the latest objective, the case study of an entire short food supply chain of ancient grains is analysed considering also the consumer perspective. The choice of different case studies allows to investigate impacts generated by a broad range of different stakeholders at the territorial level.

Thesis structure

The PhD work has been structured into three chapters:

- **Chapter 1** investigates the importance of sustainability indicators to study food supply chains by adopting a territorial perspective. It allows for a comprehensive understanding of the complex interactions between different components of food production and consumption, including social, economic, and environmental factors. Specifically, the City Region Food System (CRFS) approach is selected as the appropriate territorial framework to investigate the unique characteristics and challenges of food initiatives across Europe. The work proposes a consistent sustainability indicator scoring system that allows comparative evaluation of food system initiatives, adopting a Life Cycle Thinking approach. It advances existing knowledge and past projects, taking advantage of a participatory process, with stakeholders from multidisciplinary expertise. The indicators have been then tested on 100 case studies in 10 European countries.
- **Chapter 2** develops a territorial assessment framework by an original coupling between an Integrated Assessment and Modelling (IAM) platform, MAELIA, and Territorial LCA (T-LCA) to assess the environmental performance of integrated crop-livestock farming system at the territorial level. Through a basket of services provided by the territory under study, a linear economic model and a circular one are compared by computing the eco-efficiency ratios to get insights into the sustainability performance. The feasibility of such an integrated approach is discussed based on a case study located in centre-west of France.
- **Chapter 3** proposes a tailored solutions to match food production and consumption at the territorial level, by identifying long-term vision and key actions of short food supply chain (SFSC) to reach consumers' needs. The feasibility of the proposed methodology is tested on a case study of organic production of ancient grains in a defined area between the Emilia-Romagna provinces of Forlì-Cesena and Rimini region, Italy. The short food supply chain plays a vital role in connecting local producers with consumers, promoting sustainability, supporting the local economy, and providing access to fresh, high-quality foods.

Conclusions address the major challenges for applying the proposed methodological approaches, the main impacts related to the food supply chain at the territorial level and recommendations to transfer research knowledge into policy actions.

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Chapter 1: A sustainability scoring system to assess food initiatives in city regions

Keywords: *City Region Food System Initiatives; Sustainability Performance; Scoring Mechanism; Multi-Stakeholder Approach; Life Cycle Thinking*.

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Abstract

The City Region Food Systems approach has been proposed to achieve food system resilience and nutrition security while promoting the urgent ecological transition within urban and peri-urban areas, especially after the COVID-19 pandemic. However, the great diversity of the initiatives composing City Region Food Systems in Europe poses barriers to the assessment of their integrated sustainability. Hence, the present work is developed within the EU-H2020 project Food System in European Cities (FoodE), to build a consistent sustainability scoring system that allows comparative evaluation of City Region Food System Initiatives. Adopting a Life Cycle Thinking approach, it advances on existing knowledge and past projects, taking advantage of a participatory process, with stakeholders from multidisciplinary expertise. As a result, the research designs, and tests on 100 case studies a simplified and ready-to-use scoring mechanism based on a quali-quantitative appraisal survey tool, delivering a final sustainability score on a 1-5 points scale, to get insights on the social, economic, and environmental impacts. As in line with the needs of the UN Sustainable Development Goals, the outcome represents a step forward for the sustainable development and social innovation of food communities in cities and regions, providing a practical and empirical lens for improved planning and governance.

1.1 Introduction

Sustainability has increasingly become central to global, regional, and national agendas. Through the Sustainable Development Goals (SDGs) a shared set of guiding elements has been operationalised to make tangible progress at multiple levels (UN, 2015). Sustainable food systems defined as systems that 'deliver food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised' (FAO, 2018) are today recognized key segments in the transition to meet these goals (Sachs et al., 2019).

Despite meaningful commitments in achieving just food systems, as a result of the globalization process food and nutrition security in European cities and regions are being increasingly challenged by economic, ecologic, and health-related crises (FAO/IFAD/UNICEF/WFP/WHO, 2021; Hu et al., 2020; FAO, 2020). The recent COVID-19 pandemic has exacerbated vulnerabilities (O'Meara et al., 2022), while the current Ukraine war is intensifying the food crisis and accessibility to primary goods (McGreevy et al., 2022). More than ever, increased efforts are needed to transform the food system in a way the economic aspirations are considered together with social and environmental ones (Ivo de Carvalho et al., 2022; Fanzo et al., 2021). This urgency asks for both new paradigms able to overcome strict neoclassical interpretations of food system dynamics and new operative assessment to monitor advancements of food system with a comprehensive outlook (McGreevy et al., 2022).

Over the last decades, multiple approaches to reflect on food system sustainability have flourished. The bioregion paradigm, defined by Harris et al. (2016) as a geographical space characterized by local eco-system interactions, highlighted the opportunity for human populations to leave their steady-state economies (Evanoff, 2017) by promoting ecologically sensitive agricultural practices (Gilbert et al., 2009) to control their domestic resources (Evanoff, 2017). In the same way, the foodsheds framework strengthened the relation between producers and consumers in terms of geographical delimitation (Arthur et al., 2022), helping to analyse global changes through the lens of the food system (McCabe 2010). Basing on the foodshed delimitation, several assessment models have been developed to explore indicators for improving self-sufficiency in cities and regions (Sylla et al., 2022; Vicente et al., 2021; Zasada et al., 2019). The proposed assessments discussed the capacity of local food systems in meeting human dietary needs, but without considering social and economic aspects in the framework of the analysis. A step forward in the sustainability assessment was proposed by the framework of Agroecology-Based Local Agri-Food systems which identify four categories to evaluate food initiatives, i.e., environmental health, economic viability, social equity and right (González De Molina and Lopez-Garcia, 2021). Still, operative methodologies to measure

it are falling short. On the agroecology principle also the bio district approach emerged, defining territories as farming systems, where natural resources are sustainable managed by local stakeholders following agroecology and organic farming principles (Passaro and Randelli, 2022). Despite their specificities, the abovementioned concepts fail to consider the complexity and diversity of the relationships between (and among) people and places, beyond food flows (Blay-Palmer et al. 2018).
Across the several approaches and operative definitions of sustainable food systems (Blay-Palmer et al., 2018; Born & Purcell, 2006; Ericksen, 2008), one of the most proposed approaches to advance in this direction is the City Region Food System (CRFS). It is defined by the Food and Agriculture Organization of the United Nations (FAO) and the Resource Centre for Urban Agriculture and Food Security (RUAF) as *'an approach aimed to foster the development of resilient and sustainable food systems within urban centres, peri-urban and rural areas surrounding cities by strengthening rural-urban linkages'* (FAO & RUAF, 2015). As a result of the globalisation process, city-regions represent major places of agglomeration of goods, while at the level of social dynamics, stakeholder groups lobby for their rights, beyond the economic growth (Arthur et al., 2022). Envisioning a single network of all the urban, peri-urban and rural linkages of food consumers, producers, suppliers and processors operating in a given city-region, the CRFS approach is largely recognized for shaping a sustainable environment able to provide accessible, affordable, safe and nutritious food (FAO & RUAF, 2015).
In this respect, CRFS performances are assessed through several indicators for six areas of intervention, namely social, economic and environmental sustainability, urban-rural integration, governance and resilience (Carey & Dubbeling, 2017), which have been applied for evaluating different city-regions at global scale (Chappell et al., 2016; Forster and Escudero 2014). Nevertheless, literature does not yet offer consistent evidence of a sustainability performance of CRFS that combines Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (S-LCA) methodologies, only providing partial or alternative integrations. For example, Stillitano et al. (2021) stated that most case studies implement a stand-alone LCA to specifically evaluate the benefits and impacts of circular economy strategies in the context of agri-food activities. Few studies combined LCA with the LCC approach, and none dealt with S-LCA. Single attempts proposed to integrate LCA and LCC approaches to specifically address a sustainability evaluation of a CRFS (Sanye-Mengual et al., 2018). However, the environmental and economic impact categories considered did not provide a comprehensive assessment analysis, as they focused on specific aspects. Furthermore, some multi-criteria assessment methods were designed to assess the sustainability of farms, but the literature has pointed out that these tools are largely unsuitable for multifunctional CRFS initiatives since they focus on agricultural activities and production and fail to consider non-

agricultural activities (Barbier and Lopez-Ridaura, 2010). Some assessment methods have been designed specifically for urban agriculture, but the focus is mostly on the environmental pillar (Langemeyer et al., 2015; Lin et al., 2015; Petit-Boix and Apul, 2018; Wang and Pryor, 2019), disregarding social and economic consequences. Others have been designed without the stakeholders' involvement (Corvo et al., 2021) or not testing it to case studies (Ivo de Carvalho et al., 2022).

Moreover, despite the validity of those approaches in identifying areas of intervention at a territorial scale (Armendáriz et al., 2016; Blay-Palmer et al., 2018), most of them were built on data gathered at city-region level, and not at the initiative level. Especially, they did not discriminate against punctual variances within a food system and could not account for individual stakeholders or local variances (e.g., different districts or enterprises). Additionally, they included indicators that could hardly be measured at this level, like most of the Sustainability Assessment of Food and Agriculture (SAFA) indicators (FAO, 2013) or those developed by urbanists, implemented at the city level or at best at borough level (Teitel-Payne et al., 2016; Altman et al., 2014). Furthermore, the few sustainability assessment frameworks developed at the initiative level were anyhow either looking only at one or two pillars of sustainability or a sector or specific crop and not at the CRFS itself (Dorr et al., 2021; Stillitano et al., 2021) (see also Annex-Chapter1 (A-C1) Table 1).

As a result, the literature highlighted the need for a comprehensive and systemic approach that can ensure: 1) operationalisation of the assessment at the initiative level, and 2) an adequate representation of different sustainability dimensions, including social, economic, and environmental aspects (Trachsel et al., 2018).

Hence, the present work discloses the research carried out within the FoodE project on the development and testing of an assessment scoring framework designed on Life Cycle Thinking (LCT) and builds on previous knowledge and co-design processes, to analyse the sustainability of CRFS Initiatives (CRFSI) through a single synthetic, comprehensive and coherent mechanism. As such, the simplified scoring framework is not intended to substitute a full LCA, LCC, and S-LCA assessment, but rather to be used as a scoping mechanism in the design phase of an extensive study, or as an auto scoring tool for non LCT practitioners, or as an understanding of the sustainability performances of city region environment across a different period (Deng, Peng, and Tang 2019).

1.2 Methods

Theoretical background

Starting from the CRFS definition described by the FAO & RUAF (2015), 600+ European initiatives were scouted and selected by the FoodE project to better identify the most relevant characteristics of

CRFSI, in terms of the type of organization, food-related operations, workforce, size, and relations with customers and society. The identified key features allowed to characterise European CRFSI through their key activities, relevant external and internal partnerships, impact areas, innovation strategies and collaborative attitudes. Therefore, CRFSI can be defined as profit or non-profit entities involved in the food system in strong connection with their territorial context and being in one or more of the following activities: agriculture & fishing, food processing (e.g., transformation of agricultural products into food), food distribution (e.g., wholesale, retail, community supported agriculture), food service and consumption (e.g., catering, cooking, restauration), food waste management, education and services. Their workforce is often composed of less than 10 employees, with volunteers involved in several cases. They are located in, or nearby cities or consumption centres and they bond mutual relationships with their final users, enabling the creation of rural-urban linkages. This working definition has been used as a unit for the sustainability scoring system development.

Scoring system development

Since CRFSI are characterized by a wide diversity of functions, products, and processes, the scoring system was designed to cover and assess a wide variety of activities. The requirements for the scoring system are both to allow a rapid quali-quantitative appraisal for the evaluation of CRFSI, and to develop it both for the use by experienced practitioners and by non- practitioners for a generic analysis and understanding. Despite the fact the initial scope of the scoring system is focused on the European area, it stands to be applied globally, taking into consideration several local characteristics for further tailoring and data interpretation. This means local characteristics need to be broadly explored when applying the sustainability scoring system. The backbone of FoodE methodology for the CRFSI scoring mechanism builds on three main aspects: a Life Cycle Thinking (LCT) approach, the existent knowledge and co-design processes with practitioners from different knowledge backgrounds. The former is adopted to include all three sustainability pillars in an integrated manner (Petit-Boix et al., 2017, Sanyé-Mengual, 2015). The second is based on key national and international projects on CRFS developed in recent years and the available peer-reviewed literature. The latter is based on the previous methodological experience in co-creation processes (Manríquez-Altamirano et al., 2021; López-Forniés et al., 2017; Sierra-Pérez et al., 2016), and internal and external consultation processes followed to improve the sustainability scoring system. Overall, the novelty of the present FoodE methodological development consists first in the modelling of the LCT approach on CRFSI, then in its scoring mechanisms which provide a final sustainability result, and finally in its feasibility both for LCT and non-LCT practitioners in replicating the scoring mechanism. Furthermore, as highlighted by other scientific researches, the sustainability scoring system can support city region urban policy makers and food initiatives in taking effective interventions to improve the sustainability performance of their food system (Maliene et al., 2022). The following sections describe in detail the three aspects of the methodology.

Life Cycle Thinking approach

LCT constitutes the first conceptual foundation of the sustainability scoring system (Petit-Boix et al., 2017). The evaluation of food system sustainability within city-regions implies embracing the multiplicity and complexity of supply chains, impact pathways, and affected stakeholders in different areas. This challenge can be addressed only by going beyond the global, de-localized production approach and related processes and including all sustainability pillars: social impact (e.g., labour, health, innovation); economic impact (e.g., costs, net present value, value added); environmental impact (e.g., carbon footprint, land use, water scarcity). The three pillars of sustainability are not exclusive and can be mutually reinforcing. Furthermore, promoting the territorial proximity of food supply chains represents a key element in meeting the CRFS definition and its sustainability.

Overall, the social pillar focuses on the process of creating sustainable, successful places that promote well-being, by understanding what people need from the places they live and work at (Taslis et al., 2022; UNEP 2020). The economic pillar represents a broad interpretation of ecological economics where environmental and ecological variables and issues are basic but part of a multidimensional perspective (Peña & Rovira-Val, 2020; Estevan et al., 2018; ISO, 2017). Finally, the environmental pillar concerns the human impact on nature, its ecological processes and ecosystem services provided (Hauschild et al., 2017; ISO, 2006; SETAC, 1991). These three pillars serve as a common ground for numerous sustainability standards and certification systems in recent years, in particular in the food industry (Notarnicola et al., 2017), and were used as the basis to select a set of impact categories and KPIs for the scoring mechanism.

Previous Knowledge

To focus on relevant hotspots only, impact categories and KPIs were screened based on previous knowledge. Among key projects and initiatives operated in the recent past by FoodE partners, the ones with a relevant contribution towards an integrated methodology for a sustainability assessment of food systems segments were selected. The full list of selected projects is presented in A-C1 Table 2, along with the covered pillars and the general methodology.

Some of the research projects used a more standardised methods for their indicators choice while other studies focused on the development of new indicators, especially regarding the S-LCA, for example when it came to the assessment of innovation in urban agriculture. In general, while the evaluation of environmental impacts through LCA is already standardised, its integration with other methods to include economic and social impacts of food production systems has been tackled in a variety of ways, and it calls for a more integrated approach, to be eventually generalised for CRFSI.

To integrate previous projects, a literature review of the integrated Life Cycle Sustainability Assessment (LCSA) of CRFS was also carried out using the keywords '*life cycle sustainability assessment**' and '*food**' on the Scopus database to derive an overview of current knowledge, possible indicators, and assessment methods. A-C1 Table 2 summarizes the relevant works along with information on pillars, general approaches, and methodologies.

This literature was used in combination with knowledge from previous projects to derive an overview of existing tools and indicators that constitute the base of the sustainability scoring system. The initial design step included the most common of these indicators to then start an iterative participatory consultation for the final sustainability scoring system development.

Co-design process

The involvement of a variety of stakeholders had a key role to support the development of the integrated assessment methodology and was deemed necessary to deliver a consistent mechanism, translating the complexity of sustainability to clear and manageable metrics.

To this aim, coherently with the Citizen Science and Responsible Research & Innovation principles (Robinson et al., 2018) a participatory approach was adopted to co-design the scoring mechanism. The participatory consultation was conducted in four main steps and included multiple hierarchical levels. An opportunistic approach was applied to co-create indicators and set-up the scoring system (Winjberg, 2000) involving various experts in the field of food system sustainability. Then, the principle of completeness was applied (Geibler et al. 2006) in the co-design session aimed to inform and consult stakeholders. This latter approach was fundamental to find a balance between the analysis capacity that LCA tools could provide to actors and the ease of understand the results (Renouf et al. 2018). To ensure inputs from all stakeholders online and offline methodologies were used. Interactions between the different participants were elicited through focus group discussions (Belzile et al. 2012) carried out in small groups and led by design developers. It was crucial to achieve user participation in design and gather all relevant information (Yanki et al. 2008). Besides that, online tools such as Mentimeter were used to collect inputs from participants during and after the participatory activities (Zhang et al. 2018).

A first consultation step, aiming at involving the FoodE actors, was organised during the recurrent FoodE General Assembly (GA), composed by 23 partners with a wide diversity of perspectives and expertise on food systems. The GA included professors, researchers and students, food businesses, CRFSI, NGOs, professionals and municipal actors dealing with food policies.

Primarily, the first FoodE GA meeting (February 2020) served to kick-off preliminary discussion on the CRFSI definition and its sustainability dimensions. A live survey was launched and all attendees (around 68 staff members from the FoodE consortium partners) were involved in a participatory discussion. This initial activity was used to set the scene and create a common vocabulary on food system sustainability. In particular, participants were asked what adjectives could describe the CRFSI with which a word cloud was created based on the word frequency. After compiling the database of CRFSI in Europe, half a year later during the third FoodE GA meeting (July 2020) a second online session was organised. It consisted in a simplified participatory review to get feedback on the most effective Key Performance Indicators (KPIs) to be used when measuring sustainability and on the relative selected questions needed to investigate them. The KPIs were selected on the basis of a literature review to identify key indicators for environmental, social and economic analysis. The project partners were asked to rank the KPIs according to the City Region Food System framework defined in the first participatory activity. The results were used to design the KPIs and the relative questions.

A second consultation step on the sustainability of CRFSI was developed during the FoodE Winter School (February 2021), an online event organised by FoodE with the participation of around 50 individuals (both within and outside the FoodE consortium). The winter school was elaborated on purpose to simultaneously obtain awareness creation and stimulate participatory co-design for the assessment indicators. The involved arena included young and senior researchers, students, and professors, interested in the food system sustainability evaluation. A total of 18 organisations from 7 different countries (Spain, Italy, France, Germany, Netherlands, United Kingdom and Norway) were involved in the FoodE Winter School either as participants, speakers or organizers. Within the workshop, participants were involved in two afternoon sessions on the environmental and on the integrated economic-social assessment, respectively. The different working groups were set up to share expertise in a mixed way across the different discussion tables to ensure multidisciplinary knowledge sharing. This activity was used to test the sustainability scoring system on different CRFSI thus stimulating participants to offer their views and experiences. The feedback was collected with a focus group discussion with the participants of the workshops and then output used to achieve the final version of the mechanism.

The third consultation step assessed the relevance of the KPIs, and the availability of the data explored in the survey by involving the member of the stakeholder board established in the different FoodE related regions. The scoring system was carried out by means of a Likert scale from 0 to 5 and the questions with the lowest score were modified or deleted to improve the response rate and the clearness of the methodology. The stakeholder board is composed by a variety of 102 geographically distributed bodies across Europe, including NGO, schools, CRFSI, public administrators (PAs) and policy makers, citizens and researchers to support the definition of the priorities at local level. The detailed composition of the FoodE stakeholder board participants is showed in Table 1.1

Table 1. 1 FoodE stakeholder board composition

Country	PAs	Schools	CRFSI	Civil Society	Researchers	Total
France	2	2	2	2	2	10
Italy	1	8	5	4	1	19
Netherlands	0	2	3	0	1	6
Norway	1	1	1	0	0	3
Romania	0	2	6	0	1	9
Slovenia	1	2	1	1	0	5
Spain	8	19	3	5	3	38
Germany	2	1	0	3	3	9
Other	0	0	3	0	0	3
Total	15	37	24	15	11	102

The final consultation phase involved only experts and consisted in a final round of participatory revisions from around 15 well-recognised researchers working specifically on the sustainability of the agri-food sector. Starting from the finalized survey, a methodological refinement was advanced. Professionals from fisheries, growing systems and animal husbandries were asked to verify whether the system structure was appropriate for respondents and if the required information was likely to be measured and shared by the respondents. Discussions were organised online, both on a bilateral basis and as a mixed working group and results were used to revise the survey.

The final feature of the approach was the validation of the sustainability scoring system. This phase aimed at ensuring its applicability and at validating the data collection protocol. Also in this case, the involvement of relevant experts and stakeholders played a crucial role. Experts and researchers addressed in the co-design and participatory consultation provided various feedback on the efficacy, the detailedness and the clearness of questions. Five selected CRFSI owners were involved in testing the final survey. They were asked to answer the various questions and then to provide feedback on comprehensibility, duration, and ease of response.

Testing

The indicators have been then tested on 100 case studies in 10 European countries involved in the European project H2020 of FoodE. The scope of this specific phase was to identify potential strengths, opportunities, and weaknesses of the sustainability scoring system rather than to assess the performances of a representative sample across Europe. Hence, for the data collection, data from each CRFSI was collected through the dissemination of an online survey on Qualtrics. A complete description of the survey is included in A-C1 Table 3. Data collection took place from July 2021 to December 2021.

The results of the testing have been analysed and processed individually. A Microsoft Excel Spreadsheet Editor was first used to process collected data from Qualtrics into a spreadsheet. In a second step, R programming language for statistical computing and graphical representation was used to run calculations and process and visualize data.

1.3 Results and discussion

Sustainability scoring system

The Sustainability scoring system resulting from the described process is detailed below. All three pillars resulting in Impact Categories (IC), KPIs and description and unit of measurement are described in Table 1.2.

For the social pillar, the focus of the IC is on i) the job opportunity at CRFSI level, ii) the embedment in the community, and iii) the quality and safety of their food. For SocIC1 the number of jobs, compensation, workforce composition, training, and gender equality factors are considered. In particular, as for the job compensation, intended as the average gross monthly salary, the ranges included are related to the average salaries of the European Union in 2020 (Eurostat, 2022; Eurostat 2021). For SocIC2, the direct social impact is closely related to the engagement of certain demography, and it is measured in the number and type of events organised or even community training opportunities. Finally, SocIC3 are included ranging from food perception factors (e.g., appearance, texture, and flavour) to external food attributes (e.g., price, animal welfare degree).

For the economic pillar, the focus of the IC is on i) the general profitability and business's future outlook, ii) the embeddedness of CRFSI within the local economy, and iii) the customer and users profile. The EcoIC1 includes profit margins, revenue diversification (e.g., product revenue, activity revenue or other forms of income such as public or private funding) and business's future outlook. The The EcoIC2 is proxied by assessing the locally sourced supply and labour, as well as fair practices towards suppliers. The EcoIC3 is analysed to evaluate citizens' and consumers' fidelity, relationships, and habits.

Finally, the environmental pillar the focus of the IC is on i) the food production supply, ii) resource use efficiency, iii) waste management & circularity and, iv) transport. The EnvIC1 entails elements such as the typology of technology used for crop production, the animal feed provenance, the typology of fishing gears, the inclusion of agricultural biodiversity measures, and food characteristics. The EnvIC2 refers to the use of different resources, such as water, electricity and heating. The EnvIC3 is composed by waste production and measures to reduce or reuse waste. Finally, the EnvIC4 is related to food logistic from suppliers and to consumers.

Table 1. 2 Social, economic and environmental Impact Categories, Key Performance Indicators with the code, the description and unit of measure

Social					
Impact category	**Code**	**KPI**	**Code**	**Description**	**Unit**
Job (quantity, quality, diversity)	SocIC1	Waged jobs	SocKPI1	The number of employees that receive a salary	N of full time and part time paid employees
		Contract typology	SocKPI2	The prevalent typology of contracts within the organisation	Degree of fixed term/temporary contracts
		Average gross monthly salary	SocKPI3	The average monthly gross wage received by employees.	€/employee
		Workplace Trainings	SocKPI4	The frequency of workplace trainings per employee	Hours/ year/employee
		Gender equality	SocKPI5	Share of female waged employees over the total number of employees	%
Community outreach, engagement & education	SocIC2	Frequency of events	SocKPI6	Frequency of events organised by the initiative for the local community.	frequency /year
		Disadvantaged people	SocKPI7	Activities for the disadvantaged people of local community	Y/N
		Connection with local producers	SocKPI8	Management of food coming from local producers.	Y/N

		Volunteering activities	SocKPI9	Involvement of community people in volunteering activities	Y/N
Food quality	SocIC3	Product characteristics	SocKPI10	Taste, freshness, healthiness and nutritional quality, availability, affordability and fair price, animal welfare, food safety, food chain fairness, variety of food offered, being local, environmental sustainability	Importance degree
Economic					
Impact category	**Code**	**KPI**	**Code**	**Description**	**Unit**
Organisation profitability and outlook	EcoIC1	Annual net profit margin	EcoKPI1	Annual net profit margin in positive or negative percentage	%/year
		Income diversification	EcoKPI2	The revenue produced by product sales, organised activities, and funding received from the public and private institutes	%/year
		Business future	EcoKPI3	Expectancy on the change of the business for the upcoming 3 years relative to product sales, other revenues, profits and number of customers/clients/users	Degree of change
Local economic development	EcoIC2	Provenance of employees	EcoKPI4	Area of provenance of the waged employees	Administrative levels
		Locally sourced supply	EcoKPI5	Supplies sourced locally (from suppliers within a distance of maximum 50 km from your venue)	%
		Suppliers' practices	EcoKPI6	The presence of specific fair practices toward suppliers	Y/N
Customer and users	EcoIC3	Customers/ Users acquisition	EcoKPI7	New customers or users per year	Degree level
		Customers/users return	EcoKPI8	Quantity of customers coming back after the first time	Degree level
		Customer/user expenditure	EcoKPI9	Expenditure increases of each customer/user	Degree level
		Customers/users return reason	EcoKPI10	Quantity of customers/users coming back because recommended by others	Degree level
		Online selling	EcoKP11	Presence of online selling channels	Y/N
Environmental					
Impact category	**Code**	**KPI**	**Code**	**Description**	**Unit**

Food production/ supply	EnvIC1	Technology used for crops	EnvKPI1	The technology used for the crops produced, managed or sold	Typologies
		Animal fed provenance	EnvKPI2	The distance of the meat feed produced, managed or sold	Distance degree
		Fishing Gear types	EnvKPI3	Gear types used for the fish produces, managed or sold	Typologies
		Ancient cultivar or local breed	EnvKPI4	Cultivation, management or sell of ancient cultivar and local breed	Y/N
		Characteristics of the products	EnvKPI5	The preferences on some specific characteristics of the food produced, managed or sold	Importance degree
Resource use efficiency	EnvIC2	Water saving practices	EnvKPI6	Importance of water saving practices	Importance degree
		Electricity sources	EnvKPI7	Typology of electricity used	Renewability degree
		Heating sources	EnvKPI8	Typology of heating used	Renewability degree
Waste management & circularity	EnvIC3	Waste recycling	EnvKPI9	Amount of recycled waste according to each waste typology	%
		Sustainability commitment	EnvKPI 10	The commitment towards the adoption of a set of practices regarding energy, water, organic waste, materials and packaging	Commitment degree
		Packaging and materials recyclability and compostability	EnvKPI 11	The usage of composable and recyclable packaging and materials.	Recyclability and compostability degree
		Packaging and materials reusability	EnvKPI 12	The usage of reusable packaging and materials.	Reusability degree
Transport	EnvIC4	Distance from clients/ customers	EnvKPI13	The distance between the initiative and key clients/customers	km
		Type of transport to clients/ customers	EnvKPI14	The type of transport used between the initiative and key suppliers.	Degree of Fossil fuel employment
		Type of transport of supplies	EnvKPI15	The type of transport used between the initiative and their supplies.	Degree of Fossil fuel employment

Testing

To move each KPIs into metrics for the online scorable survey, these were translated into three types of questions (see A-C1 Table 3):

1. Binary question (yes/no), where the no option corresponds to the lower sustainable solution (1 point), and the yes option to the most sustainable one (5 points).
2. 5-points Likert scale with 5 options as answers. The options correspond to a score going from the least sustainable solution (1 point) to the most sustainable solution (5 points). In one of these questions (Q2.4), the '*I don't know* was included as a third one on the scale, with a score of 3 points. This is because, for that kind of question, the lack of related information was considered an indicator of not optimal monitoring of the process and hence of an average CRFSI performance.
3. Set of open questions, whose answer range couldn't be defined after the testing in a consistent way. The choice was established during the co-design approach to leave to the testing phase the responsibility of establishing the quantitative ranges that would lead to Likert-type scoring. These questions are Q1.1, Q1.4. Q2.1. The scored mechanism rationale behind these questions is developed given the percentiles of the cumulate answers considered in the testing phase. It means that answers in the first percentile are meant to be assigned with a score of 1 and answers in the fifth percentile meant to be assigned a score of 5 with the central values following the same reasoning.
4. Other questions (namely Q3.1), in which the respondent was given a list of 11 sustainability strategies from which he/she could choose. The scoring was then based on the number of strategies selected (e.g., 1 to 2 was assigned 1 point, 3 to 4 was assigned 2 points).

Given the necessity to build a scoring system applicable to a large set of CRFSI, active in very different segments of the food supply chain, we foresaw the possibility of two questions being not applicable to a CRFSI. In that case, the choice to include the '*I do not produce, manage or sell'* option as a central value in the scoring scale was taken. These questions are Q3.2, Q3.3.
Additionally, for each sustainability pillar, an additional blank space was included to allow CRFSI respondents in discussing additional points recognized as important and helping the contextualization of results. The overall sustainability scoring system is then obtained by aggregating the different points. To guarantee a parallel weight to all KPIs, impact categories, and sustainability pillars, the points of each question are weighted accordingly to the number of questions in the relative KPIs. In turn, the points of each KPIs are weighted accordingly to the number of KPIs in the relative sustainability pillar.
In doing so, each pillar results in a final score between 1-5 which is then aggregated with the remaining sustainability pillars to compose the final single sustainability score for each CRFSI

(always from 1-5). Based on the scoring mechanism, the highest scores (5) correspond to the best sustainability performances, whereas the lowest values (1) are associated with the lowest integration of sustainable choices. Results need to be interpreted both on individual KPIs, on each sustainability pillar, and on the overall integrated sustainability degree level. The sole analysis of the single score is highly discouraged, as it is intended only as a synthetic measure and for dissemination purposes. The distribution of surveyed 100 CRFSI for testing is described in Figure 1.1.

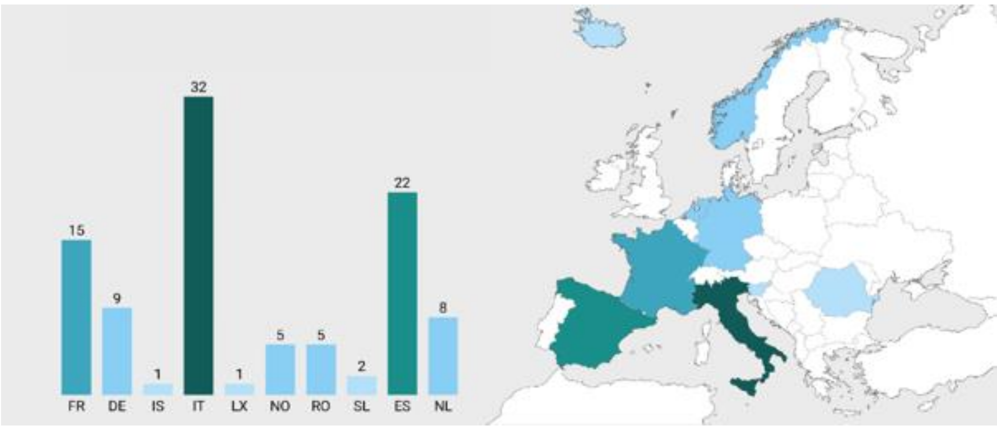

Figure 1. 1 Geographical distribution of the 100 surveyed City Region Food System Initiatives (CRFSI) across Europe

Figure 1.2 and Figure 1.3 show the total sustainability score and the score per pillar of the 100 CRFSI tested, on average and in different countries. Overall, the single average score among the three sustainability pillars is 3.30±0.36. Considering the 1-5 scale, this means that the sustainability of CRFSI is on average above the medium level, with only a few outliers having low performances (e.g., 2.18 and 2.31).

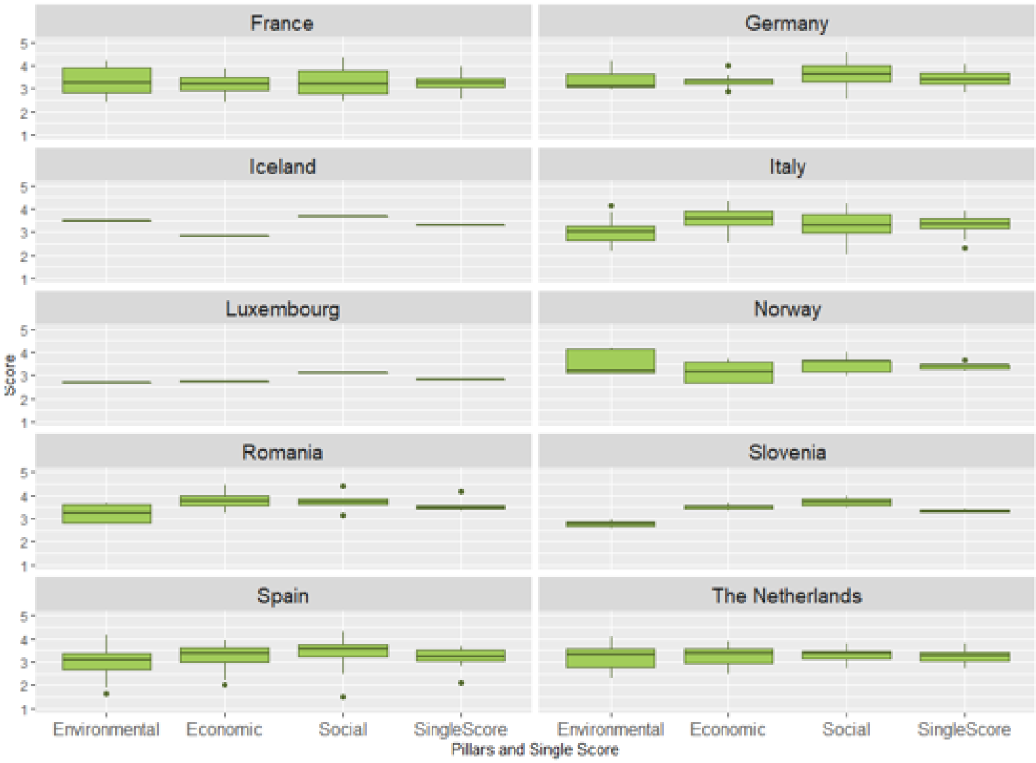

Figure 1. 2 Pillars and single score for the surveyed City Region Food System Initiatives CRFSI accordingly to Countries (n=100)

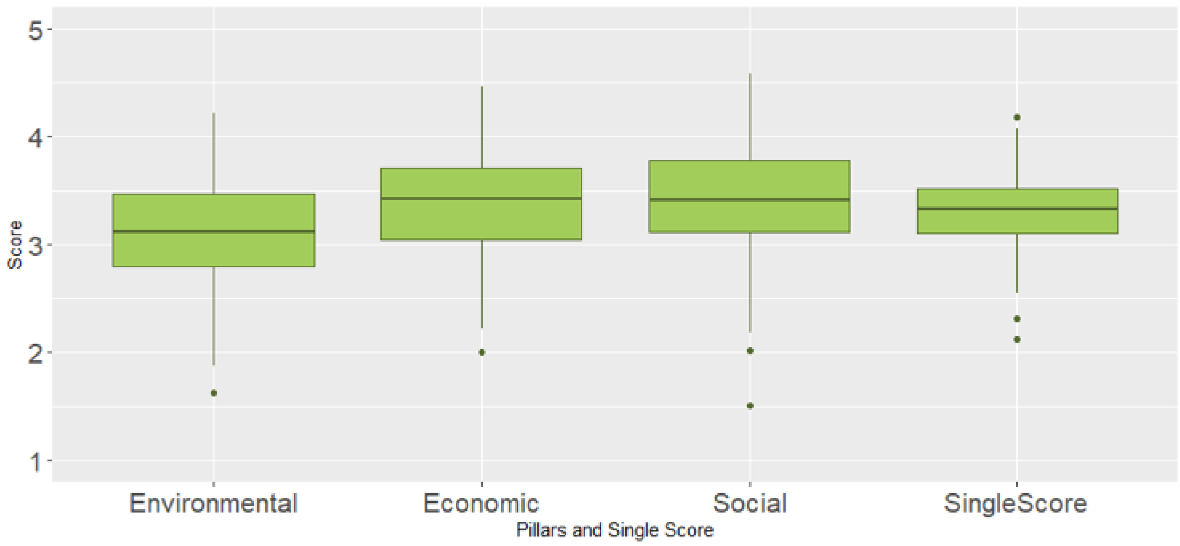

Figure 1. 3 Pillars and Single score for the surveyed CRFSI (n=100)

The scoring results of pillars and single score is quite consistent across different countries, with Germany, Romania, and Norway having a slightly higher than average score. The environmental scoring (3.15±0.10) is on average lower than the economic and social one (3.37±0.09 and 3.39±0.11). In this case, differences among countries are more evident (see Fig. 2), probably due to the diverse typologies of CRFSI involved and the number of responding CRFSI for each EU country.

Social Dimension

Figure 1.4 shows the average scores for the 3 Impact Categories (IC) of the social pillar. The highest score is related to the *'food quality'* (soclC3) having a value 4.10±0.15. This is followed by the social category *'job'* (quantity, quality, and diversity) (soclC1) (3.07±0.15), and by the '*Community outreach, engagement & education'* (soclC2) (3.00±0.21) even though the values are quite close.

The comparison of three IC (Figure 4) in the box plot shows that IC *'Job'* (soclC1) and *'Community outreach, engagement & education'* (soclC2) are similar on average even though the latter presents a higher level of diversity on the answers. However, the SocIC2 results are more heterogeneously distributed across the median, probably due to the very different settings of the tested CRFSI. The above-average results of this pillar is attributed to IC '*Food quality'* (SocIC3), which also presents the lower answers variability. Such result is explained by the relevance of the food quality concept (Sadilek, 2018) that led consumers/users to a overall consensus on the importance of it.

In general, for the social IC, as the Standard Deviation (SD) shows (0.57) concerning its average (3.39), it can be observed that the answers do not present a high level of variability.

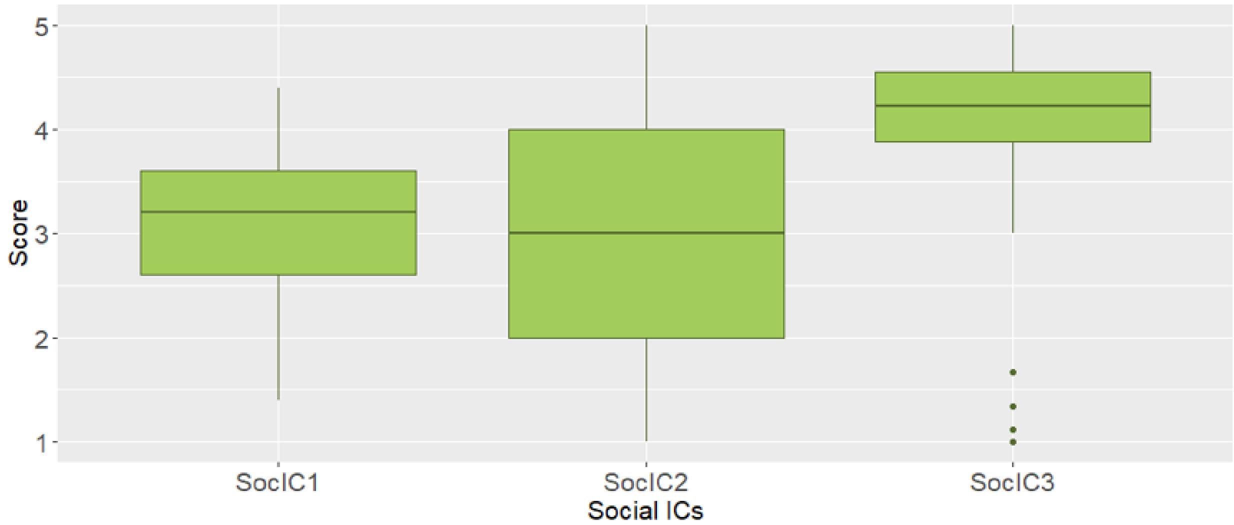

Figure 1. 4 Social Key Performance Indicators (KPIs) scoring for the surveyed CRFSI (n=100)

When analysing scores related to KPIs (Figure 1.5) for each social ICs, it is possible to get a more detailed understanding of the specific drivers of impact in each category. The highest average score is related to *'Product characteristics'* – 4.10±0.15 (SocKPI10), which is the only KPI in the IC *'Food quality*' (soclC3). This result highlights that for CRFSI owners the most important characteristic of their products is the item of *'Taste and freshness'* with an average score of 4.56±0.18. Furthermore, it is important to highlight that '*Local*' and '*Environmental sustainability*' items are the second most important information that CRFSI owners want to communicate to their customer segment with the same average score of 4.40±0.15.

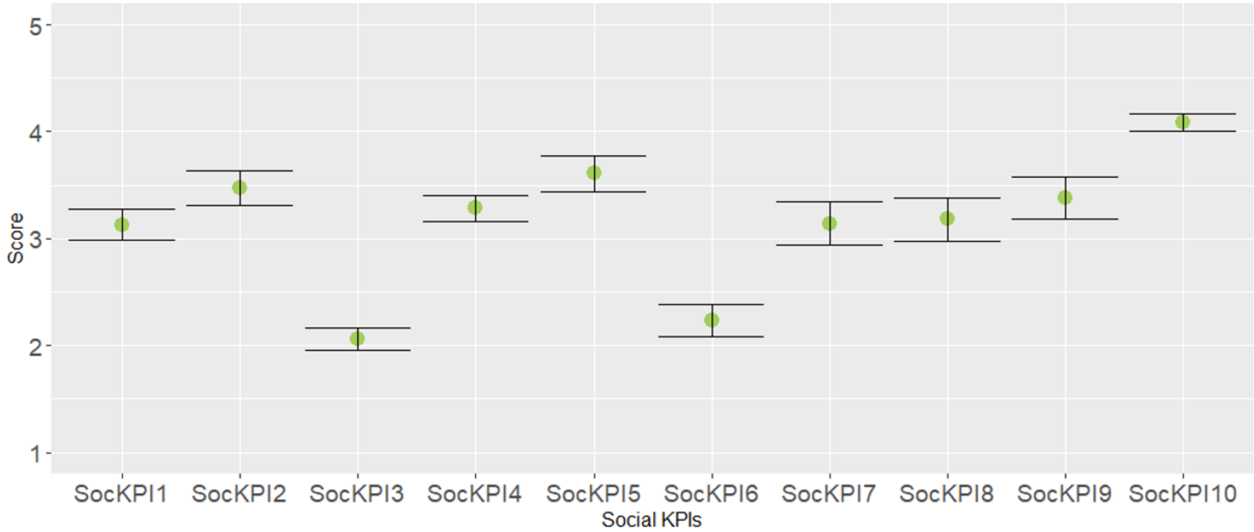

Figure 1. 5 Social Key Performance Indicators (KPIs) scoring for the surveyed CRFSI (n = 100)

While the second most important social KPI is SocKPI5 *'Gender equality'* – 3.57±0.33, related to the IC *'Job quality'* (soclC1). This result shows the proactive approach of CRFSI on the management of gender equality in the workplace. It must be noted that gender balance is proxied by the share of women in the workplace, without considering nonbinary individuals as well as qualitative or income-related aspects of gender balance.

However, the low score of SocKPI3 *'Average gross monthly salary'* – 2.05±0.20 means that CRFSI provide a relatively consistent job opportunity to both women and men, with permanent positions, trainings, but with a relatively low salary.

While concerning the IC *'Community outreach, engagement & education'* (soclC2), it is possible to argue that higher scores are derived from SocKPI9 *'Volunteers' activities'*– 3.42±0.38, and *'Disadvantaged people'* (SocKPI7 – 3.18±0.39), and the SocKPI8 *'Connection with local producers'* – 3.18±0.39. Interesting to analyse is the SocKPI6 *'Organization of outreach events'* – 2.22±0.28 which show a low score result and it is clearly affected by the limitations imposed for the spread of Covid-19.

<u>Economic Dimension</u>

Figure 1.6 shows the average scores for the 3 IC of the economic pillar which presents the lowest variability across indicators. The highest score is related to the '*Local economic development'* (EcolC2) with a value of 3.51±0.19. This is followed by the '*Organization profitability and outlook'* (EcolC1) (3.31±0.14), and then by the '*Customers and users*' (EcolC3) (3.29±0.12).

The box plot in Figure 6 shows that all three IC are similar on average even though EcolC2 presents a higher level of diversity in the answers. Given the great diversity of CRFSI, the definition and evaluation of the local dimension for CRFSI might differ significantly (Forster et al., 2015). There is not a common standard definition for short distances in food supply chains, especially for the diversity of CRFSI (Belletti & Marescotti, 2020). As a consequence, the set distance of 50 km for the EcoKPI5 'Locally sourced supply' results (e.g., fishery related CRFSI) do have different significance depending on the location of each CRFS. However, it can be noted that in general, for the economic IC, the answers do not present a high level of variability (3.37 ±0.47).

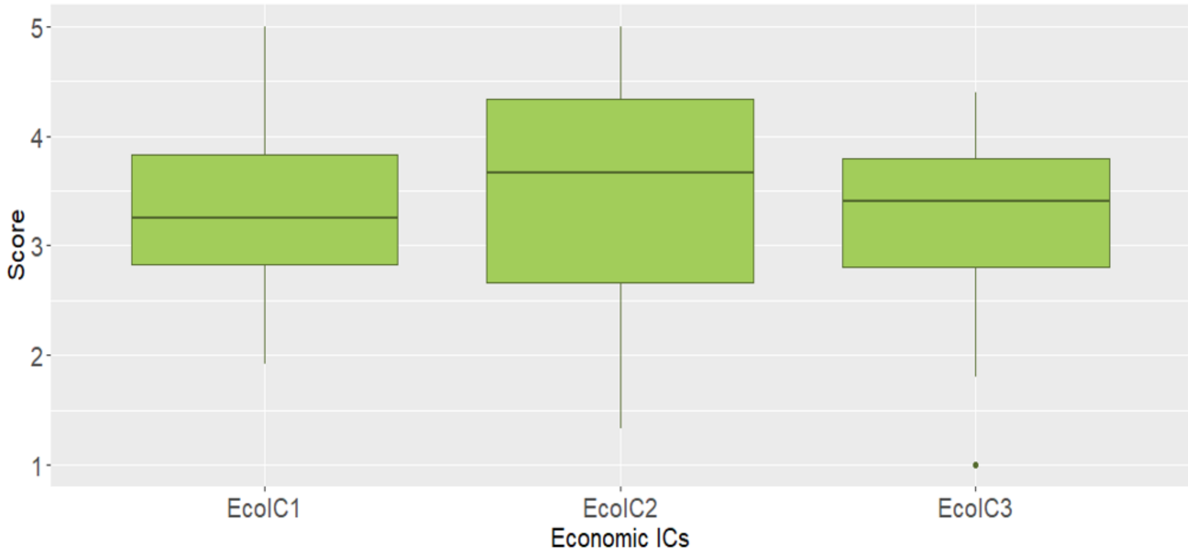

Figure 1. 6 Economic Impact Categories (IC) scoring for the surveyed CRFSI (n=100)

When analysing scores related to KPIs for the economic ICs (Figure 1.7), it is possible to get a deeper understanding of the specific drivers of impact. The highest average score is related to EcoKPI3 '*Business future*' – 3.82±0.13, which is one of the three KPIs for '*Organization profitability and outlook*' (EcolC1). A deeper overview of this economic KPI highlights that for CRFSI owners the most important change in their Business in the next three years will be the '*Number of customers/clients/users*' with an average score of 4.04±0.16. In addition, also the other items '*Product sales*', '*Other revenues*', and '*Profits*' have a high average score (3.90±0,18; 3.65±0,16; 3.67 ±0,16). It means that most of the CRFSI owners are quite optimistic about the future even with the spread of the COVID-19 pandemic.

Most CRFSI assessed their outlook quite positively in terms of sales, revenues, profits, and customers. A medium score of EcoKPI1 '*Annual net profit margin'* – 3.21±0.25 is reported, while a slightly lower than average value for EcoKPI2 '*Diversification of income'* – 2.92±0.29 is registered.

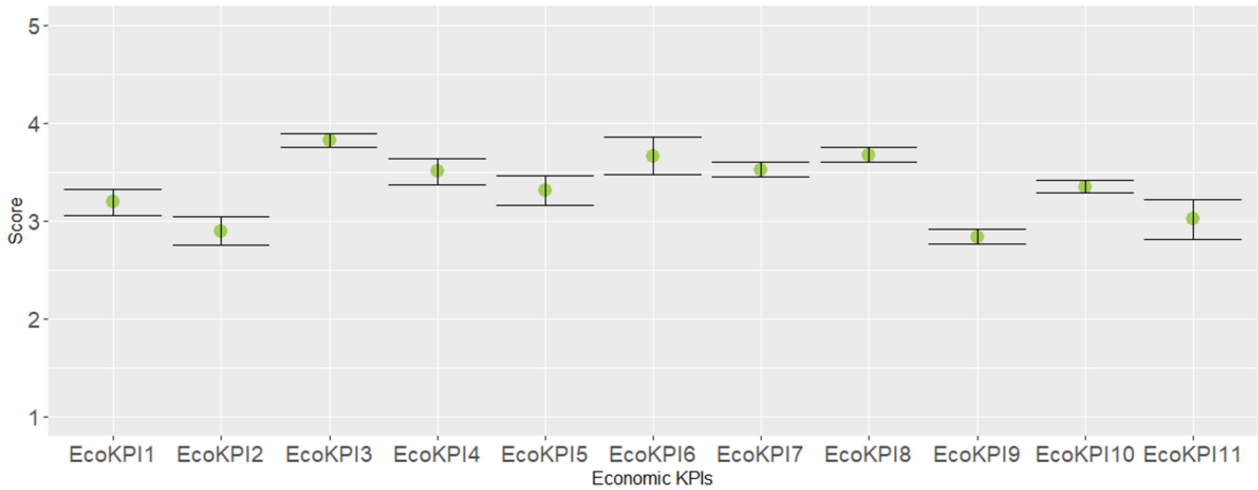

Figure 1. 7 Economic Key Performance Indicators (KPIs) scoring for the surveyed CRFSI (n=100)

As mentioned, ties to local economies are demonstrated by the consistently high scores in all EcoKPI4-6 for the EcolC2 (‘*Provenance of employees', ‘Locally sourced supply', ‘Suppliers' practices*’), in particular when it comes to the adoption of fair practices towards suppliers.

The positive outlook in terms of customers (EcolC3) is confirmed by the scores related to EcoKPI7 ‘*Customers/users' acquisition*’ – 3.53±0.15, and EcoKPI8 ‘*Return rates*’ – 3.67±0.15 thanks to the positive effect of the word of mouth (see EcoKPI10 ‘*Customers/users return reason*’). However, their expenditure does not tend to increase (see EcoKPI9 ‘*Customer/user expenditure*’). Finally, as far as online selling is regarded, the average score suggests that such a channel typology is adopted only by 50% of CRFSI.

<u>Environmental Dimension</u>

Figure 1.8 shows the average scores for the 4 IC of the environmental pillar. The highest score is related to *‘Waste management and circularity'* (EnvIC3) having a value of 3.76±0.68. This is followed by the environmental category *‘Resource use effi*ciency’ (EnvIC1) (3.21±1.01), and ‘*Food production/supply*’ (EnvIC2) (2.99±0.62) and ‘*Transport*’ (2.63±1.22) (EnvIC4), having the lowest score with the greatest SD.

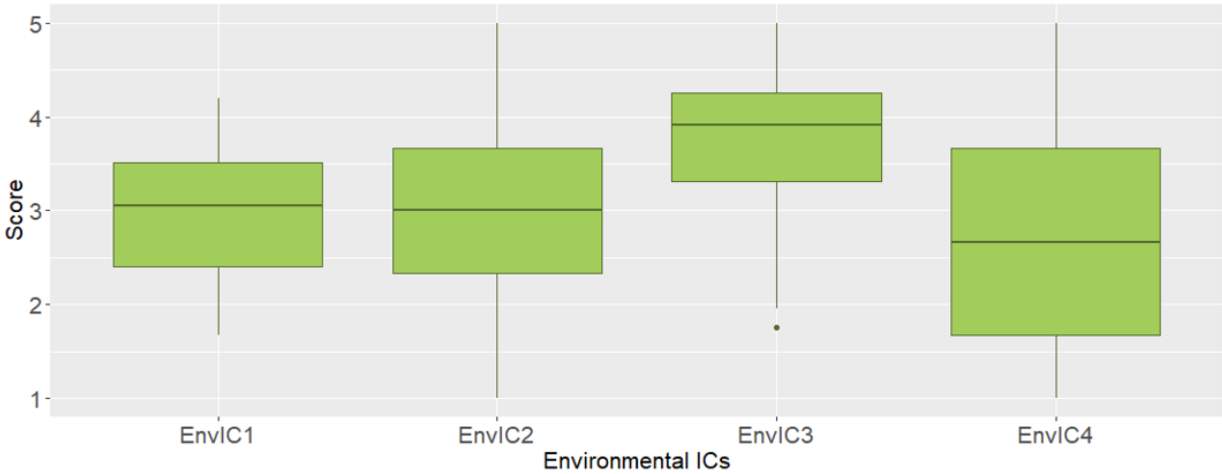

Figure 1. 8 Environmental Impact Categories (IC) scoring for the surveyed CRFSI (n=100)

The comparison of the four environmental IC in the box plot shows that EnvlC1 and EnvlC2 are similar on average even though the latter presents a higher level of diversity on the answers (1.01 compared to 0.62). When we look at the environmental single pillar score (3.15±0.53), the SD shows lower value than the one obtained in the four environmental IC.

When analysing scores related to environmental KPIs in Figure 1.9, it is possible to get a deeper understanding of the specific drivers of impact. The highest average score is related to EnvKPI6 ‘*Water saving practices’* – 4.11±1.16, which is one of the three KPIs for ‘*Resource use efficiency*’ (EnvIC2). This score is more than 1 point above the other two KPIs of EnvIC2, i.e., EnvKPI7 ‘*Electricity sources*’ – 2.67±1.40, and EnvKPI8 ‘*Heating sources*’ – 2.85±1.63. These two latter KPIs are among the lowest scores across the environmental KPIs. Such a result reveals that CRFSI still use more fossil fuel energy resources than renewable ones. However as highlighted by Gielen et al. (2019) the adoption of more energy efficient infrastructures and equipment can be more effective than using renewable energies. Such a topic has been already investigated also by the work of Amory Lovins (2019) in which the authors show the huge impact that energy saving technologies had on overall energy consumption in the last 30 years as compared to the adaptation of renewables energies (Michael P Totten. 2020).

The other environmental scores above 4 are obtained by EnvKPI5 ‘*Characteristics of the products*’ –4.07±1.07, and EnvKPI9 ‘*Waste recycling*’– 4.07±1.07.

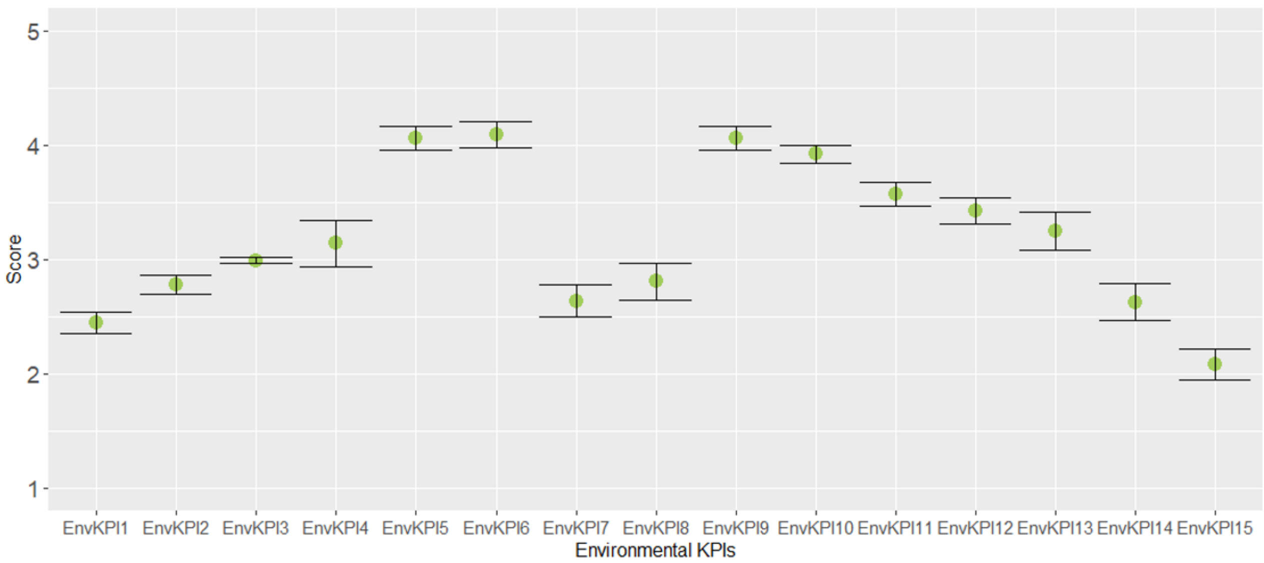

Figure 1. 9 Environmental Key Performance Indicators (KPIs) scoring for the surveyed CRFSI (n=100)

On the IC '*Food production/supply*' (EnvIC1), the EnvKPI1 '*Technology used for crops'* – 1.98±1.16 is one of the lowest-scoring indicators for the environmental pillar. This score was obtained from the sum of the possible technology strategies implemented by the CRFSI. The greater the number of strategies, the higher the score. However, since the CRFSI represent various sectors of the food supply chain and they are small and medium size activities by definition, the result reveals the difficulty in adopting multiple technological strategies at once. Furthermore, the EnvKPI1 is included in the IC '*Food production/supply*' (EnvIC1) in which KPIs scores are close between them but with a very different variability. See the EnvKPI2 '*Animal fed provenance* – 2.78±0.84, the EnvKPI3 '*Fishing gear types*' – 2.99±0.26, the EnvKPI4 '*Ancient cultivar or local breed* – 3.14±2.01, and the EnvKPI5 '*Characteristics of the products*' – 4.23±1.43. The close value of EnvKPI2 to 3 is due to the frequency of '*I do not produce manage or sell any dairy and/or eggs and/or fish*' answers in the survey sample. However, more than 20% of the CRFSI replied with a specific distance to the question, thus yielding an SD close to 0.80. The choice of kilometre distance set in the scoring system might have influenced the result. This result can both express the evidence that initiatives purchase from long-distance suppliers and/or that distances between buyers and suppliers should be better investigated on the basis of the geographical context. In the case of EnvKPI3 the value is extremely close to 3 due to the fact that almost all answers in the sample were '*I do not produce, manage or sell any fish*' or '*I don't know*', with only 4 answers with specific gear types. This is related to the low representativity of fisheries in the sample, and thus yields a value close to 3 and a low variability of answers.

The second lowest scored indicator is the EnvKPI15 '*Type of transport of supplies'* – 2.06±1.37 in the IC '*Transport*' (EnvIC4). Considering that CRFSI are located within certain urban-rural areas, it means that transport still occurs using fossil fuel means of travels. While in this EnvIC4 the best-scoring is EnvKPI13 '*Distance from clients/customers* – 3.23±1.64, understandable given that the survey was focused on initiatives level included in the CRFS. Finally, the relatively medium score obtains by the IC '*Waste management and circularity*' (EnvIC4) is also seen in its KPIs with values close to 4 in EnvKPI9 '*Waste recycling* – 4.07±1.07', and the EnvKPI10 '*Sustainability Commitment* – 3.94±0.79', and values close to 3.5 in the EnvKPI11 '*Packaging and materials recyclability and compostability* – 3.58±1.03' and the EnvKPI12 '*Packaging and materials reusabilit*y – 3.44±1.15'.

Limitations and future research needs

At the core of the CRFS approach there is the need to improve short-range food systems and strengthen rural, peri-urban, and urban linkages based on local production, low dependency on food imports and long-distance food trade (Jennings et al., 2015). As already outlined by Manning et al. (2016), scoring mechanisms can support food systems improvements in monitoring the abovementioned advancements. On this background the work proposed a sustainability scoring system where multiple indicators on the social, economic and environmental dimensions are integrated into a single score. Such integration offers an opportunity to obtain a sustainability performance overview which considers trade-offs between pillars and indicate the most sustainable evaluation option as suggested by Bunge et al. (2022).

The most relevant answers provided in the blank spaces of the online survey were also considered relevant for the discussion of the sustainability scoring system and reported in the A-C Table 4. Since the scoring system was designed to be as inclusive as possible for different CRFSI dealing with different steps of the food chain (e.g., food production, transportation, distribution, services) and different food typologies (e.g., meat, dairy, vegetables, fruits), some CRFSI faced challenges in answering one or more questions. Specific examples are provided by additional remarks 1-10, in A-C1 Table 4. This kind of challenge applies for instance to non-profit initiatives which tend to adopt different financial structures (Cestari et al., 2021) and informal mechanism (Medici et al., 2021). Relatively to other specific models of production, such as Community Supported Agriculture or Solidarity Purchased Groups, they might entail fixed subscriptions for members or customers (Medici et al., 2021) and a constant money collection from this financial source (see additional remarks 5-7 in A-C1 Table 4).

An additional point of interest is towards family-owned initiatives. Some of them obtained lower scoring values for the '*Job*' IC given the fact they don't employ anyone outside their family members. In some cases, they also work for self-sufficiency only (see additional remarks 11-13 in A-C1 Table 4).

It is also worth noticing that some terms used for the sustainability assessment might have been interpreted differently by each CRFSI. Some examples of how this might have influenced the CRFSI answers are provided in remarks 14-16 of A-C Table 4. Such a concern suggests that providing the respondents with standardized vocabulary explanation might have helped in standardising the answers meaning. Something similar emerged for the fishery related CRFSI. In EnvKPI3 ('*fishing gear type*'), the large share of the '*I do not produce, manage or sell''* or '*I don't know*' answers might be related to the formulation of the question related to fishing gears, which was interpreted differently from the fishers involved.

The lifespan of each CRFSI could have also influenced the final sustainability scoring. Examples refer to the workplace training or frequency of events which might be harder to organize in newly settled CRFSI. Or still, very young initiatives might have obtained lower sustainability scores in '*Organisation profitability and outlook'* IC because the initial years of activities can be particularly critical from a financial perspective (Bartz and Winkler, 2016) and because it is quite hard to forecast the business future they expect (Lisa-Marie Semke, 2020). In parallel, the total expenditure increase of customers and their return rate might also be quite difficult to be estimated at the very early stage of activity (Terpstra and Verbeeten, 2014) (see remarks 19-21 in A-C1 Table 4).

An additional point of attention refers to the fact that people answering the survey can influence the results (Stocké, 2006). In particular, as also highlighted in the additional remarks (A-C1 Table 4, Additional remarks 22,23), when the individual is not fully aware of the CRFSI functioning he or she might risk including biased data. Hence, making sure to address the adequate CRFSI stakeholder is a key preliminary issue for the quality of the assessment.

Relatively to the scoring system design, some impact categories were excluded based on prioritisation by stakeholders engaged, to ensure a reduced data intensiveness and guarantee the comparability of the results. As an example, animal welfare is considered just from a customer or user perspective while it is not investigated in terms of production systems. Similarly, stakeholders' trust is captured only through consumers. We recommend future context-based application to further explore those factors. Lastly, the cultural dimension was included in the scoring system through several KPIs disseminated in the pillars (e.g., *'Gender equality'*, *'Ancient cultivar or local breed'*, *'Products characteristics'),* rather than through an ad-hoc pillar. Still, as already highlighted by Pizzirani et al.

(2014), further efforts are needed to investigate the role of culture in sustainability assessments. Basing on these considerations, when applications of the sustainability scoring system are conducted in different contexts, stakeholders are encouraged to review and tailor KPIs basing on local characteristics.

1.4 Conclusions

Given the need of understanding and improving the sustainability performances of the food system in cities and regions from a multidisciplinary outlook, the present work aims to move in this direction. Based on the Life Cycle Thinking methodology, on the knowledge acquired from previous works and projects and on the extensive participatory approach with representatives from CRFSI, industry, government, universities, and research institutes, a sustainability scoring system for City-Region Food System Initiatives is developed. It is composed by 10 social, 11 economic and 15 environmental KPIs is one of the first of its kind to integrate the social, economic, and environmental pillars in a holistic, transparent, and accessible manner, resulting in a single sustainability scoring.

To identify potential strengths, and weaknesses, the scoring system was then tested in more than 100 case studies in ten European countries. When testing it, from a general perspective, the single sustainability average score among the three pillars (3.30 out of 5 ±0.07) of the selected CRFSI highlights a superior level from the average for the sustainability scoring. Results are characterized by a large degree of comparability across scales, and food sectors confirming the key role of the present mechanism in offering a unique innovative step for the European CRFSI evaluation. Overall, the social dimension seems to be the most high-scoring pillar for CRFSI (3.39±0.11), followed by the economic dimension (3.37±0.09) and the environmental one (3.15±0.10). However, such scores slightly vary concerning the different geographical areas investigated.

With the present work, the CRFSI stakeholders are offered an operational scoring system that guides them through the sustainability assessment process, providing science-based support for policy planning and decision making in the city and region food system domain. Within the FoodE project, this work will also contribute to support processes of business model innovations in the FoodE pilots and FoodE label certification standard, for the integrated sustainability of products. Moreover, the scoring system will be implemented in the FoodE App, to help CRFSI evaluating their sustainability performance and increase their visibility in the CRFS context. Further refinements of the sustainability scoring system will be advisable, with the contributions of stakeholders and researchers, tailoring it to capture additional CRFSI specificities, without endangering the comparability of results. Additionally, future development can strengthen its matching with the United Nations Sustainable Development Goals supporting its progress tracking by a quantitative tool.

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Chapter 2: Environmental performance of circular economy in crop-livestock systems: Coupling Integrated Assessment and Modelling with Territorial Life Cycle Assessment

Keywords: *Agent-based model, Eco-efficiency; Farming system; Land use scenario; MAELIA platform; Trade-offs.*

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Cirone Francesco, Vittuari Matteo, Catarino Rui, Therond Olivier, Salou Thibault, Loiseau Eleonore.

Abstract

Circular economy represents a promising strategy for agricultural systems to improve their environmental performance and efficiency by closing their input loops when implemented at a territorial scale. However, environmental assessment tools to quantify the impacts and potential trade-offs between territories and environmental impacts are still lacking. This paper proposes an innovative methodology to compare the environmental performance of agricultural management scenarios using circular economy principles versus a linear economic model. The general methodology relies on an original coupling between an integrated assessment and modeling and the territorial life cycle assessment to compute eco-efficiency metrics of scenarios according to a life cycle perspective. Results suggest that the circular economy strategy in territorial crop-livestock systems allows for maximizing the services provided in terms of food or economic function, while minimizing direct and indirect environmental impacts. Benefits are maximized when legume crops are introduced by arable farms to provide feeds for livestock.

2.1 Introduction

Agri-food systems are major contributors to the intensive exploitation of non-renewable natural resources, soil erosion, and loss of biodiversity (Valencia et al., 2022). Further, they are charged with a greater responsibility for greenhouse gas (GHG) emissions associated with the activities related to livestock and crop production within farm gates (14% more than the year 2000)(FAO, 2020). As required by the Paris Agreement (UNFCCC, 2015), and as purposed by the European Green Deal (Commission, 2020), a new land management system is urgently needed to mitigate the abovementioned environmental impacts.

Territory (or landscape) is increasingly being considered a relevant entry point of analysis to deal with sustainability and multifunctionality issues of social-ecological systems (Pérez-Soba et al., 2008), as it plays a fundamental role in shaping agricultural production activities (Mazoyer and Roudart, 1997; Cerceau et al., 2018). In addition, by providing several environmental land-use functions (Pérez-Soba et al., 2008), it generates social and economic impacts, such as the engagement of communities at the local level (Yue et al., 2021), and the provision of land-based production for economic development (Wiggering et al., 2003; Helming and Pérez-Soba, 2011). In this context, circular economy (CE) is gaining interest in addressing the sustainability issue of agri-food systems, as it aims to optimize the use of local resources, while minimizing pollutant emissions, and reducing the generation of residues (Moraga et al., 2019; see Schaubroeck, 2020 and Schrijvers et al., 2021 for a contrasting view).

The application of the principles of CE at a territorial scale in integrated crop-livestock systems can improve the efficiency of food production and nutrients, while reduce the negative environmental impacts (De Boer and Van Ittersum, 2018). Furthermore, the adoption of recycled biomass as low-opportunity-cost feeds or organic fertilizers can be an efficient CE strategy if applied at an optimal territorial scale, which is a site-specific context (Van Zanten et al., 2019). When cycles are closed at the territorial level, mixed farming systems can generate economic and social benefits for the surrounding communities (Burgo-Bencomo et al., 2019). However, to go beyond theoretical models and offer insights into the circular performance of such territorial agricultural systems, quantitative frameworks and metrics are still in need to be developed (Velasco-Muñoz et al., 2021).

Life Cycle Assessment (LCA) is a key approach for assessing the environmental performance of territorial systems (Loiseau et al., 2012). Initially designed to quantify the environmental impacts of products and services as per a lifecycle and multicriteria approach (Finnveden et al., 2009), LCA has been adapted to study territorial systems (Loiseau et al., 2013) and their multifunctionality. The established methodology, defined as “Territorial LCA” (T-LCA), computes two types of indicators for a given territory: i) a set of services provided by land management (e.g., waste management, transport, food production) and ii) the associated environmental impacts. By combining these two indicators, it is possible to compute the eco-efficiency ratios, which allows to grasp the extent to which services provided by the territory under study can be maintained or increased while reducing the induced environmental impacts (Seppälä et al., 2005).

To date, applications of T-LCA in agricultural areas to evaluate the environmental impacts of agricultural territory and inform local decision makers are scarce at best (Borghino et al., 2021). The lack of primary data, which are specially designed and collected from the filed for understanding and solving the research problem, for the studied territory is one of the major limitations in T-LCA. Accounting for the spatial variability of impacts in a territory due to biophysical and socio-technical heterogeneities represents a key issue in T-LCA (Nitschelm et al., 2016). To deal with regionalized data inventories of the assessment for the territorial scale, statistical analysis has been proposed to identify farm types for a specific region (Avadí et al., 2016), or the integration with GIS (Geographic Information System) to compute territorial emission factors for data inventory directly on land-use planning (Ding et al., 2020). In addition, so far, the only complete T-LCA is on water supply scenarios (Rogy et al., 2022), since no other research applied the eco-efficiency ratios by scenario comparison, which does characterize the T-LCA approach (Loiseau et al., 2013). In fact, identify and quantify functions provided by territories for planning scenarios is the other challenge for operationalizing T-LCA. To address these two specific issues, Loiseau et al. (2018) proposed integrating T-LCA with other modelling approaches, such as economic models, moving towards the integrated assessment and modeling (IAM) approach. IAM combines a variety of quantitative models to represent the functioning and interactions between different systems of different organizational levels and domains in a holistic platform (Hamilton et al., 2015). Thus, it provides a suitable modeling approach to quantify both biophysical and socioeconomic indicators (Beaussier et al., 2019). IAM has already been used to build and assess scenarios regarding changes in agricultural systems (Leenhardt et al., 2012; Therond et al., 2014); notably, crop-livestock systems (Catarino et al., 2021). To our knowledge, the integration between T-LCA and IAM approaches to deal with agriculture issues has been rarely investigated. For example, an integration between T-LCA and a partial equilibrium model was proposed to assess the environmental performance of the regional forestry sector through eco-efficiency ratios (Beaussier et al., 2022). In another instance, T-LCA was coupled with an agroeconomic supply and an agro-hydrological model to assess the environmental performance of regional and sub-regional cultivation of Miscanthus (Weik et al., 2022).

Hence, this study developed an innovative methodology that combines an IAM platform, MAELIA, and T-LCA to assess the environmental performance of integrated crop-livestock farming systems at the territorial level. Through a set of services provided by the territory under study, two different scenarios, a linear economic model and a circular one, were compared by computing the eco-efficiency ratios to obtain insights into environmental performance at the territorial scale. The feasibility of such an integrated approach is discussed based on a case study in western France comprising seven arable and livestock farmers.

2.2 Material and methods

The overall framework couples MAELIA (Therond et al., 2014) (http://maelia-platform.inra.fr/), a spatially explicit agent-based IAM platform (Catarino et al., 2021) with T-LCA (Loiseau et al., 2018) (Figure 2.1). MAELIA provides quantitative data describing farming system functioning, which is used as a primary source of data by T-LCA to quantify the environmental impact indicators provided and the corresponding eco-efficiency ratios. The approach represents a soft coupling, because no other interactions between the two modeling approaches are considered (Beaussier et al., 2019). MAELIA is a high spatiotemporal resolution agent-based platform for IAM of agricultural territories that considers socio-agroecological systems (Therond et al., 2014). It encompasses a farm-agent model coupled with a cropping system model to simulate the daily functioning of farming and cropping systems considering the specific climate, soil, rotation, and crop management of each field of each farm, in a given territory. Thus, MAELIA provides several output indicators useful for assessing farming system performance and resilience, such as input use, irrigation water use, crop yields and agricultural production, gross margin, and the workload of crop management operations.

Through this coupling, it is possible to compare the environmental performance of land management scenarios based on the services provided by the system. This section provides a brief description of the case study and the MAELIA platform, then, the general methodology is explained according to i.e. (i) goals and scope definition, (ii) data collection and interfacing between the two models, and (iii) computation of eco-efficiency.

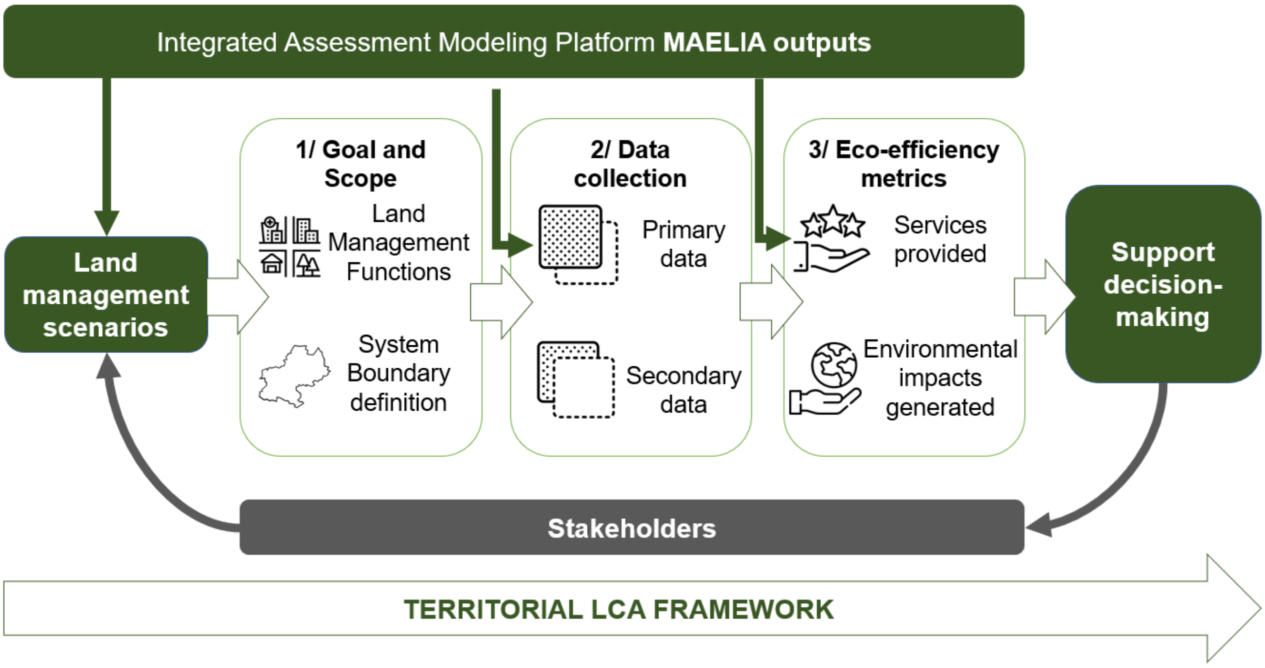

Figure 2. 1 General overview of the assessment framework based on a coupling between MAELIA, a spatial agent-based Integrated Assessment Modelling platform, and Territorial Life Cycle Assessment

Case study

Overview of the territory

The case study is located in the District of Pays de Pouzauges in Vendée, centre-west of France. This rural area is composed of farms dedicated to crops and/or livestock production. Arable land is almost entirely used to intensive cereal production, mainly wheat (63%) and grain maize (24%), while protein crops, such as fava or pea beans, occupy less than 1% of the utilised agricultural area (Chambagri, 2019). Livestock farms are specialized in dairy production, and their size ranged from 43 to 138 ha (mean 100 ± 34 ha). These values are representative of the district (Catarino et al., 2021). Within this territorial context, the case study focuses over seven specific farms, including five arable farms (i.e., AF1, AF2, AF3, AF4, and AF5) and two livestock farms (i.e., LF1 and LF2). The five AFs cultivate different types of cash crops in a rotation system (average farms size 95 ha, and average utilised agricultural area of 70 ha) while LFs produce both cash crops, crops for feed (maize silage), and milk (mixed farming system), with respectively 66 and 110 cow herds. Both AFs and LFs also manage cover crops and grasslands on their fields. Table 1 and 2 in the Annex – Chapter2 (A-C2) provide detailed information about the crops, cow's herd, yields and surface areas of each farm.

Description of the studied scenarios

Two scenarios regarding the way arable and livestock farms are linked to the global market were compared. They were defined in a previous study using a participatory approach with scientists, two agricultural advisors, and local farmers (Catarino et al., 2021). The farming and cropping system parameters required by MAELIA (see Murgue et al., 2014) to simulate the territory under study were collected through a dedicated farm survey conducted during springtime in 2019 on crop management-decision rules from 2014 to 2017 (see details in Catarino et al., 2021). LFs expressed interest in updating diet formulations for cow herds to reduce feed demand in the global market and avoid price volatility. Specifically, they wish to reduce their dependence on soya bean meal (or cake) from foreign markets by incorporating local protein sources and reducing the total cost of feeding (Catarino et al., 2021). Hence, in the current scenario (baseline), AFs and LFs behave in a linear economic system based on global market trade and do not share inputs between them. The synergistic scenario is based on circular economy principles. AFs introduce fava and pea beans (legume protein crops) into their fields to diversify their current rotation systems and prevent wheat diseases. Protein crop grains are then sold to LFs to meet the feed demand for cow meals. Agricultural advisers designed new animal feed formulations for the two livestock farmers to maintain baseline milk production, while replacing soya cakes with fava beans or peas. Accordingly, milk production did not change between scenarios. LFs provide manure as an organic fertilizer for AFs to substitute for mineral fertilizers.

Goal and scope definition

System boundary

System boundaries are defined from the cradle to territorial gates, as proposed by Loiseau et al. (2013). Figure 2.2 describes all the main activities related to farming systems included in the analysis (i.e., the foreground system). For crops, all cropping practices, including soil tillage, sowing, irrigation, fertilization, pesticide application, and harvesting were included. Breeding, milking, manure, and fodder production management were considered for livestock production systems. All activities needed to provide goods and services to farms (i.e., upstream processes) are considered outside the territorial geographical boundaries (i.e., background system) and refer to feed, fertilizers, pesticides, machinery and infrastructure, and electricity. Finally, transformation, distribution, and final consumption were beyond the scope of the analysis. For the two studied scenarios, the main difference between the system boundaries was represented by the types of inputs required by livestock. In the baseline scenario, feed and organic fertilizers in the background system were considered as inputs from the global market, whereas in the synergic scenario, these inputs came from

AFs and LFs in the studied foreground territory. Average values from 2005 to 2017 were used to assess the territorial case study.

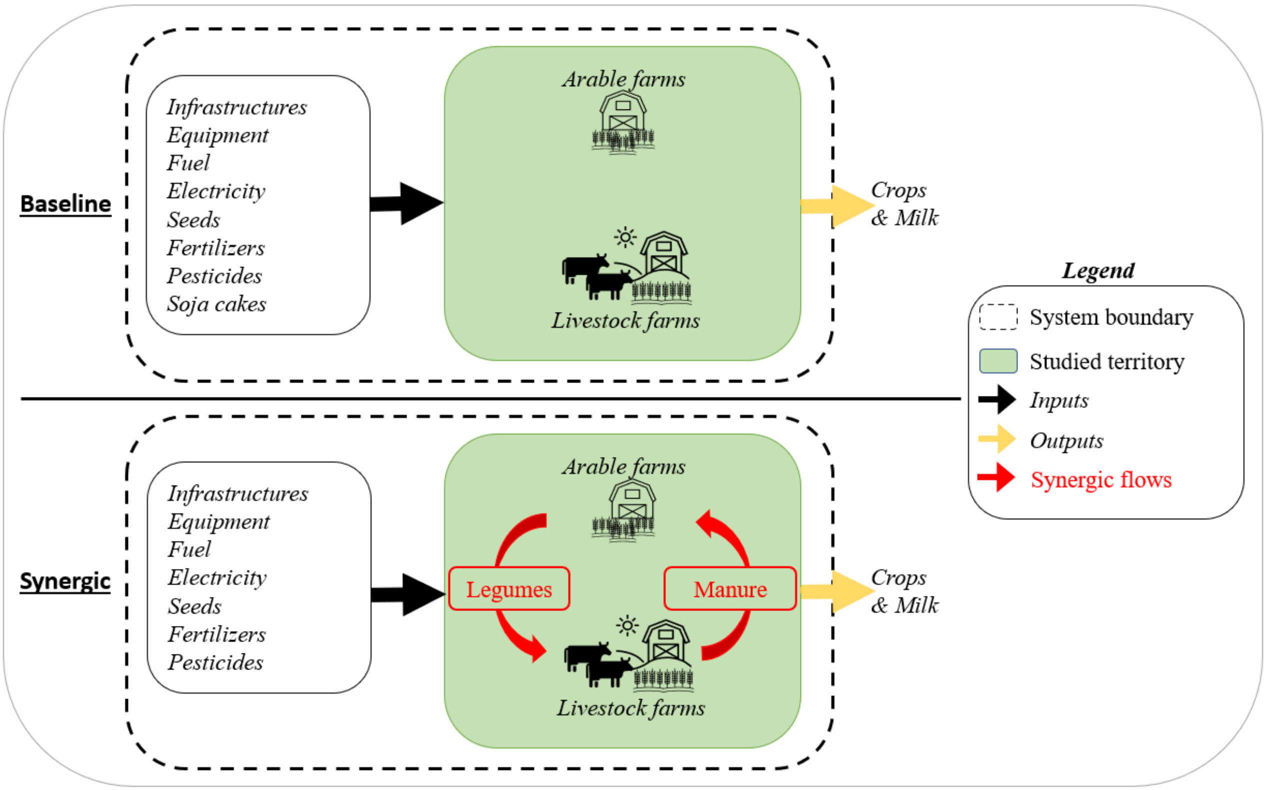

Figure 2. 2 System boundary of the baseline and synergic scenarios. The baseline scenario describes the linear production system where the studied territory receives inputs from the global market to produce crops and milk. The synergic scenario describes the circular production system where the studied territory receives part of the inputs from the global market and part of them (legumes as feed for animal meals and manure as organic fertilizers) are produced and shared within the studied territory.

Agricultural system multifunctionality

The multifunctionality of agricultural systems provides food production functions (commodities), as well as a variety of other land use functions, such as economic (income), land planning (land and resource use), and social (labor) (Wiggering et al., 2003; Rebolledo-leiva et al., 2022). Therefore, it is advisable to define several functions to assess the environmental performance of territorial agricultural systems (Nitschelm et al., 2016; Borghino et al., 2021; Rogy et al., 2022). In this study, two main functions related to wealth creation and food security were selected: i) economic profits as a source of economic livelihood, and ii) capacity to produce food (i.e., food production). They were selected based on their relevance to the scientific literature for LCA of agricultural territorial systems (Tendall and Gaillard, 2015; Rebolledo-leiva et al., 2022).

Gross Margin (GM in €) was selected as a proxy to calculate the economic profit in both scenarios. This is the assessment of overall economic returns, calculated as total revenue minus variable production costs. The variable costs for arable crop systems include the total amount of costs for pesticide and fertilizer application, whereas for livestock systems, the ingredients of the feed formula are also included.

For the overall food production function, two indicators were studied: (i) the energy content of crops and animal products (EC in MJ) and (ii) the protein content (PC in kg). EC expresses the digestible energy for animals and humans and captures the total quantity of food supplied by the system in a single unit (Tendall and Gaillard, 2015). The PC represents the nutritional quality of the food produced.

Data collection

The collection of Life Cycle Inventory (LCI) data follows a bottom-up approach and is based on two types of data: (i) primary data on quantified outputs from MAELIA, including yields and main agricultural inputs over the simulation period, and (ii) secondary data on two LCA databases, namely Ecoinvent V3 (Wernet et al., 2016) and Agribalyse 3.0 (Koch and Salou, 2020). The first database was selected because it embeds a wide range of background LCI processes and is the commonly used reference for LCA studies worldwide (Wernet et al., 2016). In turn, the second database is the most accurate LCI database for the French agricultural sector (Koch and Salou, 2020). For the livestock system, several assumptions were made to build the LCI and estimate emissions owing to the lack of primary data from the MAELIA simulations.

Crop LCI

Primary data on the hours of field farm operations, quantities of fertilizers and pesticides used, and yields were obtained directly from MAELIA. Secondary data for equipment, machinery for fertilizer, and pesticides were obtained from the Agribalyse database V3.0 (Koch and Salou, 2020) and Ecoinvent V3 databases (Wernet et al., 2016). The Agricultural Emissions Calculator (AGEC-LCI) tool was used to estimate field emissions due to fertilizer application (Santeros et al., 2020). For pesticides, all active ingredients were assumed to be emitted to the agricultural soil, to be consistent with other Ecoinvent processes (Wernet et al., 2016). The irrigation process was included only for AF1 and LF1, which have an irrigation system for maize grain production with four applications of 300 m^3/ha/year. To estimate the water consumed by maize grain, evapotranspiration data were gathered using Agribalyse 3 (Koch and Salou, 2020). To estimate water losses, an irrigation efficiency factor was applied; additionally, an 80% and 20% water runoff in rivers and ground-water, respectively, were implemented based on the work of Rogy et al. (2022). The LCA model was built by merging the production of each crop per farmer to obtain the total production of all farmers at the territorial scale. All data for livestock LCI are reported in A-C2 Table 3

Livestock LCI

The inventory for livestock was built based on three main assumptions: (i) the number of cows in lactation remained constant over the years, with a nine-month based diet; while for the remaining years, it was assumed that cows grazed freely; (ii) livestock production focused only on milk, without considering meat production; and (iii) the milk produced was constant over the years. The primary input data used to model LFs were the quantity and types of ingredients in the feed formula for animal diets A-C2 Table 4, and the amount of milk produced. Secondary data for water, energy, and milking LCI processes were obtained from Agribalyse 3.0. All data for livestock LCI are reported in A-C2 Table 5. In addition, calculation models to estimate emissions from livestock (i.e., ammonia (NH_3), dinitrogen oxide (N_2O), nitric oxide (NO), and methane (CH_4)) were developed following Agribalyse Methodological Report V.1.2. (Koch and Salou, 2020). The LCA model was built by merging: i) the milk production of each LF, which includes the LCI process of water-drinking by animals, livestock infrastructure, and the associated emissions; ii) the imported feed, which includes all ingredients imported by the global market for cow meals; iii) the local feed, which includes all ingredients produced at the territorial gate for cow meals; and iv) the energy for the electricity and heat used in the buildings where livestock dwells.

Eco-efficiency metrics

To compare the two land management scenarios, eco-efficiency indicators were computed to assess the territorial system in the T-LCA (Loiseau et al., 2014). As the basket of services provided by the two studied scenarios differ, particularly in food production and economic terms, the basis of comparison is not the functional unit, as in a conventional LCA. Instead, the eco-efficiency ratios allow for comparing services provided by the territory under study including the environmental damage caused. Thus, the formula to calculate the eco-efficiency indicators is as follows (see Eq(1)):

$$Eq(1)\ Eco-efficiency = \frac{Services\ provided}{Environmental\ Impacts}$$

The three main indicators of services provided for the two scenarios were calculated for the overall agricultural production (milk and crops) by formulas provided in Table 2.1.

Table 2. 1 Functions of the system and formulas for the assessed indicators

Gross Margin (€)	$$\mathbf{GM} = \sum_{1}^{i,f} (\boldsymbol{R_{i,f}} - \boldsymbol{VC_{i,f}}) * \boldsymbol{Ha_{i,f}}$$ $\boldsymbol{R_{i,f}}$= Total revenue (€/ha) of crop/milk i on of farm f $\boldsymbol{VC_{i,f}}$= Variable costs (€/ha) of crop/milk i on farm f $Ha_{i,f}$ = Hectares of assessed crop i on farm f
Energy Content (MJ)	$$\mathrm{EC} = \sum_{1}^{i,f} Y_{i,f} \times E_i$$ Yi,f = Total production of crop/milk i of farm f E_i= Energy content (%) of crop/milk i
Protein Content (kg)	$$\mathrm{PC} = \sum_{1}^{i,f} Y_{i,f} \times N_i$$ N_i= Protein content (%) of crop i

For crops, GM, EC and PC were calculated using data on yields, revenues, protein and energy content, and variables costs provided by MAELIA simulation for both scenarios. Milk prices, protein and energy content data were acquired from Eurostat Database, for France for the year 2021 (Eurostat, 2022).

The IMPACT World+ life cycle impact assessment (Bulle et al., 2019) was selected to quantify environmental impacts at both midpoint and endpoint levels, as it includes the latest developments in impacts due to water use and toxic substances. Midpoint characterization has a stronger relation to environmental flows and is generally associated with lower parameter uncertainty. However, endpoint characterization is easier to interpret in terms of the relevance of environmental flow (Huijbregts, 2017). The “Fossil and Nuclear Energy Use” and “Mineral Resource Use” midpoint indicators were used as proxies for the resource area of protection because IMPACT World + does not include an endpoint indicator for this area of protection. Characterization factors (CF) for 17 out of 106 substances comprised in pesticides were missing from IMPACT World+. Hence, emissions to the soil for these 17 substances were not calculated and included. A-C2 Table 6 lists these 17 substances for further improvement.

2.3 Results

In the following section, results are described for the environmental impacts, the indicators of services provided and the eco-efficiency comparison of the two scenarios.

Environmental impacts

Figure 2.3 shows the comparison of environmental impacts between the baseline and the synergic scenarios with the contribution of midpoint indicators to damages on human health (HH) and ecosystem quality (EQ), and midpoint impacts due to the use of fossil and nuclear energy (FNEU), and mineral resources (MRU). As can be seen, the impacts generated by the synergic scenario are lower than those of the baseline scenario for all indicator categories, with a greater decrease in human health and mineral resources. The contribution analysis (see pie charts in Figure 12) shows that, for the baseline scenario, around 80% of the damages on HH are due to human toxicity (non-cancer, short and long term), particulate matter formation and climate change (human-health short and long term) impacts. Meanwhile, in the synergy scenario, the contribution of human toxicity to HH damage is reduced to 72% due to a lower quantity of inputs used, including mineral fertilizers; furthermore, such contribution explains the higher decrease in mineral resources. Comparatively, the contribution analysis highlights that almost 86% of damages on EQ for both scenarios are due to impacts of land transformation, freshwater ecotoxicity, and land occupation.

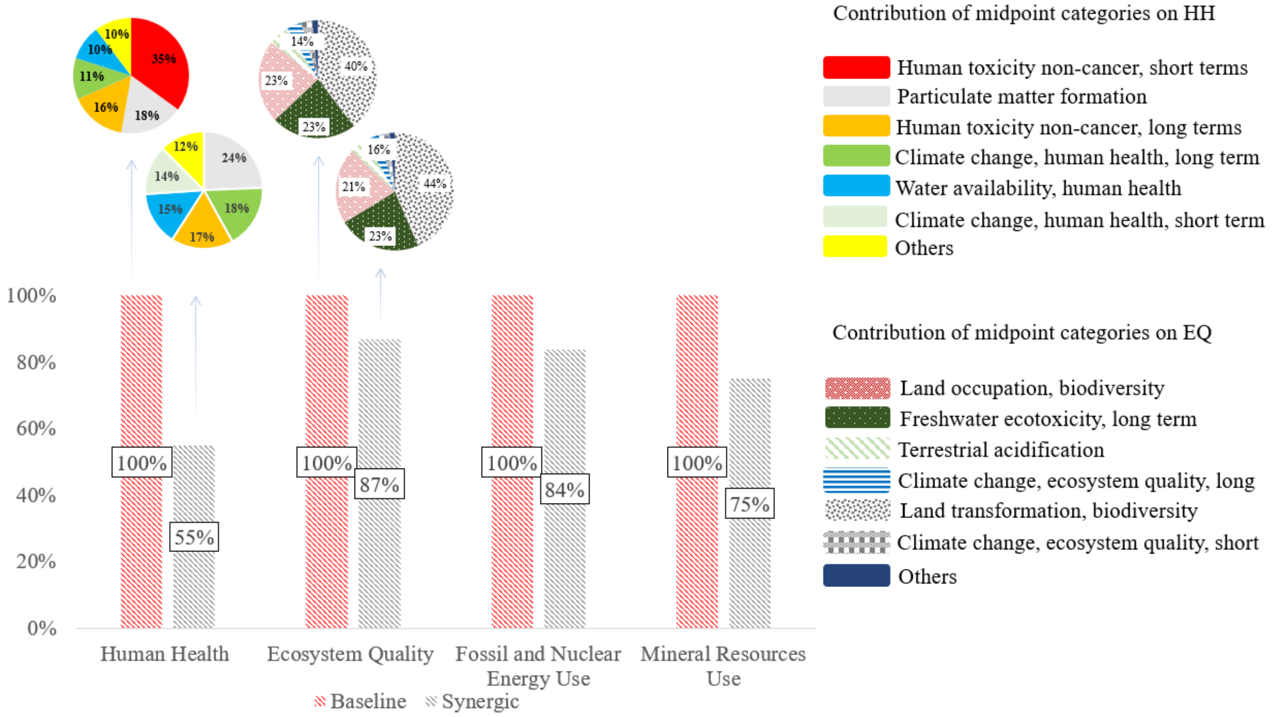

Figure 2. 3 Comparison of environmental damages between baseline and synergic scenario at endpoint level (bar graphs) with midpoint impact categories contribution (pie charts) for Human Health and Ecosystem Quality. Since IMPACT World+ does not include an endpoint indicator for the resource area of protection, "Fossil and Nuclear Energy Use" and "Mineral Resource Use" midpoint indicators were employed as proxies for the resource area of protection.

Figure 2.4 shows the contribution analysis of contributors that caused damage to the environment for both scenarios. In the baseline scenario, the main contributors to impacts for the HH category are arable crop production and imported cow feed by the global market for dairy cows. On the other hand, the impacts of the synergic scenario are mainly due to the amount of fertilizer applied to produce maize silage. Further, in the synergistic scenario, the most highly contributing process is derived directly from local crop production. The impact of fertilizers decreased with the introduction of local maize silage as an animal feed ingredient, which was cultivated with less urea and without ammonium nitrate in the territorial case study. The damage to EQ is mostly caused by arable crop systems due to land occupation and to the fertilizers used, particularly for winter wheat crops, which leave behind residual heavy-metal minerals on fields. Arable crop systems are also the main contributor to damage in the FNEU category because of the use of fossil fuels for fertilizing with fertilizer spreading machinery and the production of ammonium nitrate used in the field. The impact reduction of FNEU in the synergic scenario was derived, first, by the lower amount of mineral fertilizer applied due to the integration of grain legumes in rotations and, secondly, from a lesser diesel consumption by global transport (freight lorry and transoceanic ship) for those inputs imported into the foreground system. Finally, the major impacts caused on the MRU category were derived from the fertilization process, which is mainly caused by the use of diammonium phosphate. As the activities related to milk production and data inventory are the same within scenarios, the only difference being due to cow feed formulas, impacts did not vary between baseline and synergic scenarios. The impacts on HH and EQ for milk production are caused by direct emissions from livestock, and by materials for cow buildings, in the case of MRU. The energy process used in the buildings where livestock dwells affect only the FNEU category. To conclude, the sharing of local protein crops as cow feeds and the exclusion of the (imported) soybean as a feed ingredient markedly reduced the impact of imported feed and overall environmental impacts in the synergic scenario.

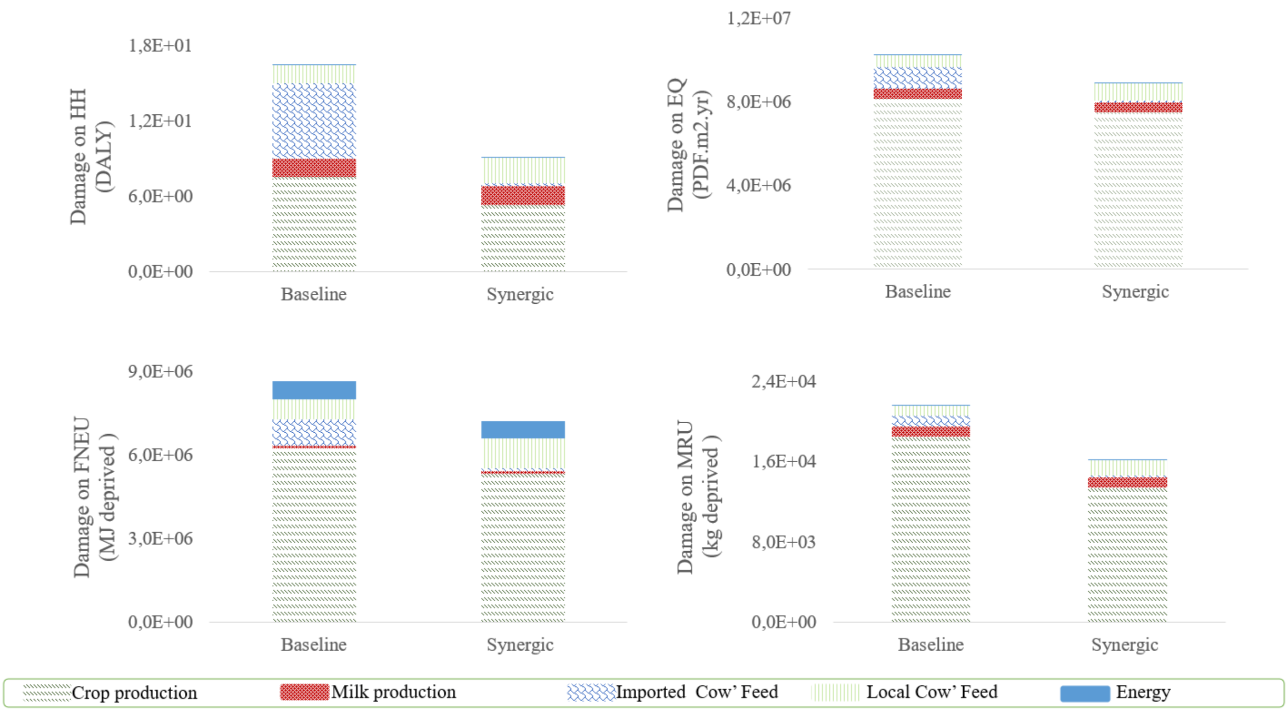

Figure 2. 4 Contribution analysis of the main activities at the endpoint level for human health (HH), ecosystem quality (EQ), and midpoint level for fossil and nuclear energy use (FNEU), and mineral resources Use (MRU) in absolute values across scenarios. Crop production includes sowing, fertilization, pesticide treatment, harvesting, and irrigation; Milk production includes drinking water for animals, livestock infrastructures, and direct emissions; Imported Cow' Feed includes all ingredients imported by the global market for cow meals; Local Cow' Feed Includes all ingredients produced in the territorial boundaries of the case study, Energy includes electricity and heat used in building for livestock.

Indicators of services provided

Table 2.2 reports the results of indicators for the services provided according to the scenarios. The introduction of legume protein crops (i.e., fava and pea beans) in the system brings positive economic impacts at the territory level. The GM increases by 4% at the territorial level in the synergic scenario. AFs increase their source of income by selling local legumes as ingredients for cow Table 4 shows the results of indicators for the services provided according to the scenarios. The introduction of legume protein crops (i.e., fava and pea beans) in the system brings positive economic impacts at the territory level. The GM increases by 4% at the territorial level in the synergic scenario. Additionally, AFs increase their source of income by selling local legumes as ingredients for cow feed, while protein crop grains bought by LFs reduce their variable costs. Thus, the synergic scenario increases the aggregated GM for the territory studied (group of farms). Furthermore, the PC produced increases by 8% at the territorial level in the synergic scenario due to the substitution of soya cakes with fava and pea beans produced in the territory under study. Finally, the EC does not significantly vary between scenarios due to the relation between the yield of arable crops and their rotation systems within scenarios. Despite the introduction of fava and peas crops, the added energy values of these crops are less in comparison to the reduction of the other crops in terms of energy content.

Table 2. 2 Values for the Gross Margin indicator estimated in euro (€), Energy Content indicator estimated in megajoule (MJ), and Protein Content indicator estimated in kilograms (Kg) divided by farmers, per crop, milk processes, and territorial level. Comparison between baseline and synergic scenario based on average values between 2005 and 2017.

		Gross Margin (€)			Energy Content (MJ)			Protein Content (kg)		
	Farms	Crop	Milk	**Territory**	Crop	Milk	**Territory**	Crop	Milk	**Territory**
Baseline	AF1	35806			4296			36137		
	AF2	33712			5140			36103		
	AF3	66291			11046			91465		
	AF4	20897		**588 238**	5725		**1 356 138**	41646		**522 596**
	AF5	36247			9096			74775		
	LF1	71877	85527		5070	461286		31015	57443	
	LF2	37001	143734		7789	846691		48575	105437	
Synergic	AF1	36061			3901			36982		
	AF2	42467			5546			48914		
	AF3	81341			10123			87991		
	AF4	20897		**612 039**	5828		**1 355 883**	56566		**565 707**
	AF5	36247			9649			92784		
	LF1	63532	94302		5070	461286		31015	57443	
	LF2	48301	152644		7789	846691		48575	105437	

Comparison of eco-efficiencies

Figure 2.5 compares the eco-efficiency results according to the services provided by the two scenarios. From an environmental point of view, the higher the eco-efficiency, the better the scenario. Figure 14 confirms the higher performance of the synergic scenario, compared to the baseline scenario regardless of the services or environmental impacts considered. However, the slight differences within eco-efficiency ratios highlight the greater efficiency of services in providing protein, rather than energy content, and financial support for the territorial context. Regardless of the function considered, HH is lower in eco-efficiency by approximately 47%, 16% for EQ, 20% for FNEU, and 28% for MRU for the baseline. This is due to the different environmental impacts caused by crop cultivation, imported feed, and local feed. In this study, the eco-efficiency performance remained maximal for the three indicators considered in the synergic scenario. Hence, the establishment of a synergistic scenario at the territory level allows for improved system performance.

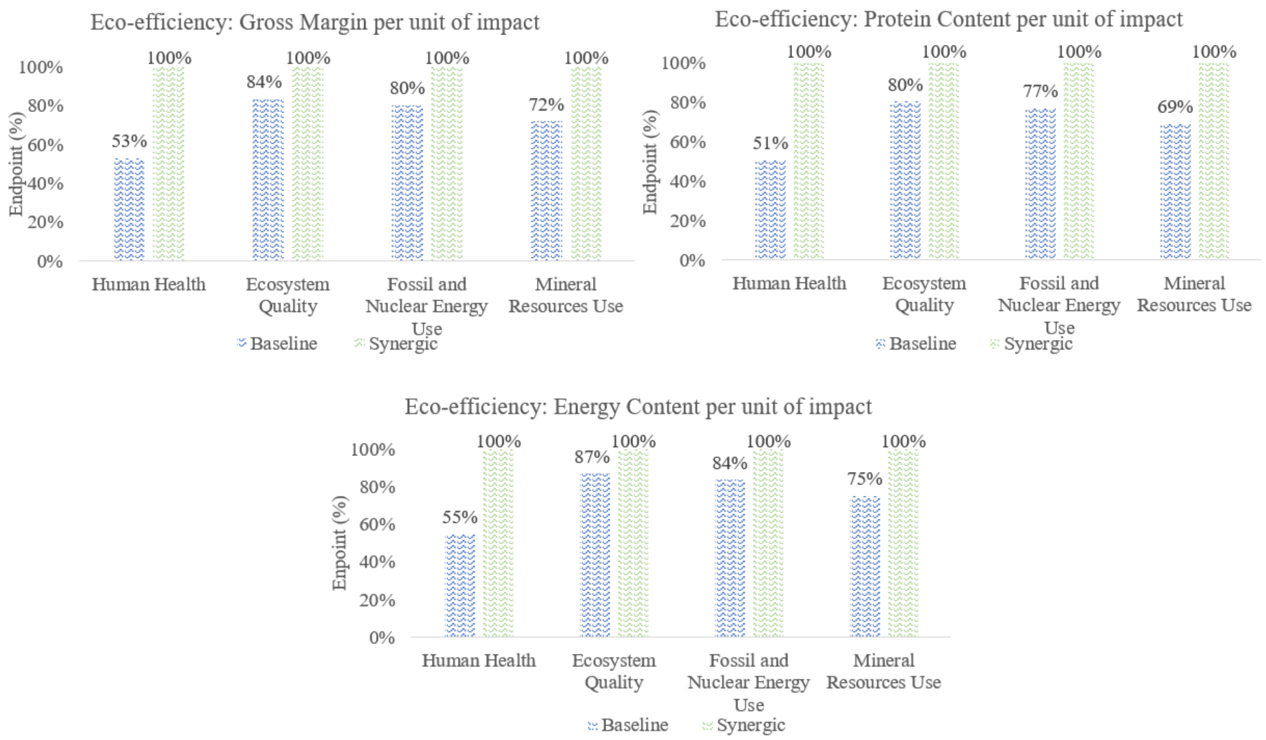

Figure 2. 5 Eco-efficiency results for the three investigated indicators, i.e., Gross Margin, Protein Content, and Energy Content for the baseline and synergic scenarios. The higher the eco-efficiency, the more performant the environment and the scenarios

2.4 Discussion

Modelling choices and limitations

The original coupling between the IAM platform, MAELIA, and T-LCA allows to understand its potential. On the one hand, the ability of MAELIA to simulate the daily functioning of cropping systems provides precise data on agricultural practices (for example the hours of fieldwork, and inputs used) and socio-economic information to overcome the issue of data availability in T-LCA (Weik et al., 2022). In turn, T-LCA allows accounting for impacts of background and foreground activities and the trade-off between services provided and environmental impacts by eco-efficiency ratios. This coupling provides a novel approach for assessing the impact of human agricultural activity at multiple territorial scales over the entire life cycle. The use of MAELIA outputs as inputs for T-LCA showed high feasibility in the coupling between the frameworks. An improvement in the current system can be to directly estimate crop field emissions using the MAELIA platform to compute more representative data with specific information on climate and soil conditions. Furthermore, to deal with the specific issue of characterization factors missing for pesticides, the OLCA-PEST project developed pesticide consensus guidelines to operationalize pesticide emissions in LCA (Nemecek et al., 2022). Thus, it can help characterize missing pesticides and improve field emission calculation for the case study. Finally, a multicriteria assessment is needed to avoid potential trade-offs between climate change and other impact categories to better detect the environmental impacts on the EQ endpoint.

With respect to the inventory of the livestock system, the feed formula and the amount of milk produced were available from the case study, since the feed formulas (baseline and synergetic) were designed to provide the same milk output while replacing the soya cake and cereal-grain mix with protein crops (Catarino et al., 2021). For the emissions associated with livestock and the manure management system, data were estimated directly by the feed formulas for the herd of cows. Calculated emissions were compared with similar LCI Agribalyse processes, to compare if the order of magnitude of the results was consistent with the case study. Estimation of manure management system could be improved by gathering primary data on livestock farmers because the feeding climate and health conditions can affect the production of manure. LFs raise dairy cows; hence, they are not meat providers but milk-specialized cattle farms. However, the allocation process between meat and milk production could not be investigated due to the lack of data on the meat side. The lack of information for infrastructure and milk production machinery in livestock farms, brought a level of uncertainty due to the use of proxy data for these LCI processes. No primary data were available for the sale price, energy, or milk protein content; and secondary data were acquired from the Eurostat database. While energy and protein content values can be considered average values because they are ingredient nutritional standards, milk sale price may differ from the average because its fluctuations are influenced by dairy cow yield and the number of dairy cows (Jongeneel and Gonzalez-Martinez, 2022).

Territorial responsibility principles based on system boundary definition

Territorial responsibility principles can be discussed based on system boundary definition for a specific case study in terms of environmental impacts. Several territorial responsibilities can be defined, depending on where goods and services are produced, processed, and consumed (Eder and

Narodoslawsky, 1999). As proposed in the T-LCA, the total territorial responsibility principle was applied in this work, which entails considering all impacts (direct and indirect) that take place within the territory under study. Such a territorial principle also suggests considering the indirect impacts incurred by the imports of inputs needed for Afs and LFs inside territorial boundaries. Based on this principle, the impacts of exports are not considered because of the definition of the system boundaries (until the territorial gate). The total territorial responsibility principle provides a clear understanding of the direct and induced impacts of crop-livestock territorial activities and allows for the quantification of pollution transfers.

Other principles, besides the total territorial ones, have already been defined in the literature, such as producer-based or consumption-based (Albertí et al., 2019; Athanassiadis et al. 2018). In the producer-based approach, only the direct impacts generated by all activities in the territory are accounted for, to the local extraction of resources or emissions of polluting substances in the territory (Albertí et al., 2019a). The application of producer-based principle in this study would entail considered all direct emissions from fields and livestock, but not indirect impacts. While, in the consumption-based principles, only the impacts generated by final consumption are taken into account in a given territory, including the impacts of inputs and outputs, regardless of where they are produced and located. Territorial responsibility can also be discussed by taking into account, for example, the wealth created, or the spatial coverage of impacts generated by human activities at the global or local level, as highlighted by Albertí et al. (2019b). However, their implementation requires additional information, such as data on food processing, logistics or consumption phase.

Policy implication at different territorial levels

The results of the case study suggest the positive effects of cooperation between integrated crop-livestock systems that could support a strategy to adopt territorial integrated crop-livestock systems as a promising sustainable production model to face environmental challenges without hindering the agro-economy at a territorial scale. Hence, it is important to further investigate why mixed crop-livestock systems are less than one-fifth of the existing farms in the European Union (see Catarino et al, 2021) and what kinds of externalities can be generated by the scalability of such a model at the regional, national, and European levels. The environmental results and eco-efficiency ratios show the positive benefits of the circular economy strategy at the territorial level. Benefits are maximized when legume crops are introduced by arable farms to provide feed for livestock, and organic fertilizers are returned by livestock farmers to arable farms. The methodology proposed to capture the benefits of the circular economy at the territorial level, supporting the crosscutting actions of the EU New

Circular Action Plan, i.e., to promote and foster circularity as a prerequisite for climate neutrality by modelling tools.

This work highlights the importance of comparing land planning scenarios that can guide policymakers in identifying specific areas of concern and target policy aims to reach with their interventions, while simultaneously considering several factors such as land use pattern and resource consumption. The framework proposed in this study contributes to this discussion by providing scientific results for policy recommendations at the European and national levels to identify possible trade-offs in reaching the policy transition purposed by the Green Deal, thus supporting the EU in:

- Evaluating policy scenarios to meet Farm To Fork (F2F) strategic aims: For example, by modeling inputs of territorial systems it is possible to quantify the amount of fertilizer and pesticide used in integrated crop-livestock systems to find the right balance in reducing nutrient losses and greenhouse gas emissions. This analysis can be implemented at a different territorial scale.
- Proving a greater level of transparency and information about the potential benefits and trade-offs of different policies: For example, for the EU F2F strategies, as well as public and private stakeholders, by comparing different land management scenarios based on different sustainable practices to foresee resulting impacts on the ecosystem.
- Long-term thinking and vision: Accounting for impacts and territorial responsibility of agricultural production, which can aid policymakers in considering long-term environmental burdens. For example, by modeling the system with a time scale up to 2030, it is possible to estimate the environmental impacts within the timeframe established by the F2F strategies.

This aligns with the EU Green Deal ambition to achieve a sustainable and circular economy.

At the European level, this approach would require data from across the EU, not only from the agriculture sector but from the food industry and distribution sectors as well, which may require better coordination and collaboration to achieve more accurate results. Additionally, the approach would need to consider the Common Agricultural Policy (CAP) schemes of the EU and how they affect environmental outcomes.

2.5 Conclusions

The objectives of our study were twofold: (i) to propose an innovative assessment approach based on the coupling between IAM and T-LCA, and (ii) to assess the environmental performance of territorial crop-livestock systems based on circular economy principles. For this purpose, the eco-efficiencies of two scenarios regarding relationships between arable and livestock farms were compared: a linear organization with connection only to the global market (baseline scenario) and a circular one in which specific inputs are shared by local farmers (synergic scenario). The results highlight a higher performance of the synergic scenario regardless of the functions (economic profits and food production) or damage considered. The introduction of grain legumes (fava and pea beans) in crop rotation to feed animals increases the production capacity of protein in the overall system while reducing the environmental impacts derived from the global market. In addition, the synergistic scenario has positive economic consequences on the gross margin of local producers, reducing variable costs for livestock farmers and generating additional profits for arable farmers. Our study proposes a methodology for evaluating land management scenarios based on circular practices to support policymakers in identifying areas of concern and targeting policy aims to reach the target aims of the EU Green Deal and F2F. By quantifying the impacts of different policy scenarios and providing robust scientific results, policy recommendations at the European and national levels can be drawn to foster the ecological transition of integrated crop-livestock systems

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Chapter 3: A mixed method approach to foster short food supply chains by matching production and consumption

Keywords: *Ancient Grains; Backcasting; Business Strategy; Cluster Analysis; Delphi; Territorial level*

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Cirone Francesco, Masotti Matteo; Prosperi Paolo; Bosi Sara; Dinelli Giovanni; Vittuari Matteo.

Abstract

The short food supply chain (SFSC) plays a vital role in connecting local producers with consumers, promoting sustainability, supporting the local economy, and providing access to fresh, high-quality foods. However, their market is still underdeveloped due to the mismatching between consumer demand and producer’s supply. On one side, production has outstripped the current supply, leading to high prices and difficulty for consumers to access these products, to the other side, producers need to struggle with higher costs to be guaranteed profit value from their food chain. Hence, the present work proposes a strategical long-term vision to foster SFSC based on a direct farmer-to-retailer model. The methodology realis on an original mixed-method approach which combines a household survey on a representative sample of consumers, clustering analysis, and backcasting. Results were finally validated through two rounds of Delphi by experts. The work is applied to a real case study within the Valcea project on the ancient grains Oroset Consortium of the Emilia-Romagna Region, in Italy.

3.1 Introduction

The evidence-based observation of the unsustainability of the global food system (Willet et al., 2019) has fostered the attention of research and the international community to the role of short food supply chains (SFSCs) in contributing to more sustainable food systems (Bisoffi et al., 2021; Sonnino, 2013). Thus, there is a growing interest to reconsider the design of food supply chains connecting producers with consumers and local territories, through several organisational forms of SFSCs such as direct farmer-to-retailer, farmer shops, farmers' markets, on-farm direct sales, community-supported agriculture, local catering procurement and digital platforms (Chiffoleau and Dourian, 2020; Kneafsey et al., 2013, UNIDO, 2020).

SFSCs can be defined as supply chains that "consist of a maximum of one intermediary between producer and consumer" (EIP-AGRI, 2014). They are often associated with positive outcomes on the environment and society since they provide fresh and nutritious food for healthier diets (Sonnino, 2013), reduce carbon footprint (Pradhan et al., 2020), contribute to close nutrient flows (Billen et al., 2021), support local economy and employment in rural areas (Jarzębowski et al., 2020), improve the sustainability of agricultural practices (Mundler and Laughrea, 2016), and empower sustainable consumption patterns (González-Azcárate et al., 2021; O'Neill et al., 2022).

Literature on SFSCs has increased remarkably in recent years (González-Azcárate et al., 2021). Yet, most of research address producer dynamics to a greater extent, while a few on consumer attitudes (Evola et al., 2022). On producer dynamics, several strategies to meet consumer expectations by SFSCs have been investigated, such as, by increasing the number of production processes and products, re-integrating activities in their business (e.g., transport, conservation, presence on the markets for sale), processing food to extend the shelf life and added value, and diversifying non-traditional multi-functional activities (e.g., tourism and education) (Brunori et al., 2010). In addition, targets farmers' activity in SFSCs mainly addresses farming system characteristics, value addition dynamics, competency challenges, intentions, as well as motivations and perceptions for their participation in SFSCs (Bayir et al., 2022; Evola et al., 2022).

Instead, research literature on the consumer side investigates mostly the socioeconomic characteristics of consumers participating in different types of SFSCs, their attitudes, motivations and perception which lead to purchase decision, while other research classifies groups of SFSC consumers (Bayir et al., 2022; Evola et al., 2022).

Recently, the UNIDO report "Short Food Supply Chains for promoting Local Food on Local Markets" (2020) provides a comprehensive global picture of benefits and issues for both producers and consumers involved in SFSCs. Benefits for producers are identified in the increase of sale prices and value-added, easier market access and differentiation, improved opportunities for cooperation with consumers and other producers, as well as the opportunity to better communicate and inform consumers on a production activity and characteristics. For consumers, benefits are represented by the access to affordable prices of qualitative and healthier food products, often from known producers, and by the fact that purchasing those products allows for supporting the local economy, and social and ethical objectives, as well as reconnecting food to farming and processing activity. On the other hand, specific issues still need to be faced. Producers can be exposed to several challenges such as the increase in costs due to newly requested functions which required investment in new equipment (e.g., for processing, transportation, selling), in the workforce, new competencies and skills, and in the diversification of production. In addition, competition between SFSCs producers can increase and those who are located in remote areas might be disadvantaged. Consumers with lower access to information and knowledge on product characteristics adapted food preparation and supplied and price-accessible stores may be excluded from the consumption of SFSC' products.

Turning the spotlights on beneficial expectations and potential issues of producers and consumers (UNIDO, 2020) highlights the challenge in matching producers and consumers in SFSCs, and thus the need for further investigation to build efficient and resilient SFSCs. To date, only a few scientific research addresses simultaneously producers and consumers perception (and also retailers) on their activities and attitudes within their participation in SFSCs (Mancini et al., 2019; Vittersø et al., 2019). Anyway, these studies only focus on perceptions and do not propose operational strategies for building shared supply. Based on the quantitative literature analysis of Bayir et al. (2022) and Evola et al. (2022), there is a need for further efforts in research on operational planning to achieve holistic and integrated SFSCs vision and more realistic and concrete design and implementation strategies. Therefore, to the best of our knowledge, there is a need for further research on SFSCs which takes into account both producers and consumers points of view and propose structured planning and implementation of activities towards more effective SFSCs. To tackle this research gap, this work develops and proposes an integrated quantitative-qualitative producers and consumers analysis aimed at structuring strategical long-term vision to foster SFSCs based on a direct farmer-to-retailer model.

3.2 Material and Methods

The study relies on a quantitative and qualitative integrated mixed-method approach. Figure 3.1 shows the methodological workflow and the stakeholder's involvement in the design and implementation of the methodology. The methodology has been tested on a case study within the

Valcea project, a program of rural development of the Emilia-Romagna region and the University of Bologna, with the Oroset consortium.

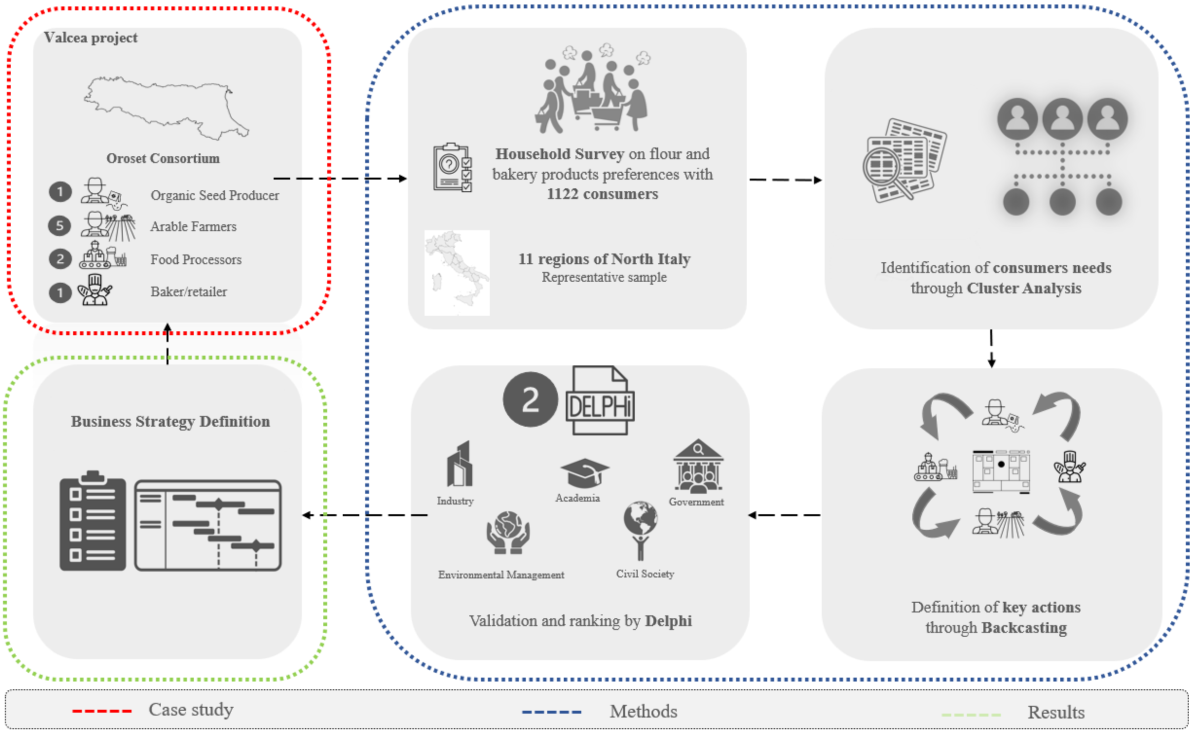

Figure 3. 1 Summary of the methodological workflow and the stakeholders involved in the design and implementation of the work. After having identified a business orientation problem with the short food supply chain of ancient grain, a household survey of a representative sample of North Italy consumers has identified several consumers' needs which influence the willingness to pay for ancient grain products. These needs have been translated to business strategies' target aims for the actors involved, and by the backcasting and focus group the key actions have been identified to reach the target aims. Finally, by the Delphi methodology these actions have been validated and ranked based on stakeholders' knowledge.

The case study of ancient grains

Ancient and minor cereals might be classified into several categories, including species closely related to wheat (like spelt, emmer, and einkorn), other cereals (such as rye, foxtail millet, oats, sorghum, barley, common millet, and teff) (Pontonio and Rizzello 2019). Although there is no precise definition of ancient grains, for this study, they are classified on the degree of human intervention. Landraces and old varieties are referred to as grains developed by natural and human selection, genetically heterogeneous, and locally adapted (Boukid et al. 2018). Ancient wheat-based foodstuffs are becoming more popular in the food market as a substitute for durum and common wheat flour. The renewed interest in ancient species is due to the need to preserve genetic diversity, the high adaptability of these varieties, the rich nutrients content and the possibility to differentiate the food production. From an agricultural point of view, they also contribute to the reduction of the genetic erosion risk caused by the intensive cultivation of modern varieties. Furthermore, ancient wheat is suitable for organic farming system due to its adaptability to low agronomic inputs and the high resistance to disadvantageous growing conditions (Arzani and Ashraf 2017). SFSCs built on ancient grains are becoming an interesting option for farmers, but also for millers and bakers to match recent consumer trends in developed countries (Longin and Wurschum, 2016). Scholars stress the need to develop interdisciplinary and multi-stakeholders coordination and collaboration among all actors participating in these specific SFSCs to ensure their effective and long-term functioning (Longin and Wurschum, 2016; Stefani et al., 2017; Chiffoleau et al., 2021). Achieving a right equilibrium between the different interests of stakeholders and warranting transparent information are, according to Casalegno et al. (2019) crucial factors composing a win-win strategy for a SFSCs. On this topic, the Valcea project aimed to build a short food supply chain that enhances the organic production of ancient grains in an area between the Emilia-Romagna provinces of Forlì-Cesena and Rimini, Italy. The final goals of Valcea were to disseminate the cultivation of an ancient grain's population identified as Bioadapt, transformed then in Oroset, and to increase the income of the actors involved in the supply chain. To reach the first objective, a supply chain agreement on production and technical lines for the cultivation of the Oroset population has been signed by all actors involved in the project. To deal with the second aim, the supply chain actors were engaged in the construction of a strategic future vision with consumers to improve the production-consumption matching in their territorial context. The actors involved for this study were: 1 organic seed producer; 5 arable farmers; 2 processors; 1 baker/retailer.

This work focused the sustainability on environmental, as it concerns biological production respecting the soil and local biodiversity; economic, as it is committed to the involvement of small-scale farmers; and social, as the actors involved are promoters of food security for local communities.

The household survey

Consumers' attitude towards flours and bakery products derived from ancient varieties of grains was investigated through a questionnaire. The latter was developed based on the Motivation-Opportunity-Ability (MOA) framework, as shown in Figure 3.2. It was developed within the seminal works by MacInnis et al., (1991) and Rothschild (1999) and in the domain of the analysis of information processing and decision-making of consumers, has been adapted to several other contexts, including those related to food management. (Bos et al., 2016; Van Droogenbroeck and Van Hove, 2017; Yang et al., 2020).

- *Motivation (M)* is defined as the intention to perform certain actions, such as purchasing bakery products. It is influenced by the personal awareness of consumers, and by injunctive and descriptive social norms.
- *Opportunity* (O) refers to the accessibility of external resources needed to perform intended actions, such as the availability of ancient grain-based products in shops, the availability of financial resources, and the possibility to expand one's food preparation skills or know-how.
- *Ability (A)* refers to the consumers' capacity to deal with the creation, management, and conscious consumption of food. It includes food knowledge, know-how and skills, such as the capacity to bake with ancient grains-based flours or the capacity to understand the nutritional information provided on the product labels.

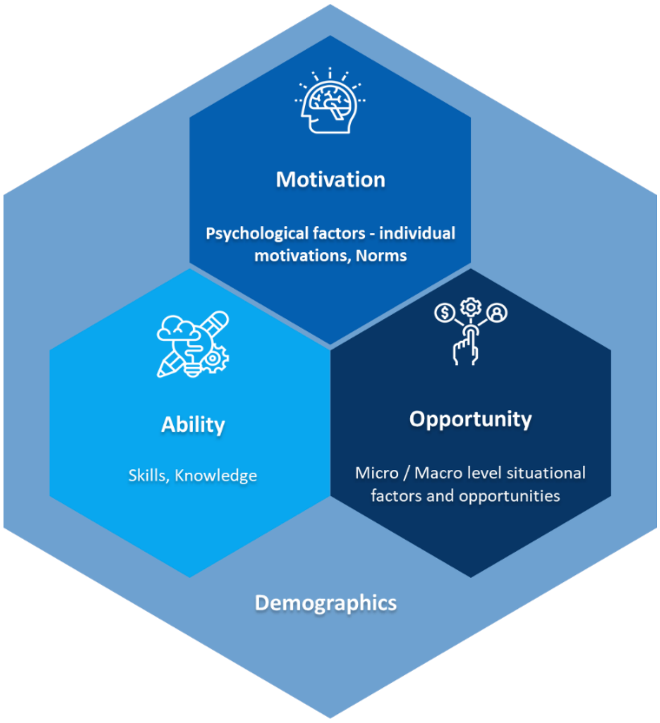

Figure 3. 2 Authors elaboration of MOA framework (adaptation from Van Geffen et al., 2016)

The questionnaire for the survey was co-designed with the contribution of Oroset consortium. Data were collected in March 2021 by an independent market research organization. The questionnaire was submitted to a sample of 1.122 consumers responsible for at least 50% of grocery shopping and meal preparation within their households. The sample was representative of the population of 11 regions of North Italy, i.e., Emilia-Romagna, Friuli Venezia-Giulia, Liguria, Lombardia, Marche, Piemonte, Tuscany, Trentino Alto Adige, Umbria, Valle d'Aosta and Veneto.

The questionnaire was composed of two sections. The first aimed to investigate consumers' preferences and habits related to purchasing flours and bakery products. To avoid biases in the answers, questions were organized to reproduce the phases of purchasing decision-making process: reasons for choosing flours and bakery products, general food purchasing habits, frequency of purchasing, use of flours and bakery products, as the frequency of home baking. The second aimed to include a discrete choice experiment to the simulation of purchasing 1 Kg of bread with different characteristics in terms of digestibility, perceived quality, social and environmental sustainability. Annex – Chapter3 (A-C3) Table 1 disclose the entire questionnaire. Discrete choice experiments are a quantitative technique for the analysis of individual preferences that are widely adopted in the domain of food choice studies (Lizin et al., 2022) Digestibility was defined as the ease of digesting bread and not feeling weighed down after consuming it; perceived quality as the presence of a pleasant aroma, of light, crunchy, and not too thick crust with ochre-yellow and brown colour, of a crumb with pleasant consistency that adheres well to the crust, and of a high nutritional value. Sustainability was mainly investigated relatively to social-economic and environmental dimensions. For the environmental side, raw materials for making bread were investigated. For the social side, the focus was on the working conditions and the respect for the rights of workers. Finally, the economic dimension was investigated though the price levels of a kilogram of bread, 2 €, 4 €, and 6 €.

Cluster analysis

The outcome of the questionnaire was a dataset with 1.122 observations and 238 variables, including the screening and demographics variables. Several clustering options were applied to the results of the survey (single linkage, complete linkage, average linkage, Ward's method, and centroid method) to identify homogeneous groups of consumers. Ward's method applied to the items of the questionnaire related to Opportunity led to the most balanced number of observations in clusters' compositions. The Caliński–Harabasz pseudo-F stopping-rule index, the Duda–Hart Je(2)/Je(1) stopping-rule index and the frequency of distribution of each cluster were applied to select the number of clusters resulting from the analysis. The measure of association Cramer's V has been used to evaluate the influence of the variables used for the clustering on the cluster obtained. ANOVA models and Bonferroni multiple-comparison tests were used to assess whether the clusters differed significantly in terms of socio-demographic characteristics. Finally, the non-parametric Kruskal–Wallis equality of populations rank tests were employed to assess if the samples came from the same population. Once assessed the demographic differences, the same tests were used to investigate whether the clusters presented significant differences in *Motivations*, *Opportunities* and *Abilities* connected to the consumption of cereal-based ancient grain products for cluster profiling.

After the identification of consumer profile groups, conjoint analysis was performed on the answer provided by the members of each cluster to the questions related to the simulation of purchasing 1 Kg of bread. The results allowed to estimate levels of utility attributed by consumers to a set of characteristics proper of ancient grains-based bread, provided by consumers preferences through the simulation of real bread purchasing. In particular, preferences were tested related to digestibility, perceived quality, sustainability, and price of bread.

Backasting methodology

Backcasting was used to identify key relevant actions to be implemented within the SFSCs to reach the end-points desired by consumers. Backcasting is used for future studies that involves a systematic process for planning backwards, starting from a desired end-point, to identify the steps necessary to link the future to present state (Kok et al., 2011; Robinson et al., 2011; Vervoort et al., 2014; Galli et al., 2016; Mendoza et al., 2017). Backcasting approach differs from forecasting since it aims at identifying and exploring the feasibility and implications of achieving specific desirable goals in a future state (Robinson, 2003), by targeting what needs to occur before those goals are attained (Vervoort et al., 2014). It consists of a step-wise approach, from an envisioned future to the present, that allows to co-create "actionable" and "proactive futures" (Galli et al., 2016: p. 242) with stakeholders who have, in this manner, the opportunity to tackle and question uncertain and challenging future issues. Therefore, stakeholders taking part in backcasting participatory activities are guided to work backwards from a desired future to the present state, by identifying all actions needed, and considering – at each step - the barriers to overcome from the present (Galli et al., 2016).

In previous research, backcasting was applied to study SFSCs but specifically with respect to alternative food networks (Cerrada-Serra et al., 2018) and to the establishment of contracts for ecosystem services (Defrijn et al., 2021), and not - to the best of our knowledge - to direct farmer-to-retailer SFSCs as it is the case of the present research.

According to this study, three main activities were carrying out, i.e., a) define and validate an overarching and desirable vision based on consumers' needs by the strategic problem orientation and future strategic objectives; b) discuss past and present drivers and barriers to the implementation of the desired vision to improve the clarity of the desired future state; c) identify future concrete actions that could help in achieving the vision, according to their consistency and feasibility. These activities were developed during the two focus groups with ancient grain producers with no more than 5 participants each. Building on Galli et al., 2016, each action has been identified starting from the question "*if you want to attain [future step] what would we need to do/have in place for that to be possible?*". According to Quist and Vergragt (2006) this method helps in defining sustainable future vision by defining changes in the business models.

Delphi

Delphi helps to gather collective points of view from experts through a structured surveys (Nowack et al., 2011). To develop a robust Delphi, often a serious of rounds are performed in which more than 12 experts and stakeholders should be engaged (Zartha Sossa et al., 2019). Although this method presents some weaknesses (e.g., it's time-consuming or the potential lack of participation (Fink-Hafner et al., 2019)), it provides high-quality results when combined with other methods, as in the case of the present research (Rowe and Wright, 2011). For this study, experts were selected based on the Quintuple Helix Approach, that foresee to involve a wide range of expert and stakeholders from academia, industry, civil society, government and environmental management to obtain an overall consensus within societal parties (Carayannis et al., 2022), giving the perspectives of both democracy and environmental concerns (Carayannis et al., 2012). For this study two rounds were implemented with the following aims:

- I° Round: to validate three most appropriate actions that ancient grains producers may adopt to reach consumers' demand.

- II° Round: to rank the three actions identified over three years.

Both rounds were developed through an english-language surveys, shared via email. The first survey was built on Google Form, Qualtrics has been selected as a suitable tool for the second round since it was necessary to rank the answers.

3.3 Results and discussion

Profiling consumers

The cluster analysis based on answers related to the Opportunity to purchase flour and bakery products led to the identification of the four homogeneous groups of consumers (profiles), in which the internal differences in the answers are minimized. Table 3.1 summarizes the main socio-demographic characteristics of each cluster of consumers. The identified groups are different also in terms of demographics, except for the ‘citizenship’ and ‘region of provenience’, which are not statistically different between groups. The clusters are named: ‘Conscious consumers’ (22.10% of the sample), ‘Low-involved consumers’ (33.42%), ‘Pragmatic consumers’ (26.47%), and ‘Demanding consumers’ (18.01%).

Table 3. 1 Demographics by clusters

Variable	**Conscious consumers**	**Low-involved consumers**	**Pragmatic consumers**	**Demanding consumers**
% of sample	22.10	33.42	26.47	18.01
Gender				
Male (%)	54.03	46.93	40.74	34.65
Female (%)	44.35	52.27	58.25	65.35
Not binary (%)	0.81	0.53	0.67	0.00
Not specified (%)	0.81	0.27	0.34	0.00
Age (years)				
18 - 24 (%)	15.32	13.33	6.06	5.94
25 - 34 (%)	28.63	20.53	10.44	15.35
35 - 44 (%)	27.02	26.13	17.85	17.82
45 - 54 (%)	21.37	21.60	28.96	29.21
55 - 64 (%)	7.26	16.80	25.93	27.23
> 65 (%)	0.40	1.60	10.77	4.46
Education				
Elementary school or lower (%)	0.40	0.27	0.00	0.50
Middle school diploma (%)	6.45	11.20	12.79	8.42
High school diploma (%)	34.68	44.80	52.86	46.04
Technical diploma or other specialization (%)	10.08	8.27	5.39	8.91
Bachelor (%)	37.10	29.33	24.58	26.73
Master/PhD (%)	11.29	6.13	4.38	9.41
Household members (average)	3.41	3.05	2.63	2.90
1 member (%)	4.84	9.07	18.18	12.38
2 members (%)	14.11	24.80	27.61	24.26
3 members (%)	28.63	27.20	31.31	32.18
4 members (%)	39.11	29.87	17.85	23.27
>4 members (%)	13.31	9.07	5.05	7.92
N° of children 0-12 y.o. (average)	0.82	0.52	0.31	0.52
0 children (%)	40.74	59.69	76.21	60.00
1 child (%)	40.21	30.62	17.48	28.28
2 children (%)	16.40	8.53	4.85	11.03
3 children (%)	2.12	0.78	1.46	0.69
5 children (%)	0.53	0.00	0.00	0.00
6 children (%)	0.00	0.39	0.00	0.00
N° of teenagers 13-18 y.o. (average)	0.64	0.50	0.26	0.35

0 teenagers (%)	52.17	60.16	76.67	69.17
1 teenager (%)	35.87	29.88	20.48	28.57
2 teenagers (%)	8.70	9.56	2.86	1.50
3 teenagers (%)	1.63	0.40	0.00	0.00
4 teenagers (%)	1.63	0.00	0.00	0.00
5 teenagers (%)	0.00	0.00	0.00	0.75
Residence				
Big city (>100.000 inhab.) (%)	38.71	31.73	29.97	22.28
City (20-100.000 inhab.) (%)	33.87	32.53	25.59	35.15
Small city (10-20.000 inhab.) (%)	10.48	14.67	12.46	13.86
Town (5-10.000 inhab.) (%)	13.71	14.13	16.50	15.84
Rural/mountain area (<5.000 inhab.) (%)	3.23	6.93	15.49	12.87
Income (average, Euros)	1.500-3.000	1.500-2.000	1.000-2.000	1.500-2.000
I don't know/don't want to declare (%)	5.24	10.40	12.79	11.88
<1.000 euros (%)	4.03	8.27	10.44	3.96
1.000-1.500 euros (%)	14.11	18.13	19.19	19.80
1.500-2.000 euros (%)	20.97	19.20	20.20	19.31
2.000-3.000 euros (%)	25.00	24.27	23.57	28.22
3.000-5.000 euros (%)	20.56	14.67	10.10	12.38
5.000-7.500 euros (%)	10.08	5.07	3.70	4.46

Behavioural aspects of consumer clusters

The cluster analysis allows to define the 4 profiles of consumers, on the base of their declared behaviours and preferences related to the purchase and consumption of flour and bakery products.

Conscious consumers buy groceries more than once a week, especially in supermarkets, but they are also interested in local shops. They are interested in taste of products and Italian/geographical indications. They cook and bake (especially bread and pasta) at home 3-4 times a week, and their main sources of information about food are labels and family members. They purchased grains-based products at least once in the last month and perceive them as tastier, richer in fibre, healthier, and more digestible than conventional bakery products. They generally like ancient grains-based products, preferring pasta and bread.

Low-involved consumers do groceries around once a week, especially in supermarkets. They are interested in the taste and price of food, while having low interest in organic labels and brands. They cook at home 4-5 times a week and bake bread and pasta at home at least once a week. Their main information sources about food are labels and vendors. They bought ancient grains-based products, but not in the last month. They consider those products tastier, more digestible, healthier, and richer in fibre than conventional bakery products. They are not interested in the caloric and gluten content of ancient grains-based products, they prefer bread and pasta made with ancient grains and have some interest in breakfast cereals and snacks

Pragmatic consumers buy food less than once a week in supermarkets and dislike online food shopping. They are interested in the taste and price of food and have a low interest in brand and organic label. They cook at home 5-6 times a week, but they seldom bake. They are not much informed about food, with food labels and family members as main information sources, disliking online information. They never bought ancient grains-based products but know them. Those products are perceived as tastier, richer in fibre, healthier, more nutrients, slightly lower in gluten and calories and easier to be cooked at home than conventional products. They might consider buying bread and pasta produced with ancient grains

Demanding consumers do groceries around once a week, almost only in supermarkets. They are quite interested in the taste and salubrity of food, cook at home 4-5 times a week, and bake at home less than once a week. Their main source of information about food is food labels, family members and, rarely, online resources. They bought ancient grains-based products at least once in the last few months, especially flour and pasta. Demanding consumers consider ancient grains-based products as tastier, more digestible, healthier, richer in fibres, slightly higher in gluten, less caloric, and easier to be prepared at home than conventional products. They are interested in flours and bread from ancient grains, with some interest also in breakfast cereals and snacks.

<u>Bread purchase simulation by clusters</u>

The results of choice experiments highlight the different levels of utility attributed by consumers to the characteristics of bread, as reported in Table 3.2.

Conscious buyers cluster bases its bread preferences on digestibility, followed by price, quality and lastly sustainability. It is also the group that assigns the highest importance to digestibility; indeed, they seek products that are very digestible or quite digestible. They are not very interested in the perceived quality; and, concerning sustainability, sustainable bread is selected more often than those with high or low sustainability. This group is also price sensible, perceiving the higher level of utility from bread costing 2 euros per kg.

Low-involved buyers assign the same level of utility to price and sustainability, followed by digestibility and perceived quality. Digestibility and perceived quality are not a priority for them, since they are more satisfied by products that are quite or poorly digestible and tend to prefer low-quality options. Also, they express high levels of utility for poorly sustainable bread and for a price of 2€/kg.

Pragmatic buyers give the same level of utility to digestibility and quality, followed by sustainability and price, they prefer bread that is at least quite digestible, with good chances to buy also the very digestible. They are also satisfied with low quality perceived and not very sustainable bread. Although the low level of importance is attributed to price, Pragmatic buyers are satisfied by a price of 6€/kg.

Demanding buyers assign higher level of importance to price, followed by sustainability, digestibility, and perceived quality of the product. They buy very digestible and very sustainable products, but they present the higher levels of utility for bread with low perceived quality and a price of 2€/kg.

Table 3. 2 Bread purchase simulation based on bread characteristics for each cluster of consumers

	Digestibility	**Perceived quality**	**Social and Environmental sustainability**	**Price**	**Average utility of bread characteristics**
Conscious consumers					
High - 6€/Kg	17.78	-0.56	-0.56	1.11	Digestibility: **62** Perceived quality: **14** Social & environmental sustainability: **2** Price: **20**
Medium - 4€/kg	14.44	-5.56	1.11	-8.89	
Low – 2€/kg	-32.22	6.11	-0.56	7.78	
Low involved consumers					
High - 6€/Kg	-3.33	-1.67	0	-3.33	Digestibility: **23** Perceived quality: **15** Social & environmental sustainability: **30** Price: **30**
Medium - 4€/kg	1.67	0	-3.33	0	
Low – 2€/kg	1.67	1.67	3.33	3.33	
Pragmatic buyers					
High - 6€/Kg	6.11	-3.89	-3.89	2.78	Digestibility: **37** Perceived quality: **37** Social & environmental sustainability: **15** Price: **10**
Medium - 4€/kg	9.44	-10.56	-2.22	-3.89	
Low – 2€/kg	-15.56	14.44	6.11	1.11	
Demanding buyers					
High - 6€/Kg	16.11	-2.22	26.11	-35.56	Digestibility: **18**

Medium - 4€/kg	-13.89	-12.22	-13.89	7.78	Perceived quality: **16**
Low – 2€/kg	-2.22	14.44	-12.22	27.78	Social & environmental sustainability: **25** Price: **39**

The analysis of consumer profiles and their answers to the choice experiments allows to identify peculiarities related to attitude and habits related to the consumption of flour and bakery products. The 4 groups of consumers express peculiarities in: the typology of shops in which they buy flour and bakery products, the sources from which they collect food information, and the level of awareness of characteristics of ancient grains-based products.

Business strategies definition

The peculiarities of consumer profiles on consumption of flour and bakery products of ancient grains are translated in six crucial aspects for ancient grain producers. Namely, i) nutritional values and sustainability characteristics; ii) presence in local markets and shops; iii) presence in large-scale markets; iv) awareness events of ancient grain products; v) consumption of ancient grain flour, bread, and pasta; vi) geographical origin of ancient grains products.

Building on this rationale, during the two focus groups organized on the 11th of June and 27th of July 2022, involving ancient grain supply chain producers, for each business aims several actions are identified and listed chronologically from the future state (2030) back to the present (now). This specific result (the list of possible key actions) provides business alternatives that should be put in place to change the current business structure of the SFSC of ancient grain for the desired outcome. Finally, the two rounds of Delphi are implemented to validate and consolidate actions proposed by ancient grain producers and provide a long-term business vision. In the I° round of Delphi, 23 stakeholders have been involved, of which 48% are from academia, 22% from industry, 13% from civil society and environmental management, and 4% from the government. The result provides a validated list of the three actions for each business aim. The three most appropriate actions have been selected based on the expert opinion. Table 3.3 summarizes the results per thematic areas, key actions, and acronyms.

Table 3. 3 Thematic areas, key actions, and acronyms

Thematic Areas	Key actions identified	Acronym
Nutritional values and the sustainability characteristics	Inclusion of nutritional and sustainability values data on packaging	NVSC1
	Communication of nutraceutical properties of ancient grains products on packaging	NVSC2
	Communication of environmental, economic and social impacts through social events	NVSC3
Presence in local markets	Creation of a local brand	PLM1
	Collaboration with local public procurement (e.g., canteens) and restaurants	PLM2

	Development of social media channels to increase awareness and visibility	PLM3
Awareness events	Usage of a social media channel	PAW1
	Creation of local events directly to the farms	PAW2
	Promotion of baking courses with local grains	PAW3
Presence in large scale retails	Agreement with large retail for fair prices and fair income for ancient grains consortium	PLS1
	Establishment of a consortium with a defined disciplinary	PLS2
	Creation of a certification system based on a participatory guarantee	PLS3
Increase production of flour, bread, and pasta	Promotion of economic advantages in producing ancient grains (economic sustainability)	PFBP1
	Construction of infrastructure for common use (e.g., grain storage centre)	PFBP2
	Increase the number of ancient grains producers in the supply chain	PFBP3
Geographical origin	Definition of a territorial label, based on the location of the supply chain	GO1
	Transformation in organic production supply chain	GO2
	Adoption of a "Talking" label	GO3

Afterwards, with the II° round of Delphi provides, the three actions are ranked over the selected period of 2028, 2025 and now. In this second round, 20 stakeholders have participated: 48% from academia, 22% from industry, 13% from civil society and environmental management, and 4% from governmental bodies.

Results lead to the definition of six sets of three actions for the promotion of ancient grains-based products to be carried out, as shown in Figure 3.3. Cases of uncertainty in the definition of the year in which an action should be conducted (such as PLM1, PLM2, PAW1, PLS3, PFPB2) are solved comparing answers form the participants to Delphi rounds to identify the most frequent indication.

Among key actions for the communication of nutritional values of products, 60% of experts identified as the most urgent key action to be implemented "*the inclusion of nutritional and sustainability values data on packaging*" (NVSC1). "*The communication of environmental, economic and social impacts through social events*" (NVSC3) was indicated as the key action to be implemented in 2025 with 45% of preferences, and "*the Communication of nutraceutical properties of ancient grains products on packaging*" (NVSC2) was considered as the last key action, to be implemented in 2028, by 65% of experts.

Concerning the actions to be adopted to increase the presence in local markets, "*the setup of collaboration with local public procurement and restaurants*" (PLM2) was identified as the most relevant for the current time with 45% of preference. Participants to Delphi considered *"the creation of a local brand"* (PLM1) as action to be conducted now or in 2025 by 35% of interviewed, as well as *"the development of social media channels to increase awareness and visibility"* (PLM3), with 40% of answers. Given the number of preferences accorded to conduct PLM3 action in 2025, this year was considered in the definition of the business strategy, while PLM1 has been set to be adopted in 2028.

For the promotion of awareness events, the key action "*promotion of local events directly to the farms*" (PAW2) has been identified as the most relevant for the actual moment, with 55% of preferences. "*The usage of a social media channel"* (PAW1) have been considered suitable for the current moment and for 2025 by 40% of respondents. Given the preferences accorded to PAW2 to be adopted as first key action for this thematic area, PAW1 has been identified as the key action for 2025. *"The promotion of baking courses with local grains"* (PAW3) was selected as action to be conducted in 2028 by 65% of interviewed experts.

The most urgent key action to be implemented to increase the presence in large scale retail market has been identified as *"the establishment of a consortium with a defined disciplinary*" (PLS2) by 45% of respondents. "*The creation of a certification system based on a participatory guarantee"* (PLS3) has been considered suitable for 2025 and 2028 by 40% of experts. However, since *"the definition of agreements with large retail for fair prices and fair income for ancient grains consortium"* (PLS1) was indicated by 40% of respondents to be adopted in 2028, PLS3 has been considered for the implementation in 2025.

Concerning the increase of the production of flour, bread and pasta, the key action *"promotion of economic advantages in producing ancient grains"* (PFPB1) should be the first to be adopted by 50% of experts. *"Increasing the number of ancient grains producers in the supply chain*" (PFPB3) has been considered for the implementation in 2025 by 45% of respondents, and *"the construction of infrastructure for common use, as grain storage centers"* (PFPB2) has been proposed for the implementation in 2028 by 35% of interviewed experts.

Finally, for the promotion of the geographical origin of products, the most urgent action has been identified in "*the transformation in the organic supply chain"* (GO2) by 65% of experts. "*The definition of a territorial label, based on the location of the supply chain"* (GO1) has been proposed for the implementation in 2025 by 75% of respondents and 80% of experts identified "*the Adoption of a "Talking" label*" (GO3) as key action to be adopted in 2028.

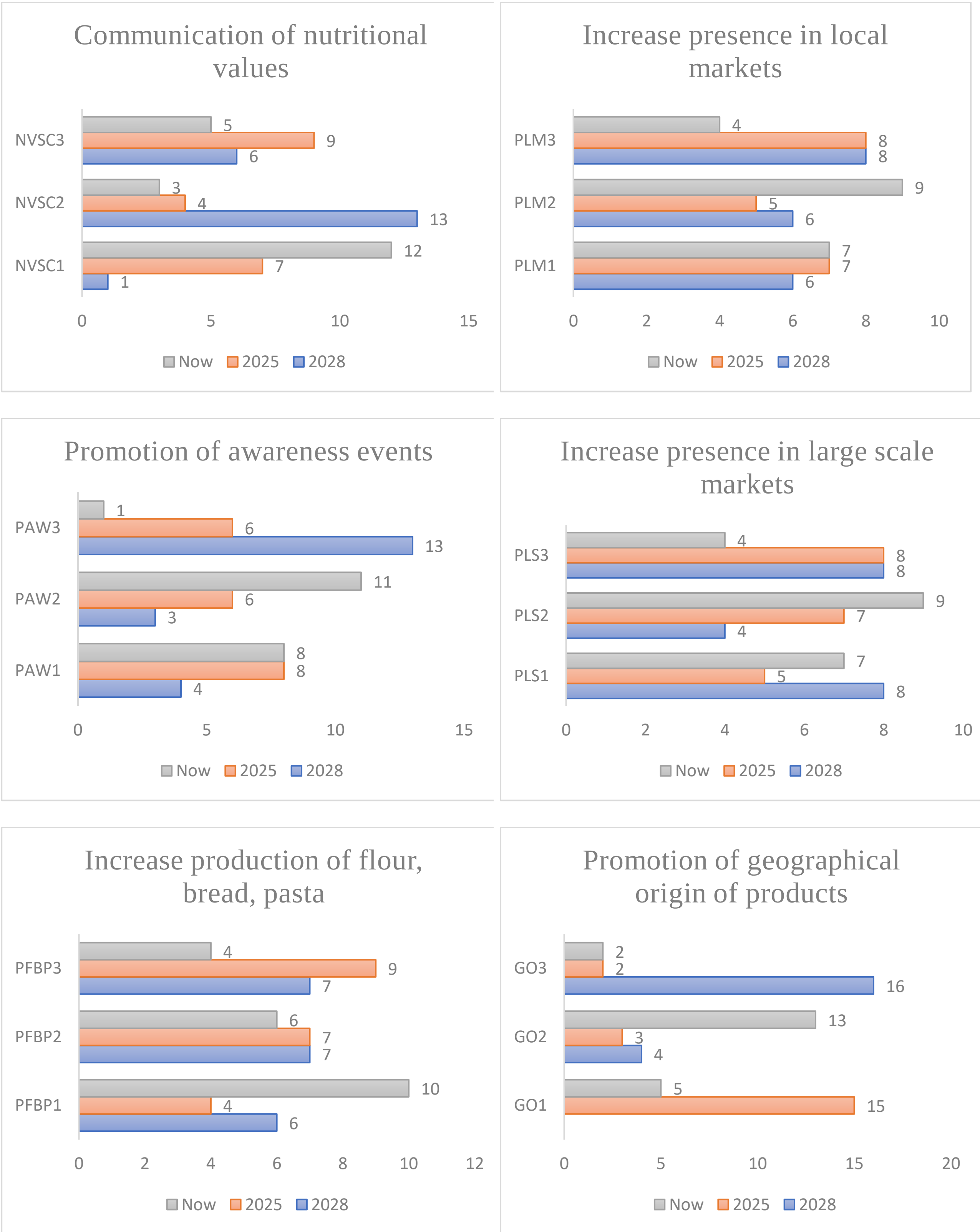

Figure 3. 3 Ranking of the three actions over the selected period of 2028, 2025 and now, following the backcasting time choice

Figure 3.4 summarizes the business strategy timeline for the adoption of the key actions. This result improves the matching between production and consumers' demand at the territorial level of Emili-Romagna region.

Actions that should be undertaken now are "*the inclusion of nutritional and sustainability values data on packaging"* (NVSC1), "*the setup of collaboration with local public procurement and restaurants"* (PLM2), "*the promotion of local events directly to the farms*" (PAW2), *"the establishment of a consortium with a defined disciplinary*" (PLS2), "*the promotion of economic advantages in producing ancient grains"* (PFPB1), and "*the transformation in the organic supply chain"* (GO2).

Actions to be conducted in 2025 include "*the communication of environmental, economic and social impacts through social events"* (NVSC3)*, "the creation of a local brand"* (PLM1), "*the usage of a social media channel"* (PAW1), "*the creation of a certification system based on a participatory guarantee"* (PLS3)*, "increasing the number of ancient grains producers in the supply chain*" (PFPB3), and "*the definition of a territorial label, based on the location of the supply chain"* (GO1).

Finally, actions foreseen for 2028 include "*the Communication of nutraceutical properties of ancient grains products on packaging"* (NVSC2)*, "the development of social media channels to increase awareness and visibility"* (PLM3)*, "the promotion of baking courses with local grains"* (PAW3)*, "the definition of agreements with large retail for fair prices and fair income for ancient grains consortium"* (PLS1)*, "the construction of infrastructure for common use"* (e.g., grain storage centre) (PFPB2), and *"the adoption of a "Talking" label"* (GO3).

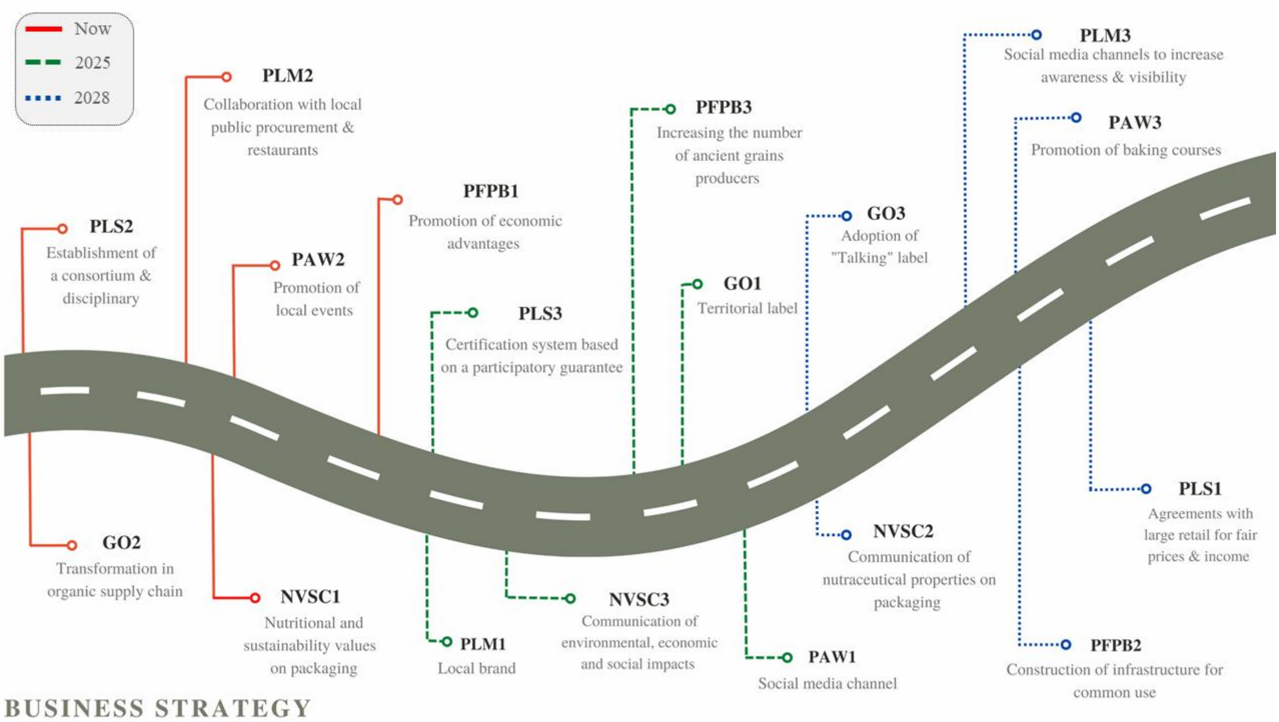

Figure 3. 4 Business strategy timeline

3.4 Conclusions

The objective of this study was to develop tailored solutions to match food production-consumption patterns at the territorial level, through an integrated methodology and by identifying the long-term vision and key actions of the short food supply chain to reach consumers' needs. Based on mixed methods research composed by a household survey and cluster analysis as quantitative methods, and focus groups and backcasting as qualitative ones, the work identifies 4 profiles of consumers, and peculiar behavioural characteristics on the attitude of flour and bakery products using ancient grains. The profiles identified are: *Conscious, Low-involved, Pragmatic, and Demanding* consumers. Then, six thematic areas to match production and consumption at the local level of the short food supply chain are disclosed: promotion of nutritional values and the sustainability characteristics, more frequent presence in local markets, organization of awareness events, more frequent presence in large scale retail shops, increased production of flour, bread, and pasta, and promotion of geographical origin of the products. Business actions are identified chronologically to provide a shared and clear business strategy for the short food supply chain. Delphi rounds with a quintuple helix approach allows a validation based on expert stakeholder consultation. Thus, it adds valuable perspectives from government, industry, civil society and environmental experts. The case study proposed is based on a representative sample of consumers (1.122) from 11 Regions of Northern Italy, giving a well-positioned comprehensive understanding of consumer preferences, attitudes, and motivations for ancient grain products. In addition, a long-term strategy allows producers to plan for the future and anticipate potential changes in consumer preferences or market conditions. This can help them to remain competitive and adapt to any shifts in the industry. Additionally, a well-defined strategy can help producers to attract and retain customers, as it demonstrates a commitment to matching their needs and staying up-to-date with market trends. This study's design allows for a comprehensive and holistic examination of the topic, providing valuable insights for researchers and practitioners alike to foster and promote local, thinking globally.

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Overall conclusions

The concepts of territory and territorial development have undergone a dynamic evolution in response to political, economic, and social transformations as the result of the intricate interactions and combinations of those elements, leading to the emergence of unique ecosystems that evolve over time. By considering the specific context and needs of a region, territorial approaches can ensure the transition toward a sustainable food system, tailored to the unique circumstances of the territorial context in which they are developed. They also emphasize the active participation and engagement of local communities and stakeholders in the development process. The research demonstrates that the effects throughout the food supply chains vary in terms of quantity and origin and that a comprehensive approach which incorporates environmental, cost, and social factors is necessary when implementing simultaneous measures.

The first aim of the research is **to investigate the environmental, cost and social indicators suitable to evaluate territorial performances of food initiatives within the City/Region context**. 10 social, 11 economic and 15 environmental key performance indicators are identified as suitable to measure sustainability performances of food initiatives within the city/region context, after testing in more than 100 case studies across 10 European countries. The sustainability scoring system provides a comprehensive and synthetic mechanism able to capture trade-offs between the three sustainability pillars of food systems dynamics. The results show a high level of comparability across scales and food sectors, highlighting the crucial role of this mechanism in advancing the evaluation of food initiatives' performance at different geographical levels. Based on the results, the social dimension scored the highest among the three pillars. Thus, it demonstrates the growing interest in food initiatives in the social aspects. The environmental dimension scored lower, demonstrating the difficulty in understanding, and finding data for some of the environmental indicators.

The second aim of the research is **to develop a territorial assessment framework to measure the sustainability impacts of agricultural systems**. The origin coupling between Integrated Assessment and Modelling and Territorial Life Cycle assessment is applied within a French territorial context of seven specific farms, including five arable farms and two livestock farms. By the eco-efficiency computation, it is possible to get insight into the relationship between the services provided by the territory under the study (such as waste management, transportation, and food production) and the environmental impacts associated. The comparison of agricultural management scenarios suggests an improvement in performance when a circular economy strategy is applied at the territorial level and local actors implement sharing inputs/outputs strategies. The cooperation between farmers at the local level maximizes crop-livestock farming systems in terms of food and economic functions while minimising direct and indirect environmental impacts.

Finally, the third aim of the research is **to propose a mixed methods approach to match production-consumption patterns at the territorial level**. The integrated quantitative-qualitative approach on producers and consumers is evaluated through a case study of an ancient grains supply chain in Italy at the Emilia-Romagna regional territorial level, in order to establish a long-term strategic vision for promoting sustainable and direct farmer-to-retailer short food supply chains. The validation and scalability of the business strategies are tested by two Delphi rounds with expert stakeholder participation. A long-term strategy allows producers to plan for the future and anticipate potential changes in consumer preferences or market conditions. A well-defined strategy can help producers to attract and retain customers, as it demonstrates a commitment to matching their needs and staying up to date with market trends in their territorial context.

Further development

Territorial approaches in food supply chains refer to collaboration and coordination between various stakeholders within a specific geographic area to improve the sustainability and resilience of food systems. It focuses on the promotion of local and regional food production, reducing food miles, and increasing the resilience of local communities to food insecurity and environmental challenges. This approach also promotes the creation of a more equitable and inclusive food system, by supporting small-scale farmers and food producers, particularly those from marginalized communities. The underlying causes of inadequate socio-economic and ecological outcomes are often unique to a particular location and must be tackled through localized strategies. To effectively address these issues, cities and regions should integrate data and metrics from various outlooks, including administrative boundaries and functional perspectives such as economic geographies of human behaviours (Tetsuya and Matsumoto, 2010). The approach proposed in this work helps to identify the unique characteristics of different territorial contexts and the challenges they face in terms of food security, sustainable production, and equitable distribution by involving a wide range of different stakeholders. In fact, the added value of the multi-actor approach, covering all stages of the food supply chain from production to final consumption, provides a shared and clear understanding of territorial dynamics. By adopting a bottom-up approach, qualitative methods help in defining social, economic, and environmental challenges of a site-specific area, as well as the perspectives and experiences of communities.

Research to policy

The European Commission encourages territorial approaches for agriculture and food supply chains. On one side, a set of policies and regulations, such as the Common Agricultural Policy (CAP) or the European Regional Development Fund (ERDF), supports farmers by ensuring a fair standard of living for the agricultural community and providing consumers with safe and high-quality food at reasonable prices. On the other side, a package of measures proposed, such as the European Green Deal, aims to make the EU's economy sustainable by achieving a climate-neutral EU by 2050, preserving and restoring biodiversity, and reducing pollution or propose a wide range of measures. However, to fully understand the effects of these policies on specific regions, quantitative and qualitative frameworks and metrics are needed.

Hence, this study aims to contribute to this ongoing political discourse by providing evidence-based recommendations for policymakers at both the European and national levels. The suitable indicators and the integrated scoring system proposed to provide a science-based support tool for policy planners and decision-makers in the city and region food system context. The scoring system allows practitioner and non-practitioner to have a rapid and simplified assessment tool which take into consideration the social, economic and environmental performance of their activities. In addition, it can provide a solid basic tool to collect data on food initiatives which operate across several agricultural sectors and can allow comparing trade-offs between initiatives in different Eu geographical contexts.

The territorial assessment framework developed can be a support tool for policy in evaluating and forecasting agricultural scenarios. Different sustainable practices, or for example Farm two Fork (F2F) strategic aims, can be evaluated to quantify resulting impacts on the ecosystem, keeping into account trade-offs between environmental, social and economic functions of the system both at in-farm and territorial levels. Finally, it can also help in discussing territorial responsibility between stakeholders to promote cooperation and targets which can aid policymakers in considering long-term environmental burdens between and within regions and territories. Finally, to promote and boost short food supply chain production, a multi-actor participation process is needed to match production and consumption wishes and built sustainable and resilient food supply chains.

Mixed methods research employed in this study increases the understanding of sustainability requirements for the current and future stakeholders in food supply chains. These policies aim to ensure access to safe, healthy and sustainable food and are essential for achieving a more sustainable and resilient food system for all EU citizens.

Limitations and further research

Concerning the sustainability scoring system proposed, research limitations can reside in the design of the mechanism. To deal with different steps of the food chain (e.g., food production, transportation, distribution, services) and with the scope to be as inclusive as possible for different food initiatives typologies (e.g., meat, dairy, vegetables, fruits), the indicators proposed and selected provide a starting point for an in-depth analysis of specific sectors. This limitation is also confirmed by the exclusion of some impact categories based on prioritisation by stakeholders engaged, and the effort required by actors in the data collection process. Aware of that, the sustainability scoring system can be tested in other contexts and researchers are encouraged to review and tailor KPIs based on a bottom-up approach with relevant stakeholders. The scoring framework is not intended to substitute a full LCA, LCC, and S-LCA assessment, but rather represents a simplified innovative tool which can help food initiatives within the city/region framework to identify strengths and weaknesses in their system. As concerned the second work, even though the coupling between agent-based integrated assessment and modelling, MAELIA platform and Territorial-LCA provides a novel approach for assessing the impacts of human agricultural activity at multiple territorial scales, further research is needed for modelling the livestock system. Furthermore, there is still a gap to fill concerning social functions at the territorial level. This lack is due to the difficulties in finding site-specific data concerning social indicators. Further research could investigate the social functions and metrics. Finally, the identified business strategies propose in the third work can vary based on the short food supply chains analysed. The work aims to demonstrate how qualitative and quantitative research can provide an integrated result in defining new territorial development strategies, more than defining one-fit for all strategy at territorial level.

Annexes

Annex – Chapter 1 (A-C1)

A-C1 Table 1. Literature review results of integrated life cycle sustainability assessment of City Region Food System

Articles	Authors and date of publication	Pillars	Methodology	Approach
Systemic Analysis of Food Supply and Distribution Systems in City-Region Systems - An Examination of FAO's Policy Guidelines towards Sustainable Agri-Food Systems	Armendáriz et al. (2016)	Social Economic Environmental	Development of an epistemic ground to understand FSDS; Analysis of the document from FAO "Studying Food Supply and Distribution Systems to Cities in Developing Countries and Countries in Transition—Methodological and Operational Guide (Revised Version)"	Systems Thinking (ST) and System Dynamics (SD)
An LCA-Based Environmental Performance of Rice Production for Developing a Sustainable Agri-Food System in Malaysia	Harun et al. (2020)	Environmental	Life Cycle Assessment (LCA) through ReCiPe 2016 method	Life Cycle Thinking (LCT)
Sustainable Agri-Food Processes and Circular Economy Pathways in a Life Cycle Perspective: State of the Art of Applicative Research	Stillitano et al. (2021)	Social Economic Environmental	Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol	Systematic literature review
A life cycle assessment of the environmental impacts of a beef system in the USA	Hiablie et al. (2018)	Environmental	Life Cycle Assessment (LCA)	Life Cycle Thinking (LCT)
Proper selection of substrates and crops enhances the sustainability of Paris rooftop garden	Dorr et al. (2017)	Economic, Environmental	Life cycle assessment (LCA) and life cycle costing (LCC)	Life Cycle Thinking (LCT)
Assessing sustainability of winter wheat production under climate change scenarios in a humid climate - An integrated modelling framework	Chami et al. (2015)	Social Economic Environmental	General circulation model (GCM), the Food and Agriculture Organization's (FAO) crop growth model (AquaCrop), a life cycle assessment (LCA) model and economic modeling	Outputs combination from different modeling tools
Quantitative assessment of the Japanese ''local production for local consumption'' movement: a case study of growth of vegetables in the Osaka city region	Hara et al. (2013)	Environmental	Multiscale analysis and scenario analysis	Flows quantitative assessment

Identifying eco-efficient year-round crop combinations for rooftop greenhouse agriculture	Rufí-Salís et al. (2020)	Economic Environmental	Life Cycle Assessment (LCA) considering different functional units and eco-efficiency assessment with market prices	Life Cycle Thinking (LCT)
Eco-Efficiency Assessment and Food Security Potential of Home Gardening: A Case Study in Padua, Italy	Sanyé-Mengual et al. (2018)	Economic Environmental	Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) to draw eco-efficiency portfolios	Life Cycle Thinking (LCT)
Incorporating user preferences in rooftop food-energy-water production through integrated sustainability assessment	Toboso-Chavero et al. (2021)	Social Economic Environmental	Integrated sustainability assessment incorporating user preferences to assess the FEW nexus	Life Cycle Thinking (LCT), Multiple sustainability indicators
Application of life cycle thinking towards sustainable cities: A review	Petit-Boix et al. 2017	Social Economic Environmental	Review of Life Cycle Thinking studies applied to urban systems	Life Cycle Thinking (LCT), Literature Review
Environmental and resource use analysis of plant factories with energy technology options: A case study in Japan	Kikuchi et al. (2018)	Environmental	Life Cycle Assessment (LCA) of different scenarios (energy technologies)	Life Cycle Thinking (LCT)

A-C1 Table 2. Previous key projects and initiatives useful for an integrated life cycle sustainability assessment of City Region Food System Initiatives

Projects	Pillars	Methodology
Glamur (Global and local food assessment: a multidimensional performance-based approach, EU FP7 project), 2013-2016	Social, Economic, Environmental	Case studies assessment through participatory evaluation, LCA, metabolic analysis, shadow pricing
SustUrbanFoods (Integrated sustainability assessment of social and technological innovations towards urban food systems, EU-H2020-MSCA-708672), 2016-2018	Social, Environmental	Case studies assessment on social and technological innovations
Re-fresh (Resource Efficient Food and dRink for the Entire Supply cHain, EU-H2020-641933), 2015-2019	Social, Economic, Environmental	Development of DSS tools, protocols, integrated models and simplified approaches
Valumics (Food Systems Dynamics, EU-H2020-SFS-33-727243), 2017-2021	Social, Economic	Structural analysis including system analysis; system simulations using system dynamics
EdiCitNet (Edible Cities Network, EU-H2020-SCC-2-776665), 2018-2023	Social, Economic, Environmental	Study, plan and implement successfully proven urban food systems
UrbaClim (Urban Agriculture – Climate Benefits Compared with Conventional Food Chains, Climate KIC), 2017-2018	Environmental	Quantitative assessment of urban farms' impacts on Climate Change
CIPURA (Climate and Innovation Potential of Urban Agriculture, Climate KIC), 2016-2017	Environmental	Systematic review
ECO-SCP-MED (Integrating Experiences and Recommendations in Eco-Innovation for Sustainable Production and Consumption in the Mediterranean Area, EU-1-CAP MED-12-12), 2013-2015	Economic, Environmental	Methodologies, tools, multilevel governance models developed in previous MED projects.
ECOTECH-SUDOE International network in lifecycle analysis and eco-design for environmental technology innovation, EU-INTERREG) 2011-2013	Environmental	Networking, education, piloting
GROOF (Greenhouses to Reduce CO2 on Roofs, Interreg NEW project), 2017-2021	Social, Environmental	Combining energy sharing and local food production
FERTILECITY I (CTM2013-47067-C2-1-R, Spanish Project), 2013-2016	Economic, Environmental	Unidirectional Building-Integrated Urban Agriculture
FERTILECITY II (CTM2016-75772-C3-1-R, Spanish Project), 2016-2019	Economic, EnvironmentalSocial	Bidirectional Building-Integrated Urban Agriculture
FEW-meter (an integrative model to measure and improve urban agriculture towards circular urban metabolism, JPI-H2020-730254), 2018-2021	Environmental, Social	Co-creation of methods of gathering, measuring and analysing data in collaboration with urban farmers for resource flow modeling
FUSION (Food Use for Social Innovation by Optimising Waste Prevention Strategies, EU 7th FP-311972), 2012-2016	Social, Environmental	Establish a tiered European multi-stakeholder Platform to generate a shared vision and strategy to prevent food loss and reduce food waste across the supply chain through social innovation
EUPHOROS (optimal greenhouse climate systems, minimal resource requirement. EU-FP7-KBBE-211457), 2008-2012	Economic, Environmental	LCA-based environmental study coupled with a complete financial assessment
SiEUGreen (Sino-European innovative green and smart cities, EU-H2020-774233), 2018 - 2021	Social, Economic, Environmental	Guidelines for a new interactive impact assessment approaches, Key questions on how to evaluate

		resource-efficient UA on social and economic aspects.

A-C1 Table 3. Survey

FoodE Survey_discover the sustainability of your activities!

Standard: Social Dimension (11 Questions)
Standard: Economic dimension (12 Questions)
Standard: Environmental dimension (16 Questions)

This survey is delivered by the FoodE European research project funded by Horizon 2020.
The main objective of FoodE is to involve European Union local initiatives in the design, implementation and monitoring of environmentally, economically and socially sustainable City Region Food Systems Initiatives.
The survey will take around 20mins and your participation in the survey will allow you to obtain a sustainability scoring on the social, economic and environmental dimensions of your activity to understand potential improvement opportunities and/or to communicate your performance and advancements to your community!
You will receive the sustainability scoring in the months following the closure of the questionnaire!

Start of Block: Social Dimension

Q1.1 How many waged employees do you have?
Full time [please indicate a number] ____
Part-time [please indicate a number] ____

Q1.2 Which contract type have you arranged with your waged employees?
All fixed term/temporary (1)
More than 50% fixed term/temporary (2)
50% fixed term/temporary (3)
Less than 50% fixed term/temporary (4)
None fixed term/temporary (5)

Q1.3 Could you indicate the monthly average gross wage (figured before any state and federal taxes, social security, and health insurance) in your organization (including both full and part time employees)?
< 1.000 (1)
1.001- 2.000 € (2)
2.001 - 3.000 € (3)
3.001-4.000 € (4)
>4.000 € (5)

Q1.4 How often does your organization provide workplace training to each waged employee? Please indicate the estimated hours/year

____

Q1.5 What is the share of female waged employees over the total number of employees?
<10% (1)
11-20% (2)
21-30% (3)
31-40% (4)
>50% (5)

Q1.6 What's the frequency of events (either in person or online) organized for the local community?
Less than 5/year (1)
6-10 /year (2)
11-15/year (3)
16-20/year (4)
More than 24/year (5)

Q1.7 Is your organization running activities for the disadvantaged people of your community?
Yes (5)
No (1)

Q1.8 Do you sell or manage products that you buy from other local producers?
Yes (5)
No (1)

Q1.9 Do you involve people from your communities in any volunteering activities?
Yes (5)
No (1)

Q1.10 How important are for your customers/users the following characteristics of your products?

	Very Unimportant (1)	Unimportant (2)	Neither Important or Unimportant (3)	Important (4)	Very Important (5)
Taste and freshness (1)					
Healthiness and nutritional quality (2)					
Affordability and fair price (3)					
Food Chain Fairness (7)					
Animal welfare (4)					
Improved food safety (5)					
Variety of food offer (10)					
Locally produced (8)					
Environmental sustainability (9)					

Q1.11
Additional Remarks Please, feel free to write here any comment/addition/remark you might have on the answers you gave in this section, to allow us better contextualise your responses.

____

End of Block: Social Dimension

Start of Block: Economic dimension

Q2.1 What is your annual net profit margin (ratio of net profits to revenues)? [please indicate (negative or positive) percentage]

____

Q2.2 What are your estimated revenues per year?

	0-20% (1)	21-40% (2)	41-60% (3)	61-80% (4)	81-100% (5)
Revenues from product sales					
Revenues from other activities					
Public funding					

Private funding

Q2.3 How do you expect your business to change in the next 3 years on the following aspects?

	Consistently Lower (1)	Lower (2)	The same or not relevant (3)	Higher (4)	Consistently Higher (5)
Product sales					
Other revenues					
Profits					
Number of customers/clients/users					

Q2.4 On average, where does your waged employees come from?
Mostly from external countries (5)
Mostly from your country (4)
I don't know (3)
Mostly from your region (2)
Mostly from your municipality (1)

Q2.5 What is the percentage of supplies sourced locally (from suppliers within a distance of maximum 50km from your venue)?
Less than 20% (1)
21-40% (2)
41-60% (3)
61-80% (4)
More than 81% (5)

Q2.6 Do you implement any specific fair practice towards suppliers?
Yes (5)
No (1)

Q2.7 On average, how many new customers (both end consumers and business buyers) or users do you have yearly?
None (1)
Almost none (6)
Few/a little bit (7)
Quite a lot (8)
Many/a great deal (9)

Q2.8 How often do your 1st time customers or users then come back?
Never (1)
Almost never (2)
Occasionally/Sometimes (3)
Almost every time (4)
Every time (5)

Q2.9 Do your single customers or users tend to increase their total expenditure?
Never (1)
Almost never (2)
Occasionally/Sometimes (3)
Almost every time (4)
Every time (5)

Q2.10 Do your new customers come because recommended by others (friend/colleague)?
Never (1)
Almost never (2)
Occasionally/Sometimes (3)
Almost every time (4)
Every time (5)

Q2.11 Do you sell on line through your own or third party platform?
Yes (5)
No (1)

Q2.12
Additional Remarks Please, feel free to write here any comment/addition/remark you might have on the answers you gave in this section, to allow us better contextualise your responses.

____

End of Block: Economic dimension

Start of Block: Environmental dimension

Q3.1 Regarding the crops you produce, manage and sell, how many of the following list of technologies do you use?
List:

- Renewable energy production (1)
- Closed-loop strategies to reduce wastewater (2)
- Natural ventilation without active cooling nor heating (3)
- Natural lighting (absence of artificial lighting) (4)
- Rainwater harvesting and use (5)
- Drought-resistance crops (6)
- Biosolarization (7)
- Crop rotation (8)
- Composting residual biomass (9)
- Organic fertilizers and biological control (10)
- Biological pesticides, plant bio stimulants, macerates and extracts (11)
- I don't know (12)

Q3.2 Regarding the meat, dairy and/or eggs and/or fish you produce, process or sell, do you prefer the ones being nourished by fed mostly coming from a distance of:
More than 60km (1)
41-60km (2)
I do not produce, manage or sell any dairy and/or eggs and/or fish or I don't know (3)
21-40 km (4)
Less than 20 km (5)

Q3.3 Regarding the fish you produce, manage, sell, what are the gear types used by these boats?
Mostly Trammel nets, demersal trawl, beam trawl, shrimp trawl (1)
Mostly Gillnets, Seine net, beach seine, Pelagic trawl (2)
I do not produce, manage or sell any fish or I don't know (3)
Mostly Traps, pots, longlining, hand lining, purse seine (4)
Mostly Spear, harpoon (5)

Q3.4 Do you cultivate, manage, or sell any ancient cultivar or raise any local breed?
Yes (5)
No (1)

Q3.5 Regarding the food you produce, manage or sell, how important is for you to cultivate or select products that:

	Very Unimportant (1)	Unimportant (2)	Neither Important or	Important (4)	Very Important (5)

	Unimportant (3)
Preserve the characteristics of the soil or fish stock	
Increase the functional biodiversity of the surrounding area	
Come from organizations caring of the diversity of their crops or breeds or fish stock	

Q3.6 How important is for you to work on water saving practices?
Very Unimportant (1)
Unimportant (2)
Neither Important or Unimportant (3)
Important (4)
Very Important (5)

Q3.7 Which type of electricity sources do you use?
All non-renewable (1)
Less than 50% renewable (2)
50% renewable (4)
More than 50% renewable (5)
All Renewable (6)

Q3.8 Which type of heating sources do you use?
All non-renewable (1)
Less than 50% renewable (2)
50% renewable (4)
More than 50% renewable (5)
All Renewable (6)

Q3.9 How much waste are you able to recycle?

	0-20% (1)	21-40% (2)	41-60% (3)	61-80% (4)	81-100% (5)
Organic solid waste					
Inorganic solid waste					

Q3.10 For each category, to which extent is your organization committed to improve its sustainability?

	Very Uncommitted (1)	Quite Uncommitted (2)	Committed (3)	Quite Committed (4)	Very Committed (5)
Reduce or reuse energy (electricity and heat)					
Reduce or reuse water					
Reduce or reuse organic waste					

Reduce or reuse production materials

Reduce or reuse construction materials

Reduce or reuse packaging

Q3.11 The packaging and materials I use are:
All Non-Recyclable and non-compostable (1)
Less than 50% recyclable and compostable (2)
50% recyclable and compostable (3)
More than 50% recyclable and compostable (4)
All recyclable and compostable (5)

Q3.12 The packaging and materials I use are:
All Non-reusable (1)
Less than 50% reusable (2)
50% reusable (3)
More than 50% reusable (4)
All reusable (5)

Q3.13 How close are you approximately to your main clients/customers on average?
More than 40km (1)
39-30km (2)
29-20km (3)
19-10km (4)
Less than 10km (5)

Q3.14 How is your product typically transported to your clients/customers?
All by using fossil fueled vehicles (1)
More than 50% by using fossil fueled vehicles (2)
50% by using fossil fueled vehicles (3)
Less than 50% by using fossil fueled vehicles (4)
None by using fossil fueled vehicles (5)

Q3.15 How are your supplies typically transported?
All by using fossil fueled vehicles (1)
More than 50% by using fossil fueled vehicles (2)
50% by using fossil fueled vehicles (3)
Less than 50% by using fossil fueled vehicles (4)
None by using fossil fueled vehicles (5)

Q3.16
Additional Remarks Please, feel free to write here any comment/addition/remark you might have on the answers you gave in this section, to allow us better contextualise your responses.

____

End of Block: Environmental dimension

A-C1 Table 4. Survey additional remarks

Additional remarks
(1) We are a research institute, so we are providing a service (perform research) rather than selling a product. This is why in the last question of this section we replied (neither important or unimportant) *(2) We are a plant-based restaurant; so, the animal welfare question is N/A. By the way, it is very important to us and that is why we made the choice. Not only for animal welfare, but also for other sustainability principles.* *(3) Do you adopt fair business practices towards suppliers? Question in my opinion N.A. for small businesses* *(4) Issues not relevant to us: fair practices and local sourcing* *(5) Lastly the question about my net profit margin does not apply to my model because the payments I collect from my members become my salary and there is nothing left. The initiative is not profit-driven, which is another point.* *(6) Our collaborative farm redistributes its products to members who work in the gardens, we do not actually sell them, they are part of a monthly subscription formula for users.* *(7) it is not possible for the customers to spend more than they already did, because there is a fixed package with a fixed payment which is prepaid at the beginning of the season* *(8) We do not use water in our processes* *(9) Some answers do not fit our structure, such as the questions about energy or the transport of goods to the customer. We will buy electric cars in the future and set up an electric filling station.* *(10) We do manage fish- however we are doing so in an aquaponics system - therefore none of the fishing gear for boats applies* *(11) We don't have employees since we are a family farm counting on family members only* *(12) We are a small family initiative with only family members involved and no employee* *(13) My work is rather a subsistence work for family self-sufficiency, without any employee* *(14) The meaning of 'our community' was a bit vague. We intended it a farm participating in our network and project stakeholders.* *(15) Affordability and fair price are different things. Affordability is cheap. Fair price it should be more expensive* *(16) I think affordability and fair price are two different things: My products are not in the affordable category, and my customers are not interested in my products and services because they are affordable, but rather for the fact that it pays "me" fairly. This is the reason that I ticked that box. Fair pay for the farmer/beekeeper is an important principle of our organization.* *(17) Given that our activity takes place in a region with limited economic resources and it is our organization's policy that all employees are members of the local community (they live in the towns closest to the farm), it can be said that we carry out activities for disadvantaged people; In other words, we employ them and we are a motor for the local economy, although we do not necessarily encourage any strict volunteer work.* *(18) As for the workplace trainings, we provide continuous day-to-day informal training to our employees, but we don't foresee any official/certified courses for them.* *(19) As we have just finished our first season focusing on building a food forest, there has been relatively little food produced yet.* *(20) The return frequency of customers is difficult to calculate given that we are a new reality, which has only been open for just over a year.* *(21) I do not know since this is my first year of implementing this initiative.* *(22) In my position as Responsible for Quality and Sustainability, I do not handle economic data and, consequently, the answers in this section are still somewhat vague estimates of my own, or mere conjectures (such as the percentage of net profits). In the same way, it is the Commercial Department that has exact information on the recurrence or not of customers.* *(23) What is your annual net profit margin (ratio of net profits to revenues)? I do not know.*

Annex – Chapter 2 (A-C2)

A-C2 Table 1 reports the cash crops, yields and the surface area for each arable and livestock farmer of the case study for:

Baseline scenario

Farm	Crop	Yield (kg/ha)	Surface crop (ha)
AF1	Barley Winter	5645	7
	Fava	4000	1
	Lupin	4000	5
	Maize Grain	3210	14
	Osr	2861	3
	Wheat Winter	5250	21
AF2	Barley Winter	6010	6
	Maize Grain	3499	22
	Osr	3292	9
	Wheat Winter	6168	19
AF3	Barley Summer	6766	21
	Barley Winter	6013	18
	Hemp	3997	10
	Peas	5000	13
	Wheat Winter	6575	37
AF4	Maize Silage	3401	29
	Mix Cereal	3171	5
	Osr	2937	2
	Wheat Winter	6076	30
	Buckwheat	1030	13
AF5	Buckwheat	1030	13
	Flax	1579	16
	Hemp	4619	12
	Maize Silage	3549	6
	Triticale Winter	6965	19
	Wheat Winter	5806	40
LF1	Barley Winter	4643	8
	Maize Silage	4991	30
	Wheat Winter	5650	16
LF2	Alfalfa	4000	3
	Maize Grain	4592	2
	Maize Silage	7446	27
	Mix Cereal	4574	6
	Triticale Winter	6547	9
	Wheat Winter	6138	19

Synergic scenario

Farm	Crop	Yield (kg/ha)	Surface crop (ha)
AF1	Barley Winter	5937	2
	Fava	4000	10
	Maize Grain	3267	10
	Osr	2851	3
	Wheat Winter	5313	21
	Barley Winter	5937	2
AF2	Barley Winter	6050	6

	Fava	4000	11
	Maize Grain	3596	12
	Osr	3371	8
	Wheat Winter	6320	21
AF3	Barley Summer	7031	17
	Barley Winter	6000	12
	Hemp	4283	9
	Peas	5000	18
	Wheat Winter	6592	34
AF4	Fava	4000	17
	Maize Silage	2830	17
	Mix Cereal	3248	5
	Osr	2467	2
	Wheat Winter	6135	29
AF5	Buckwheat	787	13
	Fava	4000	21
	Flax	1621	18
	Hemp	4734	12
	Maize Silage	3309	7
	Triticale Winter	6962	18
	Wheat Winter	5831	30
LF3	Barley Winter	4643	8
	Maize Silage	4991	30
	Wheat Winter	5650	16
LF4	Alfalfa	4000	3
	Maize Grain	4592	2
	Maize Silage	7446	27
	Mix Cereal	4574	6
	Triticale Winter	6547	9
	Wheat Winter	6138	19

A-C2 Table 2 reports the number of cows herd, and the amount of milk produced per cow for each livestock farmers for both scenarios

Farm	Herd	Milk Production (L/Cow/Day)
LV1	65	26.0
LV2	100	28.2

A-C2 Table 3 reports detailed processes used for the life cycle inventory (LCI) of crops considered for the case study and their sources of the inventories

Process	LCI sources	Database
Fertilizer treatment	Fertilizing, with spreader on bed/FR U	Agribalyse 3
Ammonia	Ammonium nitrate (AN) (with 33.5% N), at plant (WFLDB 3.5)/RoW U	Agribalyse 3
Urea	Urea (with 46% N), at plant (WFLDB 3.5)/RER U	Agribalyse 3
Organic Fertilizers	A. Manure, from cattle, stocked in concrete surface or pit	Agribalyse 3
Diammonium Phosphate	diammonium phosphate {RER}| diammonium phosphate production | Cut-off, U	Ecoinvent 3
Harvesting	Harvesting, with combine harvester, processing/RoW U	Agribalyse 3
Pesticide treatment	Plant protection, chemical weeding, with atomiser 400 l/FR U	Agribalyse 3
Pesticide	Pesticide, unspecified {GLO}| market for | Cut-off, U	Ecoinvent 3
Sowing	Sowing or planting, with classic seeder and harrow, processing/RoW U	Agribalyse 3
Tillage	Ploughing, with 4 soc plough/FR U	Agribalyse 3

Irrigation	Tillage, preparation irrigation/FR U	Agribalyse 3
Irrigation	Irrigation {FR}| market for | Cut-off, S	Ecoinvent 3
Barley seed	Barley seed, for sowing {GLO}| market for | Cut-off, U	Ecoinvent 3
Fava seed	Fava bean seed, for sowing {GLO}| market for | Cut-off, U	Ecoinvent 3
Maize seed	Maize seed, for sowing {GLO}| market for | Cut-off, U	Ecoinvent 3
OSR seed	Rapeseed, seed, conventional, at farm gate/FR U	Agribalyse 3
Wheat seed	Wheat seed, for sowing {GLO}| market for | Cut-off, U	Ecoinvent 3
Hemp seed	Hemp, grain, Champagne, at farm gate/FR U	Agribalyse 3
Pea seed	Pea seed, for sowing {GLO}| market for | Cut-off, U	Ecoinvent 3
Mix cereals	Mix of cereals and legumes, raw, at plant/FR U	Agribalyse 3
Flax seed	Linseed seed, for sowing {GLO}| market for linseed seed, for sowing | Cut-off, U	Ecoinvent 3
Alfalfa seed	Alfalfa seed, organic, at farm gate/FR U	Agribalyse 3
Triticale seed	Triticale seed, conventional, national average, at farm gate/FR U	Agribalyse

A-C2 Table 4 reports the animal feeding formulation and respective costs (Kg, and €; Cow/day) for both livestock farmers for both scenarios. Information were gathered by the Scientific Work of Catarino et al., (2021b, 2021a)

	LF1				LF2			
	Baseline scenario (Feed0)		Synergic scenario (Feed1)		Baseline scenario (Feed0)		Synergic scenario (Feed1)	
	Quantity (kg)	Cost (€)	Quantity (kg)	Cost (€)	Quantity (kg)	Cost (€)	Quantity (kg)	Cost (€)
Fodder	2.6±0	0.3±0.1	4.9±0	0.5±0.1	3.8±0	0.4±0.1	3.8±0	0.4±0.1
Hay	0.4±0	0±0	3.5±0	0.2±0	0.9±0	0.1±0.1	1.8±0	0.1±0
Maize Silage	11.9±0	1.5±0.3	9.5±0	1.2±0.2	8.8±0	1.1±0.2	8.8±0	1.1±0.2
Wheat	1.7±0	0.2±0.1	-	-	-	-	-	-
Cereal Mix Grain	-	-	-	-	3±0	0.5±0.1	-	-
Soya Bean	3.4±0	1±0.2	-	-	1.8±0	0.5±0.1	-	-
Vl3l*	-	-			3±0	1.1±0.1	3±0	1.1±0.1
Peas	-	-	3.3±0	0.6±0.2	-	-	-	-
Fava Bean	-	-			-	-	3.5±0	0.7±0.1
Total Cow Day	20±0	3±0.6	21.2±0	2.5±0.5	21.3±0	3.7±0.6	20.9±0	3.4±0.4

*vl3L is an industrial supplement.

A-C2 Table 5 reports **detailed processes** used for the life cycle inventory (LCI) **of livestock** considered for the case study and their sources of the inventories

Process	LCI sources	Database
Milking production	Conventional lowland milk system, silage maize 10 to 30%, animal class 6, at farm/FR U	Agribalyse 3

A-C2 Table 6 reports **the list of pesticide active ingredients** for which the characterization factors in relation with emissions to soil were missing from IMPACT World+

Id_product	Active_ingredient	Cas Number
Genamin T 200 Bm	Polyoxyethylene Amine	24991-53-5
Silwet L 77	Heptamethyltrisiloxane Modifie Polyalkylenoxide	27306-78-1
Adengo	Cyprosulfamide, Thiencarbazone-Methyl	-
Aviator Xpro	Bixafen	581809-46-3
Legacy Duo	Legacy Duo	-

Madit Dispersion	Madit Dispersion	-
Adigor	Huile De Colza Esterifiee	-
Rhysomax	Rhysomax	-
Madit Dispersion	Madit Dispersion	-
Pyros	Pyros	12208-13-8
Protugan	Protugan	34123-59-6
Cadeli	Cadeli	-
Notabi	Tritosulfuron	142469-14-5
Furi 10 Ew	Zetacypermethrine	-
Monsoon Active	Cyprosulfamide	-
Dash Hc	Esters Methyliques Dacides Gras	-
Fury 10 Ew	Zetacypermethrine	-

Reference:

Catarino, R., Therond, O., Berthomier, J., Bockstaller, C., Curran, M., Miara, M., Mérot, E., Messean, A., Misslin, R., Vanhove, P., Van Stappen, F., Stilmant, D., Villerd, J., Angevin, F., 2021a. A spatiotemporal dataset for integrated assessment and modelling of crop-livestock integration with the MAELIA simulation platform. Data Br. 36, 107022. https://doi.org/10.1016/j.dib.2021.107022

Catarino, R., Therond, O., Berthomier, J., Miara, M., Mérot, E., Misslin, R., Vanhove, P., Villerd, J., Angevin, F., 2021b. Fostering local crop-livestock integration via legume exchanges using an innovative integrated assessment and modelling approach based on the MAELIA platform. Agric. Syst. 189. https://doi.org/10.1016/j.agsy.2021.103066

Annex – Chapter 3 (A-C3)

A-C3 Table 1 Questionnaire

1. **Research objective**

Specifically, the activity to be promoted is aimed at assessing the consumer's level of knowledge about ancient grains and, above all, to find out which characteristics are desired, to be able to set up suitable actions to enhance them. Indeed, it is important to understand how a population of soft wheat, cultivated according to organic farming techniques and characterised by excellent flour properties, can be used and valorised to produce bread and biscuits sold through a network of specialised shops.

Therefore, the objective is to understand how the highest quality products, guaranteed by the adoption of low-impact processes, in line with the principles of technical sustainability, can have the requirements to succeed. The questionnaire aims to shed light on the level of knowledge about bakery products and flours made from ancient grains, their appreciation and consumers' expectations. Furthermore, this research aims at observing the behaviour and satisfaction of consumers towards the purchase of food products obtained from ancient grains.

Introduction to be read to the interviewee **The Emilia-Romagna Region has granted funding under the RDP 2014-2020 to the "VALCEA" project which is aimed at creating an organic supply chain** of ancient grains in the limited area of the provinces of Forlì-Cesena and Rimini. The project encompasses both the seed and milling production phases, as well as those linked to the use of the grain, so as to allow, on the one hand, the **maintenance of a cereal population** (the result of research developed in recent years by scientific institutions with the collaboration of seed companies and several farms), and, on the other hand, the creation of a supply chain capable of **increasing the income** of all its components. The results will have development prospects in areas considered marginal, where competitiveness cannot be based on quantity but on quality. The aim is to understand how the highest quality products guaranteed by the adoption of low-impact processes in line with the principles of technical sustainability can have the requirements for success. The questionnaire aims to shed light on the level of knowledge about bakery products and types of flour made from ancient grains, the appreciation for the same products, expectations and wishes. Furthermore, this research aims at observing the behaviour and the satisfaction of consumers towards the purchase of food products obtained from ancient grains.

2. **Privacy / GDPR**

Regulation (EU) 2016/679 on **the protection of natural persons with regard to the processing of personal data and on the free movement of such data** will be applied in the questionnaire.

Section 1: screening

The survey is aimed at people who are responsible for at least 50% of the grocery shopping and preparation of meals in their household.

S1: How often out of the total do you do grocery shopping for your household?

- Less than half of the time
- Half of the time
- More than half of the time

S2: How often do you prepare meals at home?

- Less than half of the time
- Half the time
- More than half the time

Section 2: General habits

Q1: On average, how often do you do grocery shopping in your household?

- (Almost) every day
- 4-5 times a week
- 2-3 times per week
- Once a week
- 2-3 times a month
- 1 time per month or less

Q2: How often have you bought food from the following shops? (1 = rarely; 7 = very often)

Categories	**Never/ not applicable**	**1**	**2**	**3**	**4:**	**5**	**6**	**7**
Online supermarkets								
Online shops different from supermarkets								
Neighbourhood/local shops (bakery, butcher shop, greengrocery)								
Directly from producers								
Outdoor markets /local markets								
Supermarkets /other Large Scale Retailers								
Take-away restaurants /home delivery (excluding pizzerias)								
Take-away pizzerias /pizza deliveries								

Q3: How relevant do you consider the following elements for your grocery decisions (1=not at all important 4=indifferent 7=very important):

Categories	**Never/ not applicable**	**1**	**2**	**3**	**4:**	**5**	**6**	**7**
Price								
Salubrity								
Taste								
Brand								
Italian authenticity								
Geographic indications (PDO, PGI...)								
Organic certification								

Q4: On average, how often do you prepare meals for your family?

- (Almost) every day
- 4-5 times per week
- 2-3 times per week
- Once a week
- Less than once a week

Q5: How often do you behave in the following ways (1 = rarely; 7 = very often):

Behaviours	**Never/ not applicable**	**1: rarely**	**2**	**3**	**4:**	**5**	**6**	**7: very often**
I plan what my family will eat <u>before I go shopping</u>								
I decide what my family will eat <u>while shopping</u>								
I use a shopping list								
I buy food products that I did not plan to buy								

Q6. How often do you use the following sources to collect information about the characteristics (benefits, intolerances etc.) of the food products you buy? (1 =rarely; 7 = very often)

Sources of information	**Never/ not applicable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Food labels
Other family members
Friends
Personally trusted vendors (baker, butcher, etc.)
Television programs
Books and weekly magazines/newspapers (e.g. RIZA-Salute, ok, Starbene etc)
Blog and specialized websites
Specialized social network pages /influencers
Training courses
Awareness campaigns

Section 3: Reasons for choosing flour and bakery products

Q7: When you buy bread, how important are the following characteristics? (1 = not at all important; 4 = indifferent; 7 = very important) (E=extrinsic feature, I=intrinsic feature)

Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Brand (E)							
Price (E)							
Origin of the product (E)							
Organic (certified) (E)							
Origin from a controlled supply chain (E)							
Recyclable packaging (E)							
Low environmental impact (E)							
Information on health benefits(I)							
Nutritional values (I)							
Short supply chain (small number of intermediaries between producer and retailers) (E)							
Production respecting workers' rights(E)							
Appearance (I)							
Taste (I)							
Leavening (I)							

Aroma (I)							
Type of yeast used (I)							
Type of flour used (I)							
Short-term fresh product (I)							
Long-life product (I)							
About to expire product offered at a lower price (E)							
The natural aspect of the product (I)							

Q8: When buying bakery products other than bread, how important are the following characteristics? (1 = not at all important; 4 = indifferent; 7 = very important) (E=extrinsic feature, I=intrinsic feature)

Characteristics	***1***	***2***	***3***	***4***	***5***	***6***	***7***
Brand(E)							
Price(E)							
Origin of the product (E)							
Presence of organic certification (E)							
Origin from a certified chain (E)							
Recyclable packaging (E)							
Environmental impact (E)							
Presence of elements beneficial for the body (I)							
Nutritional values (I)							
Short supply chain (reduced number of intermediaries between producer and retailers) (E)							
Production respecting workers' rights (E)							
Appearance (I)							
Taste (I)							
Leavening (if present) (I)							
Aroma (I)							
Type of yeast used (if present) (I)							
Type of flour used (if present) (I)							
Short-term fresh product (I)							
Long-life product (I)							

About to expire product offered at a lower price (E)	
The natural aspect of the product (I)	

Q9: How often do you buy the following types of flour? (1 = rarely; 7 = very often):

Types	**Never/ not applicable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Type 0								
Type 00								
Type 1								
Type 2								
Wholemeal flour								
Other								

Q10: Which of these characteristics motivates you to buy a pack of flour? (1 = not at all important; 4 = indifferent 7= very important)

Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Brand							
Price							
Origin of the product							
Organic (certified)							
Origin from a controlled supply chain							
Recyclable packaging							
Environmental impact							
Presence of elements beneficial for the body							
Nutritional values							
Short supply chain (reduced number of intermediaries between producer and retailers)							
Production respecting workers’ rights							
Possibility of seeing the product through the packaging							
The images on the packaging							
Intended use (bread, pasta, pizza, etc.)							
Strength / binder (W) values							

Q11: Have you ever bought ancient grain flours (produced from varieties and species of wheat that were once widely cultivated, such as Senatore Cappelli, spelt etc.)?

- Yes, I buy them regularly

- Yes, I bought it at least once in the last month
- Yes, but I did not bought it in the last month
- No, but I know them
- No, and I do not know them

Q12: [If Q11=yes] In which of these **characteristics** have you found differences compared to commercial flours? (1=worse; 4=no difference; 7=better)

Characteristics	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Flour workability							
Taste of the prepared product							
Digestibility of the prepared product							
The appearance of the prepared product							
Shelf-life of the prepared product							

Section 4: Purchasing behaviour

Q13: How often do you buy a 1kg pack of flour? (1 = once a month or less; 7 = once a week or more often)

Never/ not applicable	**1 Once a month or less**	**2**	**3**	**4**	**5**	**6**	**7 Once a week or more often**

Q14: Where do you buy the flour? (1=rarely; 7=very often)

Type of shop	**Never/ not applicable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Supermarket								
Bakery								
Mill								
Specialized/delicatessen shops								
Neighbourhood shop								
Online from the distributor's website								
Online from the manufacturer's website								

Q15 [if at least one of Q14-2-3-4-5=yes] When you buy flour and flour-based products from a local shop or directly from the producer, how do you rate these aspects? (1=not at all important; 4=indifferent; 7=very important)

Aspects	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Short supply chain (reduced number of intermediaries between producer and retailers)							

Production respecting workers' rights
Origin of the product
Advice from the storekeeper
Product's impact on the local community
Productions that reduces environmental impact
The professional ethic of the seller

Q16: How much do you agree with the following statement: I prefer to buy flour and flour-based products in a local shop rather than from large retailers (1=not at all agree; 7=completely agree)

1	**2**	**3**	**4**	**5**	**6**	**7**

Q17: I buy flour and flour-based products from large retailers because the price is cheaper than at the local shop (1=not at all agree; 7=completely agree)

1	**2**	**3**	**4**	**5**	**6**	**7**

Q18: I buy flour and flour-based products from large retailers rather than the local shop for convenience (1=not at all agree; 7=completely agree)

1	**2**	**3**	**4**	**5**	**6**	**7**

Q19: How likely are you to buy/try new cereal-based products (1=not at all likely; 7=very likely)

1	**2**	**3**	**4**	**5**	**6**	**7**

Q20: How likely are you to buy new ancient grains products (1=not at all likely; 7=very likely)

1	**2**	**3**	**4**	**5**	**6**	**7**

Q21: Do you follow a particular diet?

- yes, prescribed by a nutritionist;
- yes, suggested by a coach/personal trainer;
- yes, found on the internet /magazines /books;
- yes, prescribed by my doctor;
- no

Q22: If Q21=yes, for what reason (you can select more than one answer)

- health reasons;
- to increase my sport performance;
- to control my weight;

- for ethical reasons;
- other

Q23: Which typology of bread do you consume more often?

- Fresh bread;
- Prepackaged bread;
- I don’t eat bread

Q24: When you eat at home, how many people eat bread on average?

Number ___________

of which adults___ teenagers 13-18 years ___ children 0-12 years___

Q25: How often do you eat cereals and their derivatives?

Never	1 meal per week or less	2-3 meals per week	One meal per day	More than one meal per day

Q26: How often do you eat these types of cereals and their derivatives?

Product	Never	1 meal per week or less	2-3 meals per week	One meal per day	More than one meal per day
Soft wheat					
Durum wheat					
Corn/maize					
Spelt					
Millet					
Sorghum					
Barley					
Rye					
Rice					

Q27: How often do you eat these cereal-based products?

Product	Never	1 meal per week or less	2-3 meals per week	One meal per day	More than one meal per day
Breakfast cereals					
Pasta					
Bread					
Crackers and salted snacks					
Focaccia					

Desserts					
Pizza					

Section 5: Use of flours and grains

Q28: How often do you use flour for cooking meals at home?

Never	Once a week or less	2-3 times a week	Once a day	More than once a day

Q29: How often do you cook these products at home?

Food	Never	Once a week or less	2-3 times a week	Once a day	More than once a day
Bread					
Pasta					
Cakes					
Biscuits					

Q30: How often do you use these types of yeast?

Type	Never	Once a week or less	2-3 times a week	Once a day	More than once a day
Fresh sourdough starter					
Dehydrated sourdough starter					
Brewer's yeast					
Chemical yeast					

Q31: For cooking meals using flour, how often do you use these kitchen tools? (1= rarely; 7= very often)

Utensils	Never/ I don't have it	1	2	3	4	5	6	7
Chopping board								
Electric mixer								
Manual pasta machine								
Electric pasta machine								
Planetary mixer								
Bread machine								

Bimby or similar

Q32: In the last month, which of the following products from ancient grains, in the past largely cultivated (for example pasta, flour or Senatore Cappelli's bread, spelt), have you bought? (1=once a week or less; 7=once a day or more)

Product	**Never/ not applicable**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Pasta								
Bread								
Breakfast cereals or snacks								
Biscuits								
Flour								

Q33: Do you think that ancient grains products, compared to the conventional one, are: (1= strongly disagree; 7= very much agree)

Characteristics	**Don't know/don't want to answer**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
More digestible								
Less inflammatory								
Healthier								
Lower in gluten								
Less caloric								
Tastier								
More nutrient								
More suitable for a diet								
Easier to cook at home								
Higher mineral salt content								
Richer in fibres								
Higher in gluten								

Q34: In the near future, how probably are you going to buy these ancient grains' products? (1= very unlikely; 7= very likely)

Products	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Pasta							
Bread							
Breakfast cereals or snacks							
Biscuits							
Flour							

Q35: Usually, after eating a pasta dish (80-100 gr), do you feel…? (1=never; 7=very often)

Feeling	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Satisfied							
Weighted down							
Light							
Fulfilled							
Still hungry							
More active							
Slower/slacken							

Section 6: A focus on gluten

Q36: How much do you agree with the following statements about gluten? (1= strongly disagree; 7= very much agree)

Gluten...	**Don't know/don't want to answer**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
is a protein								
is the product of two proteins								
is present within the flour								
is present within the bread								
is present in all the bread typologies, with no distinction of quality								
is present in bakery products depending on the flour								
is present in the bread depending on how it is cooked								
is essential for the body								
is dangerous for the body								
is dangerous for the body if taken in excessive quantities								
is dangerous for the body only for intolerant or allergic people								
is beneficial for the body								
The elasticity of dough depends on the amount of the gluten contained								
The elasticity of dough depends on the strength of the gluten contained								
A gluten-free product is less caloric than a gluten-containing product								
A gluten-free diet has health benefits								

Products derived from ancient grains contain a greater <u>amount</u> of gluten than those obtained from industrial grains

Q37: In your opinion, how much does the gluten contained in baked goods (as bread) affect the following characteristics? (1 = not influential at all; 7 = very influential)

Characteristics	**Don't know/don't want to answer**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Consistence								
Taste								
Smell								
Leavening								
Elasticity of dough								

Section 7: Purchaseing simulation

Below you will be presented 9 examples of bread, with different levels of **digestibility, perceived quality and social and environmental sustainability** and with different **price levels per kg**. Please indicate the probability with which you would purchase each type of product that is proposed. Please indicate a value ranging from 0 (you would not buy it in any case) to 100 (you would buy it in any case).

We ask you to consider the following characteristics of the bread:

- digestibility: the ease of digesting bread and not feeling weighed down after consuming it
- Perceived quality: good quality bread has the following characteristics:
    - a pleasant aroma
    - a crust with ocher-yellow and brown colour, light, crunchy, not too thick
    - a crumb that adheres well to the crust, just moist, which does not crumble or become too compact. It is soft and slightly elastic in the mouth.
    - a high nutritional value
- social and environmental sustainability: a sustainable bread is produced using raw materials and processes that respect the rights of workers and the environment.

	Digestibility	**Quality perceived**	**Social and environmental sustainability**	**Price**	**Probability of purchase**
example 1	Quite digestible	Average perceived quality	Very sustainable	6 euro/kg	
example 2	Very digestible	High perceived quality	Quite sustainable	6 euro/kg	
example 3	Not very digestible	Low perceived quality	Not very sustainable	6 euro/kg	

example 4	Very digestible	Low perceived quality	Very sustainable	4 euro/kg
example 5	Not very digestible	Average perceived quality	Quite sustainable	4 euro/kg
example 6	Quite digestible	High perceived quality	Not very sustainable	4 euro/kg
example 7	Not very digestible	High perceived quality	Very sustainable	2 euro/kg
example 8	Quite digestible	Low perceived quality	Quite sustainable	2 euro/kg
example 9	Very digestible	Average perceived quality	Not very sustainable	2 euro/kg

Section 8: Demographic variables

Age: ______ years

Gender:

A. Male
B. Female
C. Not binary
D. Not specified

Citizenship: Italian Not Italian ……..

What is the highest degree you have obtained?

- Elementary school or lower
- Middle School diploma
- High School diploma
- Other diploma or technical specialization
- Bachelor
- Master/doctorate

How many people does your household consist of?

1	**2**	**3**	**4**	**>4**

Of which children 0-12 years: N°….. age….

Of which teenagers 13-18 years: N°….. age….

Where do you live?

- Big city (>100.000 inhabitants)
- City (20-100.000 inhabitants)

- Small city (10-20.000 inhabitants)
- Town (5-10.000 inhabitants)
- Rural or mountain area (<5.000 inhabitants)

What is the total monthly net income of your household?

- <1.000 euro
- 1.000-1.500 euro
- 1.500-2.000 euro
- 2.000-3.000 euro
- 3.000-5.000 euro
- 5.000-7.500 euro
- I don't know/don't want to declare it

A-C3 Table 2: clustering items and average values for clusters

Variable	Conscious	Low involved	Pragmatic	Demanding
Q1. Frequency of grocery shopping	2.58	3.03	3.25	3.06
Q2. Location of shopping (From 0='never'. to 7='very often')				
Online supermarkets	3.91	2.07	1.09	1.66
Online shops different from supermarkets	4.37	2.7	1.52	2.17
Neighbourhood/ Local shops	4.93	4.06	3.28	3.93
Producers	4.19	2.63	1.54	2.6
Outdoor markets	4.3	3.13	2.27	3.01
Supermarkets	5.74	5.97	6.07	6.15
Restaurant deliveries	4.45	3.02	1.75	2.58
Pizza deliveries	4.73	3.69	2.81	3.28
Q3 Elements influencing grocery decisions				
Price	5.64	5.64	6.09	6
Salubrity	5.6	5.51	5.77	6.1
Taste	5.95	6.07	6.26	6.44
Brand	5.47	4.86	4.56	5
Italian authenticity	5.77	5.64	5.57	6
Geographic indications	5.71	5.35	5.24	5.77
Organic label	5.49	4.91	4.46	5.2
Q4 Home-cooked meals (From 1='almost every day'. to 5='less than once a week')	1.83	1.52	1.27	1.27
Q6 Sources of food information (From 1='rarely'. to 7='very often')				
Food labels	5.51	5.13	4.9	5.36
Family members	5.38	4.61	3.69	4.56
Friends	5.27	4.27	3.11	3.99
Vendors	5.3	4.62	3.55	4.49
TV programs	5.21	4.02	2.79	3.68
Books/magazines	5.11	3.55	2.61	3.34
Blogs/websites	5.21	3.7	2.7	3.53
Social networks	5.15	3.57	2.25	3.08
Training courses	4.78	3.03	1.78	2.5
Information campaigns	5.15	3.93	3.02	3.82
Q7 Elements influencing bread purchase				
Brand	5.38	4.6	4.09	4.58
Price	5.51	5.35	5.66	5.67
Origin	5.71	5.51	5.48	5.91
Organic	5.59	4.9	4.23	4.97

Certified supply chain	5.56	5.25	5	5.6
Recyclable packaging	5.46	5.09	4.72	5.44
Environmental impact	5.52	5.17	4.85	5.41
Functional ingredients	5.66	5.36	4.98	5.64
Nutritional values	5.72	5.27	5.05	5.67
Short supply chain	5.61	5.1	5.1	5.64
Workers' rights	5.48	5.25	4.99	5.44
Appearance	5.54	5.45	5.47	5.88
Taste	5.81	6	6.3	6.38
Leavening	5.51	5.26	4.97	5.56
Aroma	5.6	5.47	5.71	5.97
Type of yeast	5.43	4.92	4.54	5.28
Type of flour	5.56	5.24	5.04	5.86
Short-term fresh product	5.63	5.52	5.44	5.88
Long-life product	5.37	4.71	4.46	4.59
About to expire prod. at a lower price	5.22	4.59	4.37	4.52
Naturalness	5.72	5.67	5.65	6.05
Q8 Elements influencing bakery products other than bread purchase				
Brand	5.45	4.84	4.49	4.82
Price	5.55	5.49	5.77	5.74
Origin	5.69	5.45	5.31	5.88
Organic	5.57	5.08	4.39	5.24
Certified supply chain	5.57	5.26	4.99	5.56
Recyclable packaging	5.54	5.15	4.89	5.35
Environmental impact	5.62	5.21	4.92	5.52
Functional ingredients	5.65	5.43	5.09	5.68
Nutritional values	5.73	5.46	5.2	5.81
Short supply chain	5.62	5.11	4.99	5.6
Workers' rights	5.59	5.18	4.94	5.43
Appearance	5.62	5.51	5.6	5.85
Taste	5.77	5.93	6.15	6.31
Leavening	5.57	5.17	4.76	5.49
Aroma	5.58	5.63	5.76	5.99
Type of yeast	5.56	5.1	4.61	5.41
Type of flour	5.67	5.31	5.03	5.76
Short-term fresh product	5.71	5.37	5.15	5.64
Long-life product	5.39	4.9	4.78	4.83
About to expire prod. at a lower price	5.42	4.95	4.61	4.67
Naturalness	5.63	5.61	5.57	6.04

Q10 Elements influencing flour purchase				
Brand	5.51	4.99	4.53	4.92
Price	5.52	5.41	5.36	5.47
Origin	5.74	5.41	5.21	5.91
Organic	5.65	5.09	4.34	5.33
Certified supply chain	5.62	5.17	4.74	5.65
Recyclable packaging	5.6	5.04	4.69	5.3
Environmental impact	5.6	5.11	4.74	5.42
Functional ingredients	5.58	5.27	4.71	5.6
Nutritional values	5.69	5.33	4.81	5.61
Short supply chain	5.61	5.12	4.66	5.52
Workers' rights	5.56	5.06	4.69	5.31
Possibility to see the product	5.5	4.68	4.07	4.7
Images on the packaging	5.42	4.32	3.6	4.1
Intended use	5.63	5.62	5.62	5.94
Strength/W	5.67	4.85	4.29	5.16
Q.11 Purchase of ancient grain flours *(*1='Yes. I buy them regularly'. 2='Yes. at least once in the last month'. 3='Yes. but not in the last month'. 4='No. but I know them'. 5='No. and I do not know them')	2.02	2.88	4.01	2.77
Q.12 (if Q11=yes) Perceived differences between ancient grain flours and conventional flours				
Flour workability	5.67	5.34	5.05 [D]	5.46
Taste of the prepared product[ND]	5.75	5.65	5.53	5.87
Digestibility of the prepared product[ND]	5.68	5.66	5.55	5.85
Appearance of the prepared product	5.63	5.34	5	5.4
Shelf-life of the prepared product	5.53	5.28	4.87	5.26
Q.23 Type of bread consumed				
Fresh bread (%)	77.82	81.33	74.07	90.59
Pre-packaged bread (%)	17.34	14.13	14.81	5.94
I do not consume bread (%)	4.84	4.53	11.11	3.47
Q29 Frequency of home-baking by product (From 1='never-less than once a week'. to 4='more than once a day')				
Bread	2.56	1.6	1.08	1.35
Pasta	2.49	1.73	1.2	1.33
Cakes	2.34	1.38	1.06	1.15
Biscuits	2.47	1.46	1.05	1.17
Q.32 Frequency of purchase of ancient grain-products (From 0='never'. to 7='once a day or more')				
Pasta	5.19	3.93	0.34	1.37
Bread	5.35	4.37	0.35	1.25

Breakfast cereals or snacks	5.1	3.4	0.2	0.69
Biscuits	5.19	3.54	0.25	0.94
Flours	5.08	3.28	0.28	1.4
Q33 Perception of ancient grain-products				
More digestible	5.64	5.35	5.02	5.68
Less inflammatory	5.6	5.09	4.85	5.38
Healthier	5.75	5.49	5.2	5.82
Lower in gluten	5.42	4.76	4.33	4.83
Less caloric	5.57	4.91	4.34	4.78
Tastier	5.82	5.23	4.84	5.7
More nutrient	5.75	5.39	5.05	5.54
More suitable for a diet	5.7	5.16	4.81	5.38
Easier to cook at home	5.67	4.93	4.15	4.71
Higher mineral content	5.65	5.12	4.72	5.26
Richer in fibres	5.8	5.45	5.34	5.74
Higher in gluten	5.35	4.22	3.83	4.1
Q36 Likelihood to buy ancient grain products by type (From 1='very unlikely'. to 7='very likely')				
Pasta	5.23	5.03	3.53	4.83
Bread	5.44	5.06	3.62	4.97
Breakfast cereals or snacks	5.26	4.6	2.98	3.98
Biscuits	5.3	4.73	3.35	4.45
Flours	5.37	4.98	3.35	4.99
Q36 Focus on gluten				
is a protein	5.48	4.75	4.7	4.8
is the product of 2 proteins	5.45	4.58	4.37	4.4
is present within the flour	5.57	5.15	5.27	5.44
is present within the bread	5.68	5.27	5.37	5.44
is present in all the types of bread. with no distinction of quality	5.34	4.77	4.52	4.55
is present in bakery products depending on the flour	5.54	5.15	5.18	5.41
is present in the bread depending on how it is cooked	5.42	4.8	4.5	5.18
is essential for the body	5.44	4.85	4.39	4.51
is dangerous for the body if taken in excessive quantities	5.07	4.2	3.57	3.77
is dangerous for the body only for intolerant/allergic people	5.3	4.86	4.76	4.9
is beneficial for the body	5.33	4.89	5.12	5.11
is dangerous for the body	5.66	4.77	4.33	4.39
the elasticity of the dough depends on the amount of the gluten contained	5.64	4.9	4.99	5.24
the elasticity of the dough depends on the strength of the gluten contained	5.64	5.03	4.99	5.2

A gluten-free product is less caloric than a gluten-containing product	5.43	4.6	3.87	4.13
A gluten-free diet has health benefits	5.45	4.6	4.01	4.45
Products derived from A.G. contain a greater amount of gluten than those obtained from industrial grains	5.48	4.59	3.91	4.09
Q37 Influence of gluten on baked goods				
Consistency	5.84	5.34	5.32	5.56
Taste	5.76	5.2	4.61	5.23
Smell	5.51	4.68	4.24	4.64
Leaving	5.77	5.32	4.88	5.44
Elasticity of the dough	5.72	5.37	5.52	5.56

Note: ND= no significant statistical differences among clusters