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SYSTEMIC CHANGE FOR SUSTAINABLE FUTURES

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THEME 4. RETHINKING AND RECONFIGURING FOOD PRODUCTION AND CONSUMPTION

Convenors: Mikelis Grivins, Marc Tchamitchian, Anda Adamsone-Fiskovica

LOCAL SOLUTIONS TO GLOBAL CHALLENGES

Healthy and Sustainable Diets: common conceptualizations and policy frameworks

Roberto Henke[a], Maria Luisa Scalvedi[b], Patrizia Borsotto[a], Annalisa Angeloni[a], Sabrina Giuca[a], Giampiero Mazzocchi[a]

a CREA – Research Centre for Agricultural Policies and Bioeconomy, Italy, roberto.henke@crea.gov.it; patrizia.borsotto@crea.gov.it; annalisa.angeloni@crea.gov.it; sabrina.giuca@crea.gov.it; giampiero.mazzocchi@crea.gov.it

b CREA - Research Centre for Food and Nutrition, Italy, marialuisa.scalvedi@crea.gov.it

Abstract:

The research is focused on building up an advanced and improved conceptual framework to orient policies supporting the promotion of HSD within the framework of national food policies. To this aim, we have analysed the documents which focus on HSD at international, European and national level. Furthermore, we have identified the policy domains that have gradients of connection with the promotion of HSD and assessed their occurrence in the documents. The preliminary results, deriving from the ONFOODS project, show that Italian national policies on HSD are very much anchored to the nutritional and health dimensions and food consumption behaviours, have elements of connection with food processing, but are poorly connected with agricultural components and productive aspects of food systems, as well as those linked to socio-economic aspects. These dimensions are instead prevalent in international and European guidance documents, probably due to their non-binding nature and strategic direction.

Keywords: healthy and sustainable diets; food policies; food environments; review

Purpose

The definition of "sustainable diets", set out by FAO in 2010 (published in 2012), includes the dimensions of the environmental impact of production and transformation processes, food and nutritional safety, public health, economic access and cultural appropriateness. In the last decade, crises and profound changes in the socio-techno-economic systems have questioned the definition and conceptual frameworks of Healthy and Sustainable Diet (HSD). A growing number of institutional documents, government agencies and high-level organizations are addressing the (re)definition of HSD, and the multiple factors that favour the creation of food systems that balance

sustainable nutritional habits with fair, ecologically correct and socially acceptable food supply mechanisms. The very definition of "sustainability" is a topic of discussion and a stimulus for research when it comes to diets since it involves different policy areas and trade-offs. We started our work on the assumption that HSD objectives should be supported by a national policy capable of connecting the various elements of food systems in a systematic and coordinated way.

The main goal of this work is to analyse what the theoretical frameworks around HSD are, from which the most widely recognized common definitions descend (Bach-Faig, A. et al. 2022). To this aim, we have analysed the documents which, from a public policy perspective, focus on HSD at international, European and national level (Italy). We have selected the documents from 2010 on, considering the FAO definition as an important milestone in the HSD conceptualization and policy uptaking. Furthermore, we have identified the main policy domains that have gradients of connection with the promotion of HSDs and assessed their occurrence in the documents.

Design/Methodology/Approach

The assessment of theoretical frameworks was carried out through a review of reports, recommendations and guidelines produced by recognized bodies acting at different levels (international, European, and national/Italy). Based on such documentation, we carried out two types of processing:

- a textual analysis to identify common and specific traits at the three geographical levels;
- an analysis of the recurrence of policy domains in the selected documentation body, starting from the conceptual framework proposed by Bach-Faig et al. (2022).

The latter was carried out by identifying, for each policy domain, three keywords. The selection was based on the most cited words in the considered theoretical background (Bach-Faig et al., 2022). A review of the words has been performed after the presentation of the preliminary results to a panel of experts at the talk organized by the Italian Association of Agricultural Economists on March 21, 2024. Consequently, the frequency keywords were processed on the selected documents. Some semantic expedients were used to refine the search and avoid bias in frequency counting. To compare the frequencies across documents with different size, the number of times the keywords occurred has been divided by the number of pages in each document, net of index and bibliography, providing an Occurrence Index to assess the extent to which HSD-related policy domains are considered and addressed in the considered documents.

Table 1 shows the selected keywords associated with each policy domain. For the documents in Italian, the translation in Italian keywords has been used.

Table 1. Policy domains and relative selected keywords utilized for the textual analysis

Policy domains	**Selected keywords**
Food price regulation	price; fiscal; tax

Food marketing and labelling	label; marketing; advertising
Food composition and reformulation	processing/processed; nutrient
Public awareness campaign	education/educative; campaign; school
Public food provision	procurement; canteen
Food waste reduction	waste; food loss
Behaviour change	consumer; behaviour; habit
Agri-Food production	agriculture; rural; farm
Socio-economic system	governance; socio/social; access

Findings

Transversal qualitative analysis

In this section we reviewed the most relevant institutional documents published after the seminal work on HSDs by FAO (2012). We scaled our analysis form the wider international reports, which mainly fix principles of a technical nature about HSDs, to European papers, which work towards a policy framework, enlarging to view also to social and economic issues, to the national (Italian) level, with the aim to locate the process of building an HSD national policy and governance in a solid international framework. The main results of this review are reported in Table 2.

Many publications, especially those published after 2016, focus on Food Environments (FE) (PEN, 2021), intended as "links" between food systems and diets. A key commonality amongst the existing definitions of FE (Brug et al., 2008; Glanz et al., 2017) is the conceptualization of the FE in terms of the spaces within which food acquisition occurs, and the series of market-based opportunities and constraints that influence people's food acquisition and consumption (Turner et al., 2018).

Regarding the European level, the table reports non-institutional and institutional approaches. Most of the non-institutional EU reports focus mainly on an "upward stream" approach, focused on the lower parts of the food system and mostly on the consumer as the main economic agent. The European institutions shift the focus more on the upstream part of the system (primary sector), following a downward stream. Moreover, they centre the attention more on socio-economic aspects, underlining the relevance of the territorial scale in favour of an integrated approach for health diets and sustainable food.

The national level shows that there is a strong focus on nutrition and health aspects. The Italian Ministry of Agriculture initiated a process to define a strategy for the development and valorisation of the Mediterranean Diet. The ultimate goal is to promote an informative and practical approach that helps guide actions to transform agri-food systems towards green and climate-resilient practices, and also to educate education on children and young people in favour of HSDs. However, education on a healthy and sustainable diet requires decisive and stringent regulatory actions that are not yet rooted in our legal system.

Policy domain occurence

We analysed to what extent the nine policy domains listed in Table 1 are treated and addressed in the documentation relating to the defined different territorial levels. Figure 1 clearly shows that the two "extra" policy domains (Food production; Socio-economic dimension) are among the most recurring. This highlights that the dimension of agricultural production is relevant in the strategic orientation documentation at an international and European level. However, at a national level, its weight is greatly reduced, in favour of policy domains such as “Behaviour change” and “Food composition and reformulation”. This confirms what emerged from the qualitative cross-sectional analysis, that is, nutritional orientation is closely linked to eating behaviours and the composition of diets, when it comes down to a national scale. The exercise brings out "invisible" policy domains, i.e. which are not contemplated by the theoretical framework used. This provides useful indications for developing our research. In particular, the European level is the one most compliant with the identified policy domains, since the Occurrence Index values are the highest in almost all domains, while the international and, in particular, the national show much lower values.

Figure 1. Policy domains and relative Occurrence Index aggregated per geographical dimension

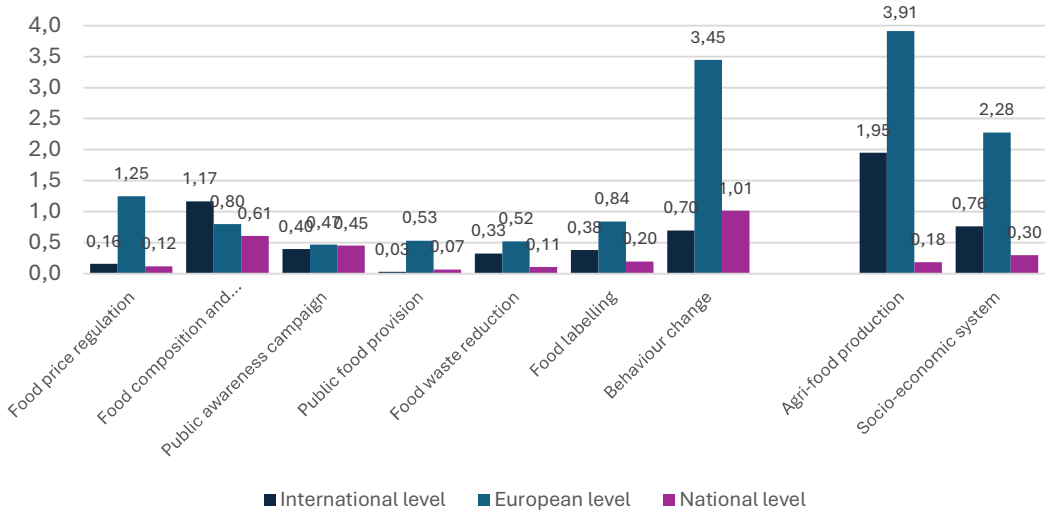

Table 2 - Main findings from the institutional document analysis

Territorial framework	**Main findings**
International	• Reports and guiding principles which do not imply binding commitments on states. Many of the findings are derived from comparative studies between different countries or data provided by them. In other cases, they are global in nature, providing guidance and direction based on a wide range of knowledge about the state of nutrition in the world and the environmental impacts of food systems. Only to a lesser extent, social and economic aspects that interweaved with HSDs are considered. • The main targets of this body of documents are in most cases national governments. To a minor extent, the reports target the private sector and food companies, or academic scholars. In very few cases they are designed to be read by citizens and consumers. • Following 2010 FAO definition of HSDs "sustainable Diets with low environmental impacts contributing to food and nutrition security and to healthy life for present and future generations", the issue of the sustainability of food systems has been placed at the core of international agendas and universally recognized approaches. • OneHealth approach: integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals, and ecosystems (Mettenleiter et al., 2023). • EAT–Lancet Commission on healthy diets from sustainable food systems (Willett et al., 2019): global scientific targets for healthy diets and sustainable food production, integrating universal scientific targets into a common framework. • Barilla Foundation: Double Health and Climate Pyramid, developed as a guideline for daily food choices that are healthy for humans and more sustainable for the planet. • After 2016: Food Environments as "link" between food systems and diets. Conceptualization in terms of the spaces within which food acquisition occurs, and the series of market-based opportunities and constraints that influence people's food acquisition and consumption (Turner et al., 2018).
European	• This section embraces a quite vast literature investigating mostly technical aspects of food policy and heathy diets. However, most of them highlight some policy recommendations on how to reach healthy and sustainable diets, ranging from consumer information and education (soft regulation) to guidelines and all the way up to regulation policies (hard regulation). • Most reports identify sustainable food policies with healthy food and the spread of healthy diets. The food system is mostly seen as in a constant state of change and evolution tied to consumer preferences and production systems.

	• Non-institutional reports approached HSDs essentially from the point of view of the physical sciences (EC-SAM, 2020). "Upward stream" approach, focused on the lower part of the food system and the consumer as the main economic agent: working on HSDs implies that the whole system adjusts accordingly, activating a flow that moves upward in the chain system. • HSDs are relevant not only for the balance of nutrients but also for the reduced impact on environment, reduction in transports, less processed food; however, it is also stressed the higher cost of these diets compared to more global diets. • Institutional (EC) reports follow a "downward stream", moving from the primary sector and looking at socio-economic aspects. Focus on the problems and needs of the primary sector and small food producers (trade-offs). All the institutional levels of governance should contribute to the construction of a sustainable strategy. • Food Environments should aim at overcoming trade-offs through mainstreaming the sustainable food approach into EU sectoral policies and developing an integrated food strategy. The new CAP moves along this path with a final goal of a Common Food Policy and the creation of a 'European Food Policy Council'.
National	• Italian food policy efforts to promote HSDs have often focused on raising public awareness of the importance of consuming healthy, safe and locally produced food. Within this framework, references to policies for HSDs are rather nuanced and focused mainly on sectoral or thematic initiatives, lacking, however, an overall vision that indicates ways and means to combine the various dimensions of HSDs. • Nutrition education on consumers, especially those with a low socio-economic profile, as well as children and young people, is considered crucial. However, education on HSDs requires decisive and stringent regulatory actions that are not yet rooted in the Italian legal system. • Lack of policy coherence for the development of HSDs, along with the multiplication of objectives and instruments derived from sectoral policies that very often do not talk to each other (agriculture, food safety, health, environment, technological development, research, education, social, budget, industry, markets, competition, trade) and that • Guidelines (CREA, 2019) include dietary recommendations inspired by the Mediterranean Diet. Extension of the concept of the nutritional pyramid to social practices (conviviality, cooking together, school, sport, traditions, seasonality, zero waste). • Food and dietary recommendations for healthy eating into the broader framework of climate-smart food systems. Policy efforts to promote HSDs have often focused on raising public awareness of

	the importance of consuming healthy, safe, and locally produced food.

Theoretical Implications

This study provides a conceptual framework based on a review of studies and reports focused on the implementation of food policy encompassing the promotion of HDS. Such framework represents a starting point for a next critical in-depth analysis aimed at designing a theoretical implementation in the Italian food environment. Food policy seems to pursue a shift of attention to a mix of technical issues (food composition), social issues (food access and cultural approach), health issues (diets), shading light onto the downstream component of the supply chain as well as to the food demand. Food policy feeds the growing interest of citizens about how food is processed, transported, kept, sold and so on, with a growing overlapping of security issues, origin of products and environmental issues (Brunori et al., 2013). Such shift is relevant for the definition of the "object" of the policy and the main policy domains covered, and for the tools that are put in place as well. In this regard, food policy lies on global universal principles, which have to do with food security and availability, food access, health and waste. Quite paradoxically, despite the attention and the action have mainly a local dimension, food policy moves from general principles that are reported in any international report on such issues. Consequently, technical aspects such as nutritional, healthy, environmental ones seem to prevail on social and economic aspects of the targets of the policies. On the target issues, food policy tends to follow an upward stream approach: through healthy and sustainable food the environmental impact decreases and, at the same time, the distortions and the trade-offs of the production systems are better balanced. On the contrary, the CAP and the primary products policies are moving in the opposite direction finally moving from general approaches and norms to local attention, designing policies that are closer and closer to local systems of production. The primary sector has always counted of a generous system of financial support through the CAP, which had looked at the consumer only for cheap food prices and then for healthy products. However, the CAP was born and still is a policy in support of farmers and farming activities, while food policy is meant to be a consumer policy where the focus is on food mainly as a public good (Biesbroeck et al., 2023). The CAP is also a highly regulated policy, based on incentives, standards and, in extreme cases on the elimination of choices available to produces and other actors of the sector. Food policy, having to do with individual choices, is less regulated and can rely on different typologies of intervention such as information, education, transparency, and mild persuasive policies (such as those connected to the food composition, food waste, and so on).

FEs represent a sort of conceptual link between the macro level of regulation typical of the upstream sectors of food and the individual choices made by consumers within a given supply of food. Little is known and investigated about the impact of EU

level policies on national food systems and also how EU could pragmatically change its policies in order to create healthy food environments in the EU.

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Scoring the environmental impact of food: lessons from the French controversy “Affichage Environnemental”

Quentin Chancé[a]

[a] UMR CNRS 6297 Laboratoire Droit et Changement Social – Université de Nantes

Abstract:

Assigning each food product a numerical rating for its environmental impact is a key social project in the ecological transition, but it is also a technical and scientific challenge. This article analyses the controversy surrounding the development of systems for rating the environmental impact of food products in France. The lessons learned highlight the interactions and boundaries between politics, technology, science and society. It reminds us of the importance of social and scientific control of public policy instruments and the importance of involving civil society in organising the transition.

Purpose

Displaying an environmental impact score on the packaging of food products (an approach similar to the NutriScore but for environmental impact) could have a strong influence on consumer purchasing practices. This would have a profound impact on food markets and the eco-design strategies of the players involved. By making it possible to estimate the environmental impact of foodstuffs, and thus give consumers the opportunity to choose the most environmentally-friendly products, this type of instrument could accelerate the transition in diets and the adoption of sustainable farming practices.

Public institutions - European and French - have been working on this idea since the early 2010s. The work carried out to design a rating system (RS) harmonised at European level has resulted in a reference methodology called PEF (Product Environmental Footprint), developed by the European Commission's Joint Research Centre. France, which is involved in this work and is the European leader in this field, has been building a database since 2010, enabling the scoring method to be applied on a large scale to thousands of products (AgriBalyse database developed by ADEME).

As a pioneer in this field, France has launched a regulatory experiment in 2020. This will enable public and private players who so wish to test the PEF reference methodology (using data from the AgriBalyse database), to improve the rating system if they so wish, and to distribute the scores generated to the general public in order to assess the impact of these ratings in real conditions.

This article analyses the controversy that arose during this experiment. It stems from differences between two formalised groups, one directly linked to the public authorities and ADEME, the other bringing together environmental and consumer protection NGOs, scientists and agricultural sector experts. The two groups have different ideas of what the rating system should be: what it should reflect, what data should be used, what

indicators it should contain, how it should be aggregated (standardisation, weighting) and how it should be displayed to consumers.

The rating systems currently supported by these two groups are EcoBalyse and Planet-score (see Figure 1). We will refer to them as RS^{GOV} and RS^{CSE} in this article:

- RS^{GOV} (for Governmental Notation System): EcoBalyse has been developed by the public authorities. The result of a government start-up aimed at facilitating information on the environmental impact of products, it is a website providing impact scores for generic products taken from the AgriBalyse database. The calculation methodology used is that which will be regulated by the public authorities. The format and visuals are not definitive (currently being decided by the public authorities) and the overall methodology is still being decided.
- NS^{CSE} (for Civil-society & Expert Notation System): PlanetScore was initially developed by ITAB (French interprofession of organic farming), Sayari and VeryGood Future). Supported by experts from civil society and the agricultural sectors, since 2023 the methodology has been the exclusive property of an endowment fund held by civil society and academic researchers.

Figure 1. Visuals of RS^{GOV} (left) and RS^{CVE} (right) scores

This contribution clarifies the history of the two rating systems, the social and technical reasons for their differences, and the consequences for the deployment of environmental food scores in society.

Design, methodology and approach

The analytical framework combines the sociology of quantification (Martin, 2020; Demortain, 2019) and sustainability assessment studies (Gasparatos, 2010, 2010; Alrøe et al., 2016; Reid and Rout, 2020). This work allows us to:

- Define the work of quantification as a "social act aimed at enabling or promoting agreement between individuals, between groups, between organisations, in time or space" (Martin, 2020) - in this case on the extent of the environmental impact of goods and services.
- Combining this social process with a technical, scientific and normative substrate: theories from different scientific disciplines and fields of expertise produce models, algorithms and databases that are linked together to form the calculation tools. The resulting rating system encapsulates worldviews: "By choosing the tools the analyst(s) "subscribe(s) to" and ultimately "enforce(s)" a particular worldview

as the legitimate yardstick to measure the performance of a project which might be incompatible with the worldview of the affected stakeholders." (Gasparatos, 2010, p. 1620).

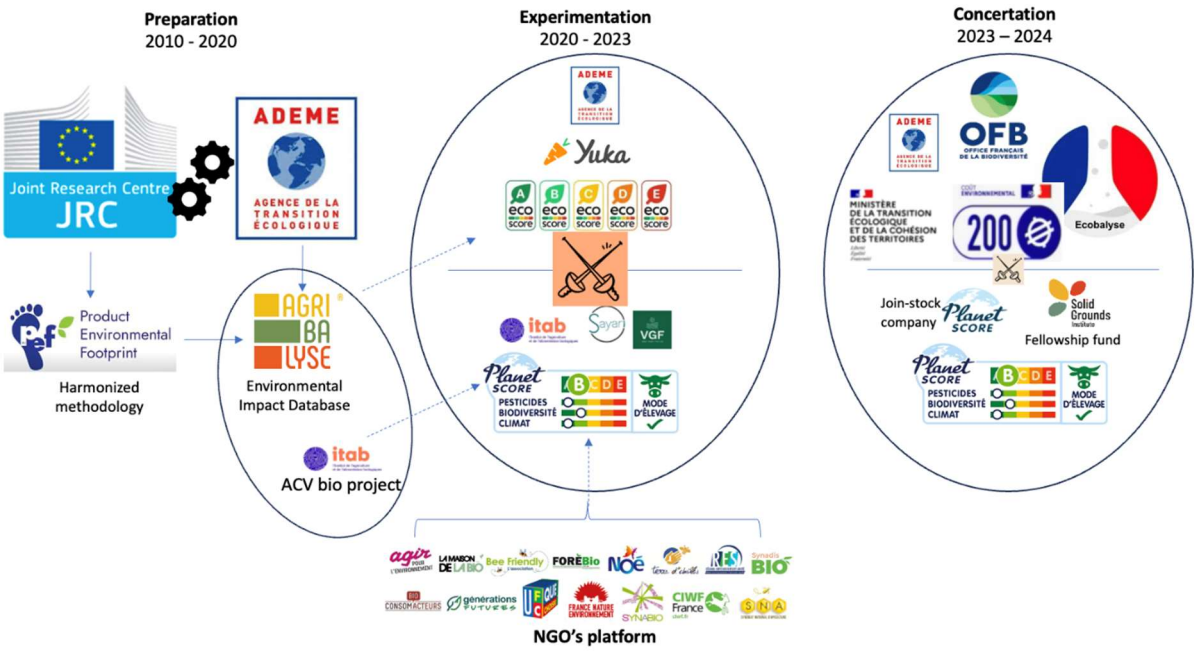
- Radical transparency (Reid and Rout, 2020) is essential to guarantee the social legitimacy of NS. This transparency concerns not only the content of the calculation but also how it was obtained, what it means and its limitations.

The controversy between the two RS (GOV and CVE) is analysed using the sociology of controversies (Callon et al., 2001), and particularly the work of (Barthe et al., 2022), which distinguishes the process of 'societal problematization' from the process of 'technical problematization'. The former refers to the way in which stakeholders debate the purpose and integrity of the project (in this case, environmental scoring). The second refers to the way in which technical issues are discussed.
The survey is based on semi-structured interviews with the two RS developers and on the analysis of a mixed corpus of documents: (i) reports from the experiment conducted as part of the Climate Resilience Act, available on the ADEME website, (ii) reports and technical documents published by the European Commission concerning the environmental footprint of products, (iii) documentation produced by the RS developers (EcoScore, EcoBalyse, PlanetScore) and (iv) an academic bibliographical study focusing on life cycle analysis, both in specialist literature and in the social sciences, facilitated understanding of the LCA methodology framework. I also participated in and contributed to methodological debates in France by taking part in the 'ecologist' working group organised by ADEME and by coordinating an interdisciplinary research collective (CESIAe) set up at the request

The origin of the „Affichage Environnemental“ controversy: does environmental RS fight or facilitate greenwashing?

In this section, we describe how the Environmental Signage policy project became a controversial issue, leading civil society to fight against the government's RS^{GOV} proposal and to propose its own tool for calculating RS^{CVE} impacts. The controversy pits the two scoring tools against each other in terms of their ability to combat or facilitate greenwashing.

Figure 2. Chronology of actors and devices participating to the “Affichage Environmental” controversy



Consumer and environmental NGOs assess RS^{GOV} as a greenwashing tool

This section explains how RS^{GOV} has been associated by various stakeholders with institutional greenwashing. This is surprising given that the political intention of the public authorities, which prompted the development of RS^{GOV}, was precisely to combat greenwashing through science and technology.

With the benefit of almost 10 years' experience in harmonising a methodology for calculating environmental impact (Product Environmental Footprint) and collecting data describing the life cycle of hundreds of products (AgriBalyse), the French government has launched an experimental phase to roll out environmental impact scores for food and textile products.

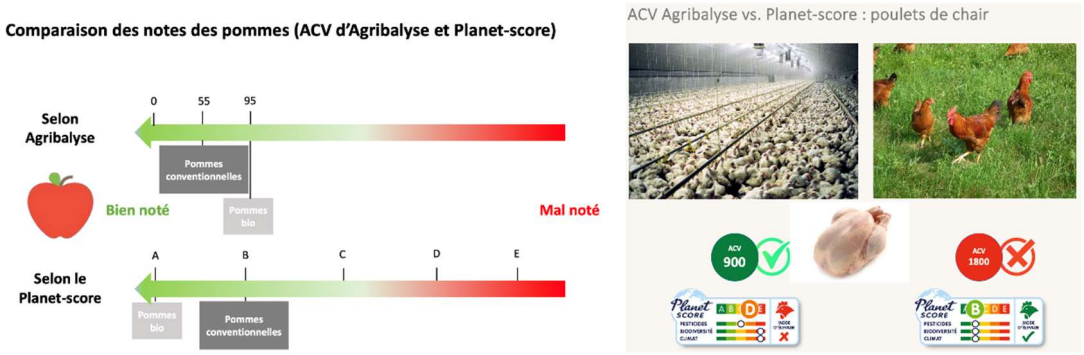
The "Environmental Labelling" experiment (see Figure 2) is an area of experimentation provided for and framed by the Climate Resilience Act (2020). The public authorities are thus putting the Environmental Signage project on the agenda in a participative governance format, involving civil and professional stakeholders in the methodology and institutional database (PEF & AgriBalyse). 18 projects have been submitted to the French Ministry for Ecological Transition, which is in charge of steering this experiment. Two of them will become operational and gain in recognition: the EcoScore, developed by digital companies (Yuka), and the Planet-Score developed by the ITAB (French organic technical institute), the Sayari consultancy and Very Good Future.

The start of this experimental period (2020-2021) coincides with the public release of the AgriBalyse database (September 2020), the use of which was strongly recommended. One of the candidates had been working on this database for 4 years via the ACVBio research project (specifically for the collection of data for organic products). This was the ITAB, which created PlanetScore. During their work, the members of the ITAB had identified various limitations and biases in the modelling of environmental impacts as

carried out by AgriBalyse, which led to the calculation of impact scores that they considered dubious. So even before applying and proposing their own scoring system (RS^{CVE} for PlanetScore), the ITAB had explicitly and publicly warned of the risks posed by using the AgriBalyse database as it stood (and therefore of the limitations of RS^{GOV}, which will be based almost exclusively on it).
The experiment put the spotlight on the scoring results of the AgriBalyse database, but also exposed its biases and shortcomings in the public arena. Civil society and stakeholders in the agricultural sector were able to compare the scores of hundreds of products. Inter-category scores: comparing beetroot with flour, cheese, eggs or beef. Intra-category scores: between the same food family but from organic or conventional production systems.
The biases identified by the ITAB have been reported by environmental and consumer NGOs. The RS^{GOV} scores indicated a very significant difference in impact between plants and animals (a difference of up to a factor of 100) and rated the most intensive systems very favourably - both in terms of inputs (fertilisers, pesticides) and spatial concentration (livestock farming). Extensive livestock rearing and agro-ecological farming methods (particularly organic) were assessed as the worst for the environment (see Figure 3).

Consumer and environmental associations then put together a series of pleas warning of the risk of institutional greenwashing if the government were to rely on the RS^{GOV} calculation method. This risk was formulated and disseminated in a series of reports, forums and seminars between December 2020 and March 2023, written by both NGOs and agricultural technical institutes. These documents explain the limitations of the PEF calculation method when applied to the agricultural sector, using both AgriBalyse scores which, in their view, illustrate inconsistencies in the classification of products and orders of magnitude, and detailed technical information. These technical elements relate, for example, to the choice of functional unit, the methods used to allocate impacts, the weightings chosen to rank the importance of impact indicators in relation to each other (does climate count for more than biodiversity?), modelling biases and even a lack of transparency.), modelling biases and even the complete absence of impact characterisation indicators (in particular those relating to ecotoxicity and the inclusion of pesticide impacts, the impact on biodiversity, the climate impact, the way in which carbon storage in soils is integrated for grasslands, etc.).

Figure 3. Examples of visuals produced to compare RS^{GOV} and RS^{CVE} scores (left, NGO press release, July 2021 / right, Planet-Score seminar at the French National Assembly, June 2023)



This control of the effects of calculation standards on the scores generated by civil society organisations and agricultural technical institutes echoes elements formulated by the Scientific Council of the experiment in its March 2020 report. It had already pointed out that "the impacts on biodiversity and soil carbon storage were not taken into account" (AE Scientific Council, 2020, p. 15) and mentioned the limitations of the PEF scoring methodology integrated into AgriBalyse (and therefore into RS^{GOV}). These biases were due to a lack of maturity and to limitations referenced by the scientific community in life cycle assessment. As a result, the AgriBalyse database (version 3.0, used during the experiment) "does not capture intra-category variability, for example associated with production methods or the origin of ingredients" (ibid, p.20).

This first phase shows how political goodwill was overtaken by technical problems. The dissemination of RS^{GOV}'s scoring results was intended to put on the agenda the idea of controlling dubious environmental claims by means of figures (thus combating greenwashing), and thus to structure and stimulate companies' eco-design initiatives by using quantified evaluation tools. In the end, haste led public institutions to alienate the very players they wanted to take with them in a virtuous process. This phase of experimentation put the issue of environmental scoring of food products on the agenda. But this was to the detriment of the credibility of the government's methodology (and to the benefit of Planet-score). From being a collective, participative and unifying approach to a project supported and legitimised by the public authorities, the experimentation discredited the intentions of the public authorities and the calculation tools they were proposing.

An alternative solution has emerged, based on a different calculation methodology with fewer institutional roots but greater recognition by civil and professional stakeholders. We will now present this alternative.

RS^{CVE} creates a calculation path using another epistemological approach

RS^{CVE}'s methodological proposal is based on a different methodological approach to RS^{GOV}. The calculation process is structurally different in that it is a two-stage process, superimposing two epistemic frameworks: life cycle analysis and multi-criteria analysis. This dual approach radically transforms the profile of food scores, i.e. the environmental classification of products in relation to each other, both between different food families (plant-animal) and within the same family.

RS^{CVE} is calculated as follows:

- Firstly, a score is generated using the LCA-PEF method from the AgriBalyse base, by correcting certain impact modelling elements as referred to above. These initial scores essentially reflect the differences between food families. These scores, graduated according to the PEF scale, are transposed onto another scale ranging from 0 to 100 via a mathematical transformation (logarithmic normalisation).
- In the second stage, around ten non-PEF indicators are used to assess the environmental impact of production systems and the value chain. Unlike the first calculation, which assesses the impact by accounting for material and energy flows, the second calculation is based on a characterisation of flows that are poorly counted in LCA (pesticides in particular) and on an assessment of agricultural production and supply chain practices (grazing time, crop rotation, risk of deforestation by origin of ingredients, etc.). In practice, this means that standardised scores can be varied from 0 to 100 using bonus-maluses (-4, +2, +10, -8 etc. depending on the corresponding indicator).

Creating this calculation layer in addition to and outside the PEF reference framework enables the RS^{CVE} designers to extract themselves from the methodological formalism of the LCA reference framework (see part 2 for more details). This has the consequence of facilitating the introduction of numerous indicators, but also of modifying the epistemic foundations of the calculation, relying in this sense on another scientific paradigm in the sense of Kuhn (way of qualifying the problem-solution pair and the problem-solving methods).

This transformation of the epistemic framework for calculating environmental impacts is not without consequences: other knowledge and research communities are mobilised, which differ from those mobilised in the PEF reference framework. This approach leads to a shift in the origin of the scientific legitimacy of the calculation tool. RS^{GOV} bases its scientific credibility on (i) the institutional recognition of LCA as the

international reference method for environmental assessment and (ii) the reputation of the technical and scientific expertise of the European Commission's Joint Research Centre, which developed the PEF method. RS^{CVE} does not have the same support, mobilising instead a combination of scientific and technical sources, including for example (i) prospective scenarios from institutions such as IDDRI or CNRS, (ii) academic publications from the agronomic and ecological sciences, (iii) expert reports produced by NGOs and consultancies specialising in the agricultural sector.

A battle ensued between the defenders of RS^{GOV} (particularly ADEME, which is heavily involved in the LCA community and the development of the government method) and RS^{CVE} (a civil and professional society comprising NGOs, agricultural institutes and representatives of general and organic retailers).
The former considered that their method was the most scientifically robust, as it was based on a life cycle analysis framework validated by the European Commission. They criticised the latter for their partisanship, defending an agricultural model (organic farming) rather than accepting the figures produced by science.
The latter considered that the results of the government method produced greenwashing, with figures to prove it. They criticised the former, using examples of ranking products that showed that the technical basis of life cycle analysis was not very robust, because it was not aligned with the sustainability assessments produced by the ecological sciences.

The tension between the two parties was all the greater because the regulatory framework originally provided for the existence of a single calculation methodology. The regulatory framework stipulated by decree that the methodological standard for all environmental assessments would be the RS^{GOV}, implying either alignment with it or the legal disappearance of any RS that did not apply the official calculation approach.

A tug-of-war ensued between public institutions and civil society, with each defending its own tool. This had the effect of delaying regulatory timetables on the one hand, but also of changing public policy positions on the regulatory framework. Lobbying work carried out in 2021 and 2022 by the French and European NGOs with the authorities at these two levels made this change possible. At European level, this work has resulted in a change to the framework of the GreenClaims Directive, which opens up the possibility of coexistence between state and independent methodologies. In France, discussions have begun on the government's calculation methodology.

Concertation: a round of technical participation to overreached the limits of RS^{GOV}

The government was originally due to set the single government method by decree during 2022. However, controversy prompted it to postpone this deadline and open a consultation process in March 2023. This consultation, organised by the Ministry for Ecological Transition, invited all stakeholders to contribute to improving the

government method. The official release of the state start-up EcoBalyse presented at the event - taking the form of a website serving as a platform for demonstrating the government's methodology - is being used to unite stakeholders and gather their contributions. It also demonstrates the government's desire for transparency by "opening the bonnet" of its calculation tool. All the calculation details are open source and stakeholders can simulate calculations for different ingredients or recipes.

The consultation opened with a speech by the Minister for Ecology, who affirmed that the existing biases in the government's methodology had been taken into account. Her team then listed the various points of progress and work in progress, including the failure to take into account a number of important criteria such as the positive externalities of agriculture, the inclusion of pesticides and the lack of a robust indicator for assessing the impact on local biodiversity.
A new framework was then proposed to deal with calculation biases. RS^{GOV} will now be based, on the one hand, on the LCA-PEF base, the technical improvement of which is the responsibility of ADEME, and, on the other hand, on a non-LCA base, the development of which is being carried out in consultation with the stakeholders and, in particular, with the Office National de la Biodiversité (French National Office for Biodiversity). During the spring, working groups were set up, including one for ecologists, to discuss how to create these non-LCA LFE impact indicators.

Although significant progress was made on RS^{GOV} via the various working groups, it is not possible here to analyse the progress made. Neither in terms of methodology nor scoring results. No publication or report on the method or the scores generated has been officially released since the end of summer 2023. The EcoBalyse tool has closed access to the food section since March 2024 (following the agricultural crisis). However, official announcements should be made from June 2024.

The technical dispute: Is science-based approach socially trustworthy?
In this section, we propose to explain why the controversy is still not over. This requires attention to the technical content of the NS and the results they produce, but above all to the audiences who construct them, those who observe them and the way in which the social legitimacy of the NS is constructed. We therefore need to analyse the components that shape the legitimacy of the NS in the eyes of stakeholders.

To identify the components of RS legitimacy, we analysed the lexical register used by the collectives of each RS (GOV and CVE), paying attention to the way in which they justify the merits of their RS and the way in which they qualify the technical choices of the other party. This leads us to analyse two sets of justifications relating to the "scientificity" of the calculation and the transparency of their designer.

A technical dispute about which methodology is scientific, transparent and trustworthy

First of all, we need to describe how the players involved in the controversy stage the oppositions between RSGOV and RSCVE. Stakeholders such as ADEME and the Planet-Score designers are at loggerheads over two points: the "scientificity" of their method and "transparency". Both elements form an integral part of what might be called registers of justification, enabling each to explain and prove to the various professional, political and civil parties the integrity of their work and the reasons for adhering to it.

Scientificity is an integral part of the controversy, since - in order to end it - we need to be able to determine which score repertoire is the "truest". Are RSGOV assessments more credible and scientific than RSCVE assessments? Which of the two systems provides better information on environmental impacts? Which is fairer and more accurate? How can two RSs produce such different representations of the world when they are assessing the same quantity?
The technical problem here is at the heart of the matter, but it is also virtually insoluble for most stakeholders for two reasons: (i) answering the above questions requires judges to have a very high level of expertise in the technical operation of the RS, and (ii) both RS claim to be based on Science. Each relies on a community of scientists and experts who defend the merits of their approach. How do you decide between two scientific disciplines? Which is the more 'scientific'?

RSGOV is based primarily on the scientific discipline of LCA. Its approach is rooted in the natural sciences, is intended to be non-political, and draws on a large body of theoretical and conceptual thinking on how to count environmental impacts. RSGOV uses the technical work carried out by institutions whose legitimacy has been established (in this case the JRC and ADEME).

RSCVE is based on several scientific disciplines that can be described as empirical or observational. The calculation system combines bibliographical references associated with ecological, environmental, agronomic and prospective sciences. The attachment to these disciplines is justified in terms of a pragmatic and systemic approach to the functioning of agroecosystems and social change. Although the theoretical underpinnings are more scattered across the indicators and therefore form a less homogeneous picture, it is nonetheless solid and validated by in-situ observations (a principle of the sciences studying complex systems).

RS^{GOV} stuck in a normative infrastructure: how to manage the LCIA gilded cage?

There is a normative infrastructure within national and international public institutions that makes LCA the standard for constructing environmental NS (Suikkanen et al., 2023; Sakellariou, 2018; Benoît Norris and Revéret, 2015). This normative infrastructure is the result of a long historical process implemented by the LCA community to assert its recognition as a holistic scientific discipline and make its tools the reference for carrying

out an environmental assessment by political decision-makers. This has had the effect of creating a path dependency around techniques derived from this discipline rather than others.

RSGOV is embedded in this infrastructure, constraining by path-dependency the innovation methods that can be implemented by the government. Indeed, RSGOV's developers use the old consensus built at high institutional levels, and limit the use of other disciplinary fields and tools (e.g. ecology or agronomy) to correct the method's shortcomings. To understand these lock-in effects, it is necessary to explain the history of the LCA discipline and its use as an environmental management tool (Heiskanen, 1997).

The LCA emerge in the 1960's as a classic multicriteria method, but applied to a succession of process. The purpose of its application is to define if product A is better or worse than product B. The better or worse being defined by the scope of the study. As all stages - from extraction to transformation until the consumption - are evaluated, the method took the name of "Life Cycle Analysis". However, it is primarily a multicriteria method. As such it can be implemented in a variety of ways, depending on multiple elements: the purpose of the study, the kind of impacts that should be evaluated and the criteria chosen to represent them, the methods used to calculate these criteria, the method used to aggregate and interpretate the results... A consequence is that most of the LCA studies realized in the 1990's reached very different conclusions. "Rather than disqualify LCA as a serious decision support tool, these findings triggered an international collaboration among scientists and LCA practitioners from industry and consultancy on furthering LCA methodology development and harmonization" (Bjørn et al., 2018, p. 22). Scholars and practitioners federated to build further consensus in the way LCA should be applied; harmonization being a key to its credibility and diffusion.

The growing LCA community used the support of international organization for this purpose. The International Standard Organization (ISO) was used in the 1990's to set the general framework. In the 2000's different national and international non-profit organization linked to international institution (as the FAO or the European Commission) created working-group to reach consensus about standardize metholodies. Such consensus-building process led to stabilize packages called LCIA, setting predefined impact categories, methods to model these impacts and interpretation kits. When initiating an LCA analysis, the practitioner selects the LCIA he wants to use in its LCA software. Several LCIA exists like ReCIPe (Netherlands), IMPACT World+ (Canada, USA, Denmark, France, Switzerland), EcoScarcity (Switzerland), LIME (Japan), TRACI (USA).

The Product Environmental Footprint (PEF) is one of these LCIA, developed by the European Commission unsing the expertise of its Joint Research Center.

The PEF has been produced to tackle greenwashing, by using a quantitative evaluation system to compare all products in all sectors above the classic system of standards and allegations. The idea was to assess how much green a product is by calculating its environmental impact. And the motivation of this quantitative journey came from studies showing that environmental benefits claimed by standards and allegations generally lack scientific control.

If the EU intent is noble – revealing the environmental impact using the LCA science – the resulting LCA methodology (PEF) has not been tested. The work engaged by the JRC aimed at harmonize the various existing LCIA methodology to avoid the initial gap of LCA : the diversity of resultats due to diverse configuration of the tool. As a consequence, the work was essentially theoretical and funded on consensus-building. The application of the resulting LCIA (PEF) really started with the experimentation phase initiated in France, leading to the controverse previously described.

No one could expect that the tool didn't work correctly for assessing agricultural products. As explained, the potential limits of PEF were not evaluated for a specific sector, as it was supposed to be applied to all sectors and the central goal of PEF was to delineate a harmonized methodology for all European countries. Neither the Joint Research Center of the European Commission nor the Scientific Committee of the French experimentation were mandated to assess the credibility of the results on actual products. As the scientists mobilized to the French experimentation writted in their first report : "There will be no discussion here of the appropriateness of using these methods [LCA - PEF] rather than others." (Conseil Scientifique AE, 2020, p. 15).

Moreover LCA scholars published special issues dedicated to the limits of LCA applied to agricultural (Notarnicola et al., 2017; Sala et al., 2017) and focused on its specific gaps like pesticides (Fantke, 2019) or biodiversity (Damiani et al., 2023). However, this scientific knowledge was produced once the PEF consensus was reached. As a consequence, institutional and expert group mobilized during the PEF development couldn't integrate such knowledge, and scientists involved in the french experimentation may not expect that such limits could exist (even some were recognized). Nowadays, a gap still remains between the knowledge produced by LCA scientific community and LCA institutional spheres, leading to a hole in the expertise process engaged in the RSGOV conception.

This history of LCA and PEF bring attention to the chronology of the expertise and the scientific knowledge production. It shows the gap between two worlds: the scientific one and the tecno-politic one. In its most advanced debates, the scientific LCA community recognized its limit to produce robust tool for some specific environmental issues and evaluation, and precognized to combine indicators and evaluation methods coming from other disciplines (Notarnicola et al., 2017; Sala et al., 2017).

For RSGOV conceptors (ie: French Ministry of Ecological Transition), stepping out the PEF is necessary but it doesn't imply excluding all the interest of an LCA approach. However it implies to create a specific expertise on LCA and beyond-LCA practices for evaluating agricultural products' sustainibility – which doesn't exist currently. Such engagement is necessary to shift the controverse from a scientific or technical problem (which RS is good or bad) into a political one. As matter of fact, the resolution need to engage a new round of consensus-building with the experts of the European Commission as the French controversy directly question the credibility of its previous results. The results from the concertation phase, which including the corrective made to the RSGOV – shall be discussed by scientific and social bodies, to assess both the methodological patch and the effets on the resulting scores. Finally it imply for politics bodies to question their definintion and the process chosen to define a science-based policy.

The co-existence between RS^{GOV} and RS^{CVE} : a technical necessity

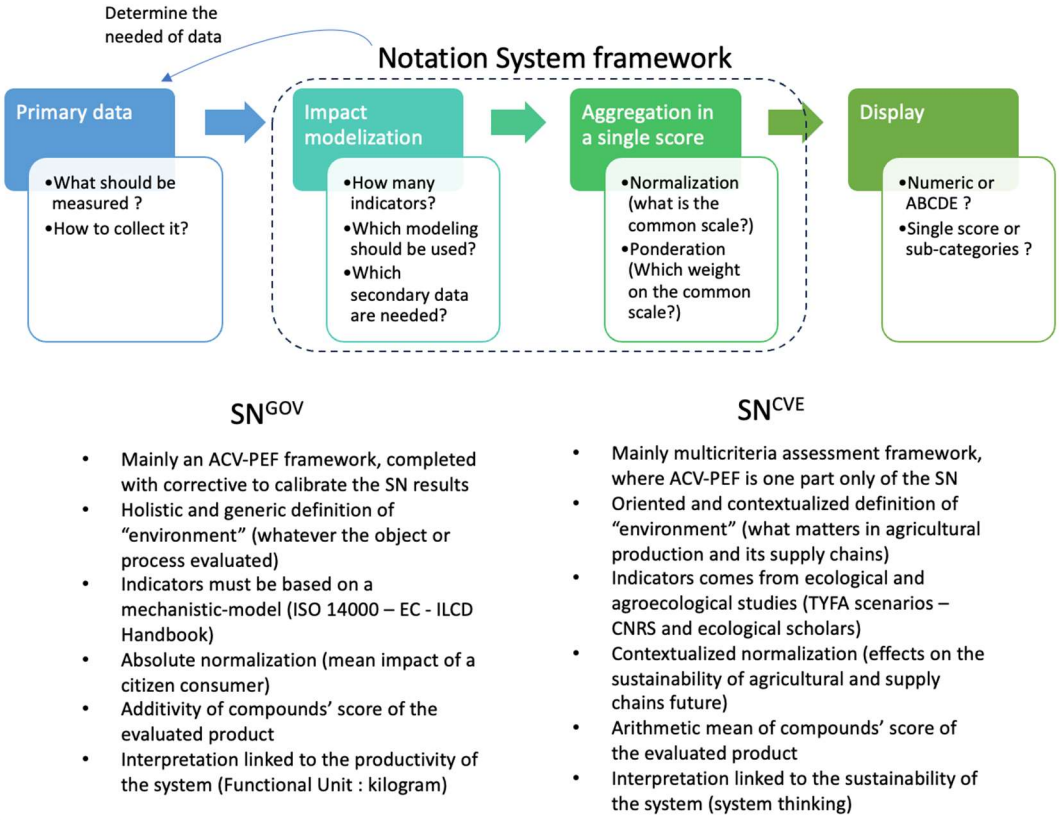
Finally, we return to the issue of the coexistence of the two approaches. Assuming that the methodological biases of RSGOV are resolved, why maintain two rating systems? To understand this point, it is necessary to link the technical choices of each RS (see Figure 4) to the societal function expected by their designers. For example:

- RSGOV is built on a base used to estimate the impact of food products, but also that of clothing, furniture, a washing machine, etc. This requirement forces us to use a cross-sector scale, i.e. one that can be used to equate the scores generated with those of other sectors of activity. This requirement means that a cross-sector scale has to be used, i.e. one that can be used to equate the scores generated with those of other sectors of activity. This reference scale corresponds to the average impact of an "average European consumer".
- RSGOV framework gives its designers the option of not arbitrating on the directionality of production models (even if the scores generated do). This necessity is part of a political choice to use a framework considered to be politically neutral. No prospective study of the transition to a virtuous agricultural model has been used to assess the consistency of the scores generated.
- RSGOV is based on an additive approach based on the weight of the ingredients. If a food product mixes different ingredients, it is the sum of the impacts of each ingredient that provides the final score. This additive logic aims to promote sobriety and accentuate the effect of eco-design approaches based on inter-category substitution (replacing meat with vegetables).

- RSCVE is built on a base used specifically to assess the impact of food products, and is not intended to be harmonised or applicable to other sectors of activity. This means that a normative scale (score from 0 to 100) can be used to facilitate the adoption and parameterisation of indicators that are consistent with the specific characteristics of the agricultural sector. This choice has made it possible to insert a multitude of indicators (e.g. relating to pesticides, biodiversity, the value of grasslands, etc.) that were missing from the LCA base. It also makes it possible to highlight the importance of changes in practices and not just the differentiation between categories.
- RSCVE uses normative reference frameworks, describing progress trajectories and making it easier to identify the key points to be addressed. This makes it easier to choose indicators, weight them and check the results against empirical knowledge produced by disciplines such as ecology, agronomy and sustainability studies.
- RSCVE is based on an average approach, in line with the non-linearity of impacts specific to agricultural products (problem of coupling between impact and positive externalities of agricultural production systems). For a composite product, the information scored gives a rating that is the algebraic average of the scores for its ingredients.

To understand the value of the coexistence of these methods, it is therefore imperative to move away from a purely technical and dual debate aimed at defining which is more scientific and relevant. Instead, we need to assess the purpose of these RSs and what they imply once they have been put into practice. In other words, what the figures cause once they have become autonomous objects, grasped by non-experts who take them at face value. By proceeding in this way, it becomes possible to shed light on the complementary nature of these approaches. This takes us beyond the dichotomous aspect (impossible coexistence) to recognise the value of a duality in epistemological approaches and their effects (Obermeister, 2017).

Figure 4. Schematic representation of the two notation systems



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What does ‘local food’ mean for rural residents in three municipalities in Portugal? - A bottom-up study

Paola A. Hernández[a], Sérgio Schneider[b]

[a]MED – Mediterranean Institute for Agriculture, Environment and Development; CHANGE – Global Change and Sustainability Institute, Universidade de Évora, Núcleo da Mitra, Apartado 94, 7006-554 Évora, Portugal, paolaher@uevora.pt

[b] Federal University of Rio Grande do Sul, Av. João Pessoa, 31 – Centro, Porto Alegre, Rio Grande do Sul, Brazil, CEP:90.040-000, schneide@ufrgs.br

Abstract:

In the realm of sustainable food systems, the concept of local foods has sparked widespread interest and discussion. The existing focus on exploring consumers' participation in local food networks in urban settings has inadvertently side-lined other consumer segments and territorial specificities, such as in rural areas. Understanding local food systems in such areas can be relevant for fostering sustainable agricultural practices, community well-being, and rural development. This paper aims to fill this gap by first discovering the perceptions around local food, to then local food system participation in rural areas. Forty-five rural residents in three rural municipalities in Portugal were asked to provide three words that described their personal understanding about ‘local foods’, providing a total of 117 terms. We learned that no common notion for ‘local food’ existed, and, instead, that its meaning oscillated between routinary and familiarity. Three definition clusters emerged following an open coding analysis that organised the shared notions in 3 distinct groups: ‘from the land’; ‘from here’, and ‘the usual’. This study did not engage in any epistemological debate about what local is. Instead, it showed that local foods are perceived by rural residents beyond the simple act of eating, but as a relationship to the land, known places, and habits. Highlighting the cultural aspects that shape local food consumption in rural areas helped underscore consumers’ identity with local foods and surpass the understanding of local food system participation based solely on a purchasing rationale.

Keywords: local food, rural, residents, consumption, bottom-up knowledge.

Purpose

In the realm of sustainable food systems, the concept of local foods has sparked widespread interest and discussion, with a focus given on the advantages derived from heightened local food production and product valorisation through consumer support (Goodman, 2004). Scholars, such as Tregear (2011) and Fonte (2013), have extensively explored local foods, raising concerns about relying on abstract theoretical assumptions.

Main issues stressed have predominantly centred on the uncontested positive benefits of local food networks (LFN), focusing exclusively on health benefits, reduced food miles, and improved market access (Born and Purcell, 2006; Trivette, 2012). Unfortunately, this focus has resulted in a neglect of crucial consumption-related issues, such are social justice and adequate access to healthy food (Mount et al., 2013).

The existing focus on exploring consumers' participation in local food networks in urban settings has inadvertently side-lined other consumer segments and territorial specificities, such is the case of rural areas. Reina-Usuga et al. (2018) argued there is a pressing need to adopt a territorial perspective on LFN, because they are shaped by a combination of elements that define a particular territory. In the case of rural areas, local food consumption responds to the insights around sustainable agricultural practices and rural development, and recent discussions have linked cultural heritage and territorial embeddedness to local food systems (Torres-Salcido and Sanz-Cañada, 2018).

This paper seeks to unveil the perceptions around local food and how consumers acquire these items, which influence local food system development in rural areas. It presents an understanding of local food consumption based on a survey carried out to 45 rural residents in three municipalities of Portugal. The leading research question here is what socio-cultural aspects affect local food consumption in rural areas? based on the assumption that understandings and forms of accessing local foods are different in rural areas than in urban settings. To answer this question, it develops a clustering of consumers guided by two questions of the survey. First, it develops a common language to explore the multifaceted meanings and cultural significance of 'local food' within rural communities, elucidating the diverse interpretations and values associated with locally sourced produce. Second, it considers the forms of acquiring local food as identified by respondents themselves to refine the bottom-up categorisation of consumers.

This paper is organised as follows. Initially are the methods explained, followed by a presentation of our findings. Then come the theoretical implications and last come the conclusions.

Design/Methodology/Approach

Data collection

Data collection took place from February to April 2023 as part of the doctoral research work titled “Patterns, strategies, and challenges for rural residents to access local foods” funded by the Portuguese National Funds through the FCT - Foundation for Science and Technology under the PhD Scholarship SFRH/BD/146108/2019 and under the Project UIDB/05183/2020. Sampling was carried out in three predominately rural (PR) municipalities of Portugal: Évora, Mértola and Arouca, which correspond to municipalities with a population density equal or below 100 inhabitants/km2. The three

municipalities were chosen from a national mapping of Local Food Networks (LFN) developed by Hernández et al. (submitted) because of holding the highest number of LFN per cluster, as identified by Hernández (2023).

Data was collected through a 15-minute consumer survey done to residents of each case study site to inquire about their local food consumption habits. Sampling was done purposefully to guarantee geographical distribution and socio-cultural diversity (e.g., gender balance, diverse ages, and backgrounds). Surveying was done in Portuguese language to passers-by in public spaces, including, but not limited to, producers' markets, on the street, coffee shops, workplaces, convenience markets, museum, food fairs, supermarkets, etc. Printed pamphlets of the survey were also distributed at local food shops, upon authorisation from owners, and collected afterwards. An online survey was sent around by the city hall communications office in Arouca, from which 5 answers were randomly selected for this study to avoid sampling bias. The only requirement for taking part in the survey was consent for participation and that respondents resided in one of the municipalities selected as case study. A consent form was given to each respondent informing about the study. Surveying stopped once saturation of answers was evident in each municipality. In total, 48 surveys were collected, 45 of which were valid. The reason for invalidation was that respondents lived outside of the municipality's boundary.

Data analysis

Two data sources from the survey were mainly used for the analysis in this paper, using a mixed-methods analytical approach that combined qualitative and quantitative data. First, answers to open-ended Question 8 ("Identify 3 words that describe what 'local food' means to you?") helped develop a typology of consumers, based on their notions about local food. Second, we cross-compared the consumer types with the responses to multiple-choice Question 17 ("Where do you mostly acquire local foods? Number the 3 preferred options by order of relevance") to discover any possible link between the preferred venue for consumers to have access to local foods and the notions they had about these foods.

In both data sources, responses were organised into broad themes, or conceptual categories, using open coding which is a useful technique for microanalysing qualitative data (Strauss and Corbin, 1998). Analysis was done using a bottom-up approach, resulting in two outputs: i) the identification of three clusters encompassing respondents' broad perceptions of local food (Question 8), and ii) four categories of preferred channels to acquire local foods (Question 17). Two in-vivo codes mentioned by respondents, as well as an original code, were used as labels for the definition clusters. The categorisation of consumers based on their preferred channel to acquire local food was done in two steps, because this question asked respondents to score their answers. First, answers were reclassified into four channel groups following a gradient from shorter to longer food chains. Then, answers were graded according to the relevance

mentioned by respondents: the first answer was given 0.5 points, the second 0.3, and the last 0.2 points. In the event of a tie, the subcategory with the largest number of responses was selected.

Theoretical approach

The three different lenses proposed by Pascucci et al. (2016) to understand consumer participation in alternative food networks guided our discussion. Although our approach is not specific to members of these networks, their proposed framework captures the conceptual notions that consumers have about locally produced foodstuffs acquired through market and non-market channels in our study. Specifically, the three lenses are insightful because they hint at the motives of rural residents to consume local foods, based on their perceptions of these items and the cultural aspects behind food acquisition.

Findings

Responses from a total of 45 rural residents were collected from a consumer survey in the three case studies: 16 in Évora, 14 in Mértola and 15 in Arouca. As sampling was done purposefully, the sample was almost equally distributed in terms of gender and age. However, differences were found in aspects that can have an impact on people's material means, lifestyle choices, and interests, but which were not further explored in this paper. In fact, almost everyone surveyed affirmed consuming local foods in one way or another (2 out of 45 said they did not). Consumption of local foods was reported to occur at different frequency rates and quantities. For example, 21 reported that 25% of their diet included local foods, 17 declared 25-50%, and 5 reported that 50-75% of their food was local. Respondents informed that they acquired these foods using multiple methods, often relying on self-production in home gardens, other times relying on food purchases, or exchanging them with neighbours.

When inquiring people about whether they participated or not in any food purchasing agreement of local food *("Do you have any form of regular arrangement with one or more local producers to buy food in exchange for money or work?"*), six responded affirmatively, and 39 did not. This informed that people preferred unstructured, pre-existing channels to acquire local foods. Notably, the Local Food Networks mentioned by respondents corresponded to those labelled 'fixed' types by Hernández (2023), with examples such as food fairs, farmers' markets, food shops, restaurants, etc. Non-market channels included receiving foodstuffs from relatives or friends, and food trails. Most respondents affirmed having a network of people in the community with whom they discuss food issues regularly (27 out of 45).

3.1. Local food definition clusters

From the survey, we learned that no common understanding for 'local food' existed, and that people's definitions of the term did not necessarily coincide with those registered in the literature on local food consumption. Instead, its meaning oscillated

between routinary and familiarity, and the concept was for everyone to define based on their personal experiences and values, like found in the United Kingdom by Truninger and Day (2013). A total of 117 words were reported in this data entry, ranging from kinds of foods, cooking methods, 'buzzwords', locality names, and food adjectives, among many others. Three definition clusters emerged from the categorisation of the words used to describe 'local food'. These local food definition clusters organise the shared notions that the sampled rural residents had over this food type in 3 distinct groups (Table 1): 'from the land'; 'from here', and 'the usual'. Granting the freedom to respondents to come up with concepts that best described the term to them was useful to attain their personal insight and grasp some of the collective imaginaries. Clusters, thus, reveal the various kinds of 'local food', as defined by the residents themselves.

Table 1. The three definition clusters of words describing 'local food'.

Cluster No.	**Definition cluster**	**Characteristics of 'local food' meaning in sample**
1	"from the land" *'da terra'* in Portuguese in-vivo code 29.7% in sample	Associated with the 'how' of food production, referring often to the methods used. Examples included concepts like *organic, traditional, produced at home, natural, own, vegetable garden, safety,* etc. Terms used to qualify food or make a judgement of it, such as *good, healthy, quality, not fried, fresh,* etc. also belong here.
2	"from here" *'daqui'* in Portuguese in-vivo code 18.6% in sample	Understood as something that happens somewhere. This cluster includes the 'where' food is, with 'I' as the point of reference. Concepts in this category included *zero-kilometres, produced in this zone, from the region, where one lives, existing in the region, close to me, produced in the municipality, producers' market, proximity, Évora, special to each area,* etc. This group also includes words hinting at the item's availability timeframe, which is strongly linked to a place or space. Examples include *in season, seasonal,* and *availability*.
3	"the usual" *'o de costume'* in Portuguese original code 51.7% in sample	Described as something that is familiar, part of a routine, and providing a sense of comfort. It includes familiar things and faces, "the habitus" of Bourdieu (e.g., *things from home, daily routine, ours, daily routine, street vendors and the fish vendor,* etc.). However, most of the words referred to 'everyday foodstuffs' or items that are commonly

		part of people's diet (e.g., *bread, meat, milk, cheese, sausages, legumes, coriander,* etc.) were also included in this cluster.

3.2. Local food acquisition

Four channels were identified by consumers as preferred outlets to acquire local foods: self-production, short food supply chains, hybrid (or mixed) channels, and large retail venues. A link was perceived between the notions that consumers had of 'local food' and the venues chosen to acquire these items, which helped enrich the picture of local food consumption in our sample. Although all venues were mentioned across the definition clusters, differences among types of channels were clear. Consumers belonging to cluster 1 ("from the land") preferred short food supply chains (SFSC), including box scheme, specialty food shop, producers' market, local restaurant, food fair. Consumers in cluster 2 ("from here") were most in favour of hybrid channels, or relied on multiple channel types, to acquire local foods, such as on self-production, short food supply chains and purchases in supermarkets. Most respondents grouped in cluster 3 ("the usual") opted for large retail venues to acquire local foods exclusively (e.g., super and hypermarkets). Responses in this cluster were followed closely by hybrid channels and presented the largest number of respondents growing their own food. Table 2 shows the summary of our findings.

Table 2. Local food consumption according to the preferred channel to acquire local foods.

		Preferred channel to acquire local foods				
Definition cluster of 'local food'		**Self-production**	**SFSC**	**Hybrid**	**Large retail**	**Total**
1	"from the land"	1	7	5	1	14
2	"from here"	2	3	5	2	12
3	"the usual"	4	2	6	7	19
Total		7	12	16	10	45

Theoretical Implications

From the findings we inferred there are cultural and symbolic aspects that must be considered to understand rural residents' behaviour around local food, because food

consumption is seen beyond the act of eating and, instead, a relevant element of people's culture and identity. The three lenses proposed by Pascucci et al. (2016) helped establish the linkage between the definition clusters and respondents' preferred channel to acquire local foods while confronting the reductionist approach of viewing consumers merely as rational choice actors. This framework facilitated the development of a bottom-up analysis of local food consumption based on consumers' perceptions of local foods and the cultural aspects behind food acquisition (Table 3).

Table 3. Proposed theoretical framework to discussing local food consumption.

Cluster of 'local food'		**Consumer issues**	**Key question**	**Local food consumption motives** **(Based on Pascucci et al., 2016)**
1	"from the land"	modes of doing, values	how?	ethical consumption
2	"from here"	physical proximity, location	where?	supply chain, organisational perspective
3	"the usual"	familiarity, habits	what? and who?	rural development perspective

Cluster 1 ("from the land") includes consumers with a certain degree of awareness on food issues. They are concerned on how food is produced and pay attention to the environmental and health impacts from food processes (e.g., food certification, food safety regulation, etc.). Given their ethical approach to consumption, in Pascucci et al.'s terms, it comes as no surprise that they would opt for shorter commercialisation channels to acquire local food, because they have more control over the methods of how food is produced, including food quality.

Respondents in cluster 2 ("from here"), on the other hand, associated local food as by-products of processes that can be traced back to a place, hinting at the organisational lens by Pascucci et al. (2016) behind food system processes that enable local food consumption. For consumers in this group, it implies that the food supply chain is coordinated enough to reduce the environmental footprint of agriculture, to guarantee that foods in season are available, and that indications of origin can embed food items territorially. Hybrid channels came up as preferable to acquire local foods by members in this cluster, signalling at the recognition that food access venues can be improved to facilitate local foods in multiple forms, if the food chain is organised.

Last, cluster 3 ("the usual") corresponds to respondents who associate 'local food' to things or manners that resemble the familiar ways of living in the countryside (e.g.,

common foodstuffs, items and icons that help build a common identity, etc.). One can argue this goes in hand with the current approach to rural development in Portugal that seeks to promote rural areas as romanticised places of consumption for urban visitors (Figueiredo, 2011). Unsurprisingly, the preferred channel to acquire local food in this cluster was large retail, which hints at the success of supermarkets in making common, everyday things available to consumers in these areas, indistinctively of the how or from where. What matter most to consumers in this group appeared to be the association to foodstuffs and the stability of these items in the supply chains. We can also argue that this approach goes also in line with the failure of historic and current agri-food policies in protecting small family farms in these areas (Calvário R. and Castro, I., 2022).

Conclusions

A consumer survey was undertaken in 3 predominately rural municipalities in Portugal (Évora, Mértola and Arouca) to expand knowledge on local food consumption in these areas. This study relies on a survey done to 45 residents and does not attempt to be representative. However, it focused on the perception and cognitive meanings of 'local food' in the case studies selected.

Three consumer clusters emerged based on the definition that rural residents gave of 'local food', following the notions identified by respondents themselves: "from the land" (values), "from here" (locality), and "the usual" (habits). The three lenses proposed by Pascucci et al. (2016) on consumers' participation in alternative food networks served to establish a link between the definitions of 'local food' and the venues chosen to acquire these items, which enriched not only the picture of local food consumption, but the cognitive and symbolic meanings of 'local food' in our sample. We argue that rural residents have a unique understanding of what local foods are, based on their perceptions of and relationship to these items. Likewise, these actors are participating in local food systems through processes and channels assessed as adequate to their cultural needs, which often do not equate to those taking place in urban settings.

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Analysing the design process of coupled innovations between agriculture and food sectors within local value chains: an analytical framework

Margot Leclère[a], Blandine Renault[b], Tristan Gérault[c], Marie-Hélène Jeuffroy[d], Chantal Loyce[e]

aUniversité Paris-Saclay, INRAE, AgroParisTech, UMR Agronomie, 91477, Palaiseau, France, margot.leclere@inrae.fr

bUniversité Paris-Saclay, INRAE, AgroParisTech, UMR SADAPT, 91477, Palaiseau, France, blandine.renault@agroparistech.fr

cUniversité Paris-Saclay, INRAE, AgroParisTech, UMR Agronomie, 91477, Palaiseau, France, tristan.gérault@inrae.fr

dUniversité Paris-Saclay, INRAE, AgroParisTech, UMR Agronomie, 91477, Palaiseau, France, marie-helene.jeuffroy@inrae.fr

eUniversité Paris-Saclay, INRAE, AgroParisTech, UMR Agronomie, 91477, Palaiseau, France, chantal.loyce@agroparistech.fr

Abstract:
Transition towards sustainable agri-food systems relies on a deep change of practices at various levels, which requires the coordinated design of radical and systemic innovations, both in the agricultural and the food sectors, also called “coupled innovations”. The purpose of this paper is to propose an analytical framework to analyse existing processes of design of coupled innovations, based on an abductive approach and the successive analysis of five local value chains. This framework is characterized by four main components: (i) a GIKE (Goal-Idea-Knowledge-Experimentation) scheme to provide a visualisation of the dynamic of interaction between the key components of a design process, (ii) a map of the actors to show the diversity of the actors involved and their relationships, (iii) a geographical representation to present the specificity of the area and (iv) a narrative to provide additional insights on the innovations designed. The application of this framework to five local value chains was used for cross-cutting learnings regarding coupled innovations and their design process within food reterritorialization dynamics. Therefore, we assume that this framework could provide actionable knowledge to help actors from agri-food systems that want to engage a transition towards sustainable agri-food systems.

Keywords: coupled innovations; sustainable agri-food systems; cross-analysis; innovation tracking; multi-actor design

Context and purpose of the study

To meet current challenges linked to food security, human health, and ecosystems preservation, transition towards sustainable agri-food systems is required (Caron et al., 2018). This transition relies on a deep change of practices at various levels, which requires the design of radical and systemic innovations, both in the agricultural and the food sectors, while design processes were historically disconnected between them (Brun et al., 2021). This transition also request reshaping the roles of the agri-food system's actors and their interaction modes (Vilas-Boas et al., 2022). In this context, coupled innovations, i.e., novelties designed in a coordinated manner between agricultural and food sectors, has been identified as a key avenue to support transition towards sustainable agri-food systems (Meynard et al., 2017). However, the design of such coupled innovations remains quite a challenge as they result from a complex and dynamic multi-actor process during which a diversity of actors who do not always share the same values nor knowledge have to (i) build a common vision for the future, (ii) explore new ideas, (iii) share their knowledge, and (iv) mobilize and produce new resources (knowledge, methods, tools, etc.) to coordinate their innovation processes (Boulestreau et al., 2023). Drawing on recent advances in 'on-farm innovations tracking' (Salembier et al., 2021) and 'coupled innovations tracking' (Boulestreau et al., 2022), we assume that the development of a framework to describe and analyse not only existing coupled innovations (as objects) but also the complex associated design processes will support actors to initiate their transition towards sustainable agri-food systems. The purpose of this paper is to present such an analytical framework. We have developed and tested it through an abductive approach based on the description and the cross-analysis of the dynamic of emergence of five local value chains in France.

Materials and methods

1.1. General approach

The framework was developed and tested as part of a two-year research project (spring 2022 to spring 2024) that aims to analyse and compare existing local value chains, and especially their dynamic of emergence, based on the assumption that they were ideal spaces for testing new forms of coordination between actors and designing coupled innovations. We adopted an abductive reasoning, meaning that the *'original framework is successively modified, partly as a result of unanticipated empirical findings but also of theoretical insights gained during the process'* (Dubois and Gadde, 2002). In other words, it means that the successive individual and cross-cutting analysis of the selected local value chains and the associated learnings contributed to the progressive formalisation of the framework, initially mainly based on the literature.

1.2. Overview of the initial framework

Drawing on design science and innovation studies – which define innovation as an innovative design process that consist of a joint expansion of ideas and knowledge feed by action (Hatchuel and Weil, 2009; Prost et al., 2018) – and on recent work on farmers' transition pathway in relation with their value chain (Brunori et al., 2019; Revoyron et al., 2022), five themes were initially identified as key components of the framework: (1) the historical background and the geographical context, (2) the composition and the evolution of the network of actors, (3) the construction in time of goals shared among actors, (4) the innovations and new ideas that emerged and how they have been experimented and (5) the nature and the origin of the knowledge mobilized during the process.

1.3. Local value chains selection and data collection

Five local value chains were successively selected and analysed (Table 1). The first two cases were selected based on a national screening that was carried out by reaching out around 300 facilitators from Territorial Food Programs in France and by exchanging with 94 project leaders. Both cases were specially chosen because of (i) their historical depth, (ii) the involvement of a group of local actors sharing the same vision and (iii) the existence of interrelated innovations in agriculture and food sectors clearly design to support sustainability transition of agri-food systems. The three other case studies were also selected based on the previous criteria (ii) and (iii) but were also searched and chosen to cover a diversity in term of farming systems, location and date of emergence (Table 1), with the aim to test progressively the ability of the developed framework to be suited to a diversity of situations. Information on the collective dynamic that supported the emergence of the selected local value chains were collected through semi-structured interviews of key actors involved in the process (farmers, processors, advisors from extension services, actors from public authorities or local rural development structures, etc.). These actors were chosen using the snowball sampling method starting from a central actor, identified as the 'leader' of the dynamic of emergence of the studied value chain. When available, this material was completed with data from grey literature (web sites, technical documents, minutes from collective meetings, collective charters, etc.). Collective meetings were also organized to validate, with the interviewed actors, the analysis performed based on the framework

Table 1. Overview of the five local value chains used to develop the analytical framework

	Description of the local value chain initiative studied	**Type of farming system**	**Location: region and type of agriculture**	**Launch of the initiative**
#1	Development of a chestnut value chain through the	Arboriculture	South-East of France; mountain agriculture	2000's

	development of a multiproduct processing unit			
#2	Structuration of a local value chain to produce bread from a mix of old wheat varieties	Cereal growing	Ile de France region; peri-urban agriculture	2000's
#3	Implementation of a platform to collect, process and market organic and local vegetables	Market gardening Polyculture with vegetables	South-West of France; crop-livestock farming	2015
#4	Development of a micro-sugar refinery locally supplied by organic sugar beet	Polyculture including industrial crops	North of France; large scale crops-growing basin	2000's
#5	Structuration of a value chain around a group of dairy cattle, goat and sheep farmers to produce a local cheese	Livestock farming	Central France; crop-livestock farming	2018

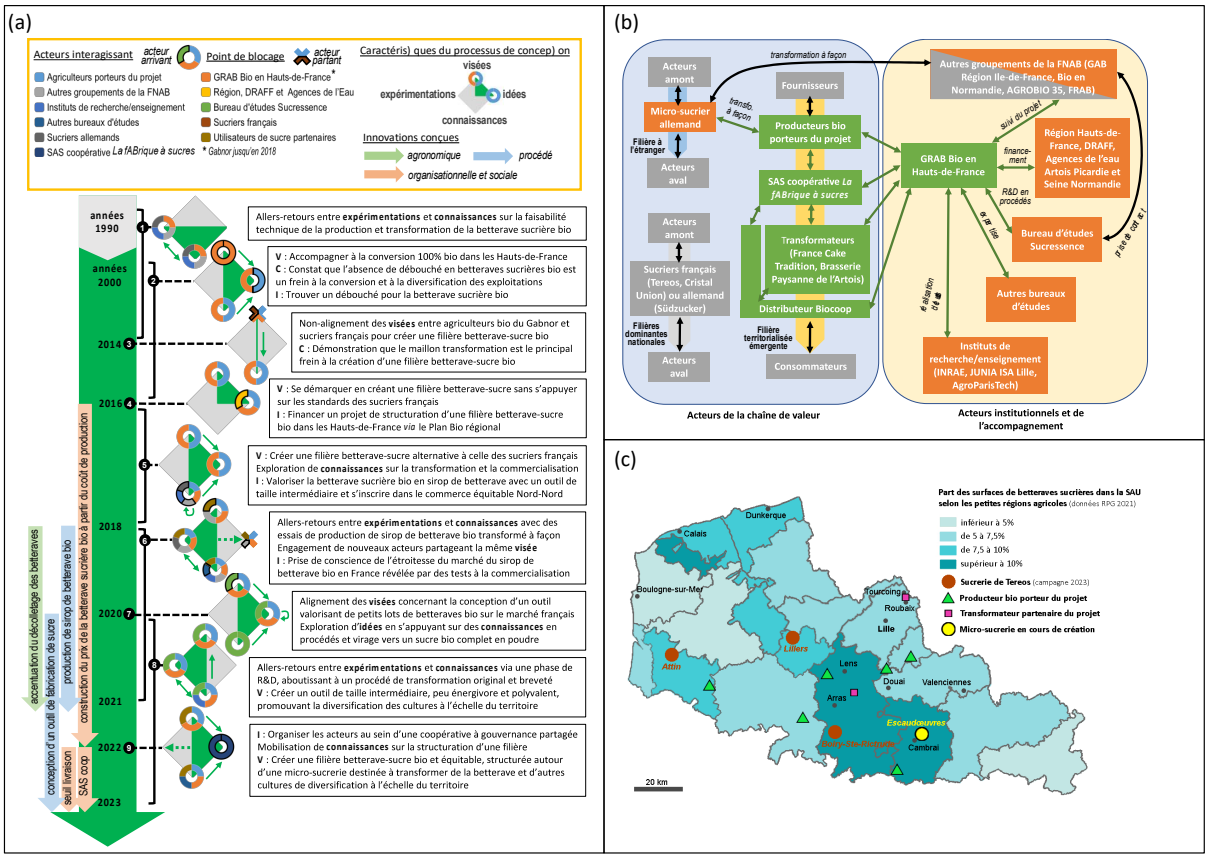
Findings

1.4. Development of a four-item analytical framework …

Our abductive approach led to the development of an analytical framework composed by four elements: (i) a GIKE (Goal-Idea-Knowledge-Experimentation) scheme (Fig. 1a), (ii) a map of the actors (Fig. 1b), (iii) a geographic representation (Fig. 1c) and (iv) a narrative. More precisely, the GIKE scheme is a visual representation that shows how the four key components of a design process (i.e., the construction of shared Goals, the exploration of Ideas, the production and mobilization of Knowledge, and the Experimentation of imagined solutions/ideas) interacted over time to enable different types of innovations to emerge (dynamic representation). This representation also give insights on which actors were involved at each step of the dynamic. Complementarily, the map of the actors, that is also a visual representation, gives an overview of the diversity of the actors involved and their relationships (static representation). Specifically, this representation allows to distinguish the actors that are designing and implementing the innovations (so-called 'actors of the value chain', on the left side of the map) from the ones that are supporting the coupled innovations design process in itself by providing knowledge or facilitation skills for instance (on the right side). Finally, the geographic representation aims to capture the "territorial" dimension by providing information about the pedo-climatic context (ex. soil type) and/or the agronomic characteristics (ex. area covered by the studied crop) as well as the distribution of the main actors in the area. Overarching these three visual representations, the narrative

(usually a written document of around 10 pages) is used to structure the process of design of coupled innovations into several phases and to provide additional information about the agronomical, technological or organizational innovations themselves or the knowledge used or produced during the design process.

Figure 1. Overview of the three visual components for the case study #4 (in French) of the analytical framework developed to analyse the process of design of coupled innovations within a local value chain: GIKE scheme (a); map of the actors (b); geographic representation (c).



1.5. … to analyse and compare processes of design of coupled innovations

The systematic application of the framework to the five local value chains supported cross-cutting learnings regarding coupled innovations and their design process within dynamics of emergence of local value chains. For instance, the analysis of the GIKE schemes highlighted the central role of the collective experimentation within the process of knowledge acquisition, especially to prove the technical feasibility of the products and test the economic viability of the value chains. The implementation of such experiment at wider scale as "proof-of-concept" resulted indirectly in the design of new and original modes of coordination between the actors. For instance, in the local value chains #1 and #4, the actors experimented the production of their new products by using

process factory outside their territory (ex. in Germany for the case study #4). In both cases, this "relocated" experimentation implied for the actors to re-organise and coordinate their work schedules in order to make it cost-efficient. Concomitantly, the comparison of the five maps of the actors led to the identification of contrasted ways to support the emergence of local value chains (in terms of actors and skills) with for example in one case the strong implication of a dedicated 'external' structure on the request of the farmers that want to develop the local value chain (#4) and in another case the punctual solicitation of various support structures according to the needs (#1). Finally, the combined analysis of the maps of actors and the GIKE schemes allowed to identify that an enabler to coupled innovations was the presence of one (or two) key actors in the network embedding both a strong belief into the main goals and specific facilitation skills, thus allowing to keep the momentum and the direction of the multi-actor dynamic.

2. Practical implications

Transitioning is a continuous and progressive process during which actors are mobilizing several types and forms of knowledge (Quinio et al., 2022; Šūmane et al., 2018). We assume that this study contributes to the production of actionable knowledge – i.e., produced by and for action – to feed transition towards local agri-food systems in different ways. First, the individual analysis of the five local value chains formalised thanks to our analytical framework provides inspiring "story-telling" that can contribute to open up the range of options and stimulate creativity of the actors. Complementarily, the cross-cutting analysis could be used as a "tool-box" to anticipate potential lock-ins or create favorable environment to coupled innovations based on the learnings from past experiences. Finally, the analytical framework in itself could be used by the actors "in transitioning" in order to engage a reflexive process about their own dynamic of agroecological transition.

Theoretical Implications

This work ambitions to enrich the ongoing reflections around extending the "innovation tracking" methodology (Salembier et al., 2021). Initially developed to understand on-farm innovation, this approach was thus mainly focusing on describing the farmer's logic of actions and evaluation criteria. Tracking "coupled innovations", that usually involved a network of actors and new forms of coordination, thus raises the question on how to adapt this crucial step of "understanding the reasons and the underlying processes behind the innovation". One theoretical implication could be to use this work and especially the *ex-post* analysis of the framework to formalise the key components of an analysis of a process of designing coupled innovations and to describe the resulting innovations. In addition, we assume that the better understanding of past or ongoing coupled innovations design processes is also a way for research to develop suitable methods and tools to support more actively the actors, especially within action-oriented

research projects aiming at supporting the agroecological transition of agri-food systems (de Koning et al., 2021).

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THE ROLE OF CONSUMERS IN AGRO-FOOD SYSTEMS

The Portuguese nitrogen footprint, a challenge in a Mediterranean country

Soraia Cruz[1], Joana Marinheiro[1], Cláudia Marques-dos-Santos[1], Allison M. Leach [2] & James N. Galloway[3]*

[1]Forest Research Center CEF, Associate Laboratory TERRA, School of Agriculture ISA-UL, University of Lisbon, Lisboa, PT; [2]University of New Hampshire, Durham, USA; [3]Environmental Sciences Department, University of Virginia, Charlottesville, USA; [*]scruz@isa.ulisboa.pt

Abstract:

A nitrogen (N) footprint quantifies and connects N losses with consumption patterns. The N footprint of Portugal was estimated for consumption and production, based on Leach et al. (2012) approach, and compared to a typical Mediterranean diet N footprint. Total N footprint takes into consideration the footprints from energy consumption (housing and transport) and food consumption and production. The N footprint in Portugal was estimated to be 27.9 kg N cap-1 yr-1. Food production is the main contributor sector of the Portuguese N footprint (~ 80%), mainly from animal-based products, followed by food consumption, transport and housing sectors. Following the Mediterranean dietary recommendations, food consumption and production N footprint in Portugal can achieve a reduction of 44% and 30%, respectively. Mediterranean diet shows huge potential to reduce N losses into the environment.

Purpose

Agriculture is the main source of reactive N (Nr) emissions to the global environment, followed by burning of fossil fuels. Beef and dairy products are responsible for 56% of Nr emissions in Europe. Population growth and their individual dietary choices are intrinsically connected to the increase of Nr emissions. The Nitrogen Footprint concept emerged out of the necessity to communicate the importance and the negative effects of N to the general public. A nitrogen (N) footprint quantifies and connects N losses with consumption patterns. This concept needs to be disseminated worldwide to show how personal consumption may affect N pollution and become a serious problem to human health. Regardless Portugal is a Mediterranean country, the typical Mediterranean diet is not followed at risk. In the actual diet, Portuguese daily protein consumption is 120 g/cap (19.2 g N/cap/day) but the recommended dose for an average sedentary adult is, roughly, 50 g/cap/day (8 g N/cap/day) (IOM, 2005). The main reason for this excess is due to the high animal protein-based meals in Portugal. The N footprint for Portugal was estimated for both consumption and production, and the potential of the Mediterranean diet analysed.

Design/Methodology/Approach

Leach et al. (2012) approach was used to estimate the N footprint for Portugal. The N footprint model takes into consideration the individual footprints from energy consumption (housing and transport) and food consumption and production (Fig. 1).

To assess the N footprint from food consumption it was assumed that all N consumed is excreted and released into the environment as human waste since the average adult does not incorporate N as body muscle. A weighted average approach was used to assess the N removal from wastewater treatment.

For food production, the concept of Virtual Nitrogen Factor (VNF) was used, where all Nr losses to the environment are accounted from the initial N input as fertilizer (Fig. 2) until what is actually consumed. The VNF represent the amount of Nr loss to the environment per N consumption and was estimated for each by-product, crop and animal produced in Portugal. The Mediterranean diet N footprint was estimated based on the national food wheel recommendations and compared to the Portuguese food N footprint.

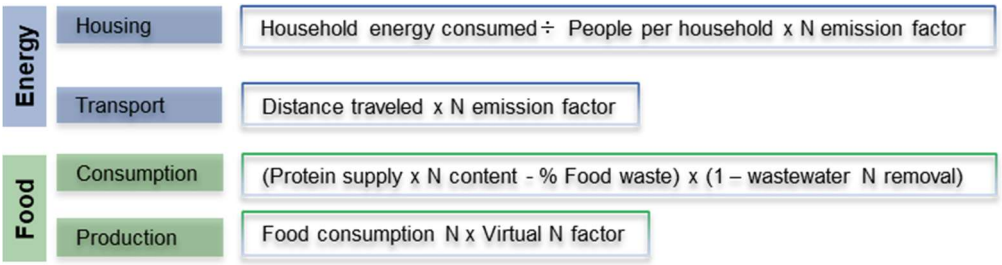

Figure 1. Nitrogen footprint based model

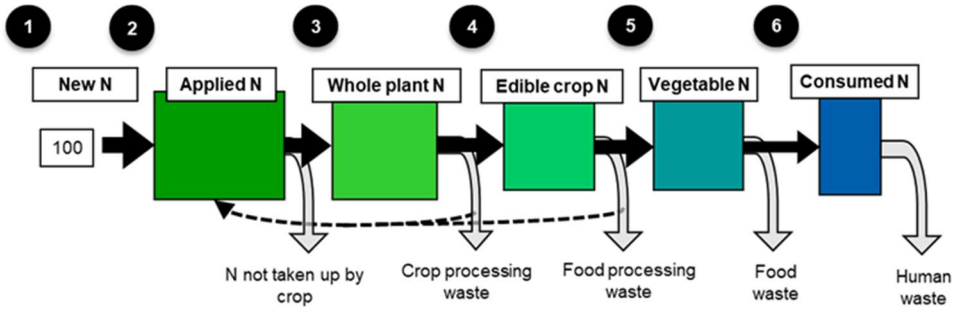

Figure 2. Crop production process for VNF estimation

Findings

The N footprint in Portugal is overall 27.9 kg N cap-1 yr-1 for the last year of available data (2018). Around 80% of the total footprint is from food production, followed by food consumption, transport and housing (Chart 1). Food product with the higher contribution to this result is bovine meat (Chart 2). Following the food wheel for Mediterranean dietary recommendations and decreasing the daily protein intake, food

consumption and production N footprint in Portugal can achieve a reduction of 44% and 69%, respectively.

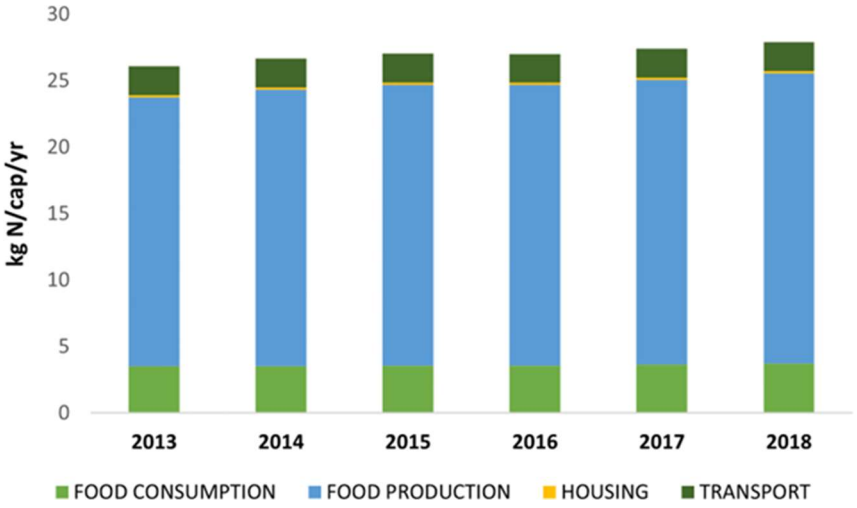

Chart 1. Total Nitrogen footprint for Portugal per sector (2013-2018)

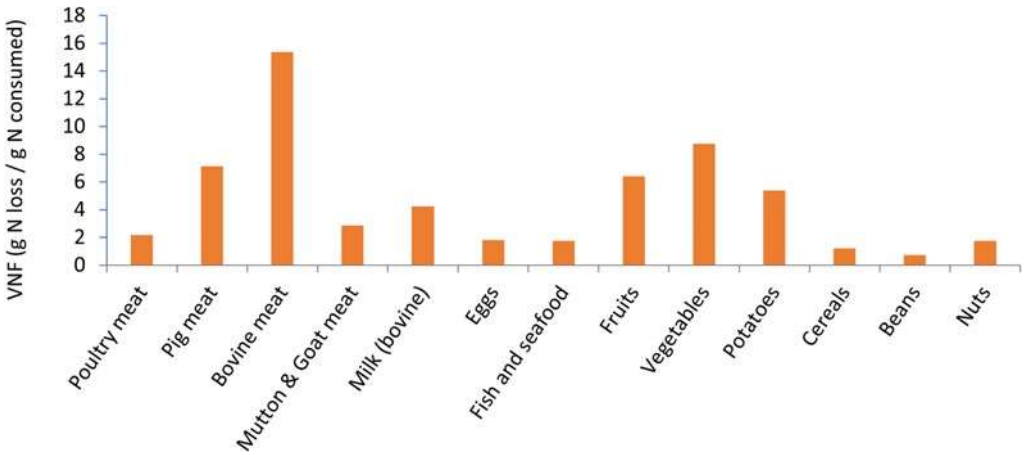

Chart 2. VNF for plant-based and animal-based products

Main conclusions

Food production is the main contributor sector for the total N-Footprint in Portugal, in particular animal-based products, followed by food consumption. Mediterranean diet can reduce the impact on the final N footprint, especially by favoring the consumption of fish over meat and increasing the consumption of plant-based proteins. Mediterranean diet has the potential to help mitigate N losses into the environment, not only in Portugal but across all the other Mediterranean countries.

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Threat or opportunity? An analysis of perceptions of cultured meat in the UK farming sector

Louise Manning[a], John J. Dooley[b], Illtud Dunsford[c], Michael K. Goodman[d], Tom MacMillan[b], Lisa C. Morgans[b], David C. Rose[e], Alex Sexton[f]

[a] The Lincoln Institute for Agri-Food Technology, University of Lincoln, LManning@lincoln.ac.uk

[b] School of Agriculture, Food and Environment, Royal Agricultural University, john.dooley@rau.ac.uk; tom.macmillan@rau.ac.uk; lisa.morgans@rau.ac.uk

[c] Cellular Agriculture Ltd, Felin y Glyn, Llanelli, illtud.dunsford@cellularagriculture.co.uk

[d] Department of Geography and Environmental Science, University of Reading, m.k.goodman@reading.ac.uk

e School of Food, Land and Agri-business management, Harper Adams University, drose@harper-adams.ac.uk

[f] Department of Geography, University of Sheffield, a.sexton@sheffield.ac.uk

Abstract:
The implications of cultured meat production for farmers have not yet been thoroughly investigated and are poorly understood. The purpose of this research was to engage with the UK farming sector in critically assessing cultured meat as a technology which could profoundly affect farm livelihoods and rural communities. Six focus groups were undertaken with 75 UK farmers from a variety of farming sectors and regions. Questions focused on farmers' views, knowledge and feelings towards cultured meat and the potential impacts of it on farm livelihoods and businesses. All meetings were recorded, transcribed, and thematically analysed. Farmers expressed complex and considered reflections on cultured meat, raising several perceived opportunities and risks within the themes of 'socio-economic' 'ethics and affective' narratives and 'environment-based' narratives. Concentration of power, food system control and transparency associated with cultured meat emerged from the conversations, as well as cultured meat's potential impacts on the environment and on jobs, rural communities and connecting with the land. Ensuring farmers' voices and potential 'counter-narratives' inform the development of cultured meat is not only inclusive, but could identify unexpected impacts of this emerging technology as well as opportunities for collaboration. While not claiming to be representative of all UK farming, this study filled a gap in knowledge on farmers' perceptions of cultured meat and engaged UK farmers as a way of starting the substantive process of greater inclusion of agriculture in cultured meat innovation pathways.

Keywords: Cultured meat, Farmers, Livelihoods, Business, Opportunities, Threats

Purpose

Farmers in the United Kingdom (UK) face an uncertain future with a number of potential disruptions including the development and scale up of cultured meat production. There is growing concern over the negative externalities of the global production of meat and dairy products (Funke et al., 2021). Livestock production has significant environmental impacts including associated greenhouse gas emissions, deforestation and air and water pollution due to the nutrient run-off (Specht et al., 2018), thus cultured meat is being considered as a potential alternative. For agricultural sustainability-related transitions to be responsible, inclusive, ethical and just, the views of all affected stakeholders should be heard and included in the development of alternative sustainability pathways and trajectories (de Boon et al., 2022; Klerkx and Rose, 2020).

The aim of this research was to explore farmers' perceptions of cultured meat production and the impact that they felt could result in terms of their farming businesses, livelihoods and for rural communities more generally.

Design/Methodology/Approach

We adopted a qualitative approach based on a constructivist epistemology to explore UK farmers' understanding of cultured meat, what it could mean for their their livelihoods and potential implications of cultured meat on their farming business (Manning et al., 2023). A focus group methodology was chosen due to the novelty and uncertainty of the topic being investigated, as well as the exploratory nature of the research questions, which benefited from a discursive approach.

A convenience sampling approach was followed for the exploratory focus groups, where existing researcher networks were used to contact farmers, with location, sector and type of farming enterprise considered. Primary data was collected through six focus groups with 75 farmers in total from across the UK between Nov 2022 – Jan 2023 (Manning et al., 2023). The questions, designed to facilitate discussion, were the same in all focus groups and based on a topic guide used by two facilitators. Three key questions were asked:

- What do UK farmers already know and think about Cultured Meat?
- What do they perceive to be some of the risks and opportunities afforded by Cultured Meat for UK farming?
- What might the impact be of Cultured Meat on their farming businesses, livelihoods and rural communities?

Farmers were asked to expand on their initial perceptions (views and feelings) of cultured meat; their knowledge of the process and product; the perceived impacts on

farming businesses and rural community; and potential business scenarios that might arise from it. All focus groups were recorded and transcribed. The transcripts were prepared and annotated to generate open coding, which was reduced using a reflexive thematic approach as described by L. Finlay (2021) and grouped into levels using Nvivo 20.

Findings

The unit of analysis within this research was at the focus group level. Farmers' perceptions included their knowledge, views of and feelings towards cultured meat and potential implications for their businesses and livelihoods. In their discussions, the farmers often finished each other's sentences, and so it was difficult to extract individual voices. Farmers identified several opportunities and risks from cultured meat production, around the themes of 'ethics and affective' narratives, 'environment-based' narratives, and 'socio-economic' narratives. Prominent discussion points were: food-system control and transparency, impacts on the environment, jobs, farming/rural communities, and connecting with the land.

Each focus group went through a journey of views and feelings about cultured meat and the impact it could have. Focus group data revealed that farmers were uncertain about what cultured meat would consist of and as a result how it would compare with traditionally produced meat. In terms of affective responses, the farmers collectively used a range of negative language when discussing cultured meat including about the product itself (Frankenstein food, toxicity) and potential marketing practices (cheap, dictate, greed, horrendous, scary). Alternatively one farmer stated that such technology may provide protein and nutrients to a population that currently can't afford meat, although they presupposed that cultured meat would be less expensive that traditionally produced meat. The farmers raised concerns over the power dynamics in food supply chains associated with cultured meat, the control of intellectual property (IP) and the potential for corporate lock-in. They also felt that the value derived from cultured meat would not be shared equally across the supply chain, describing potential future business models as the "Americanisation" of the UK food supply chain.

Nevertheless, farmers were open to considering the potential environmental and economic opportunities of cultured meat given the pressures of rising populations, environmental impact of food production and needing to address food waste. They tended to agree that 'game-changers' are needed in the food system, indeed some felt that the food system was broken. They questioned whether cultured meat would indeed be more environmentally beneficial than current methods of producing meat, and the potential for negative impacts such as land abandonment during a transition away from producing meat on land. They also expressed concern that cultured meat might be produced in countries were regulatory restrictions were less and then imported into the UK to compete with existing methods of meat production. It was felt that there could be opportunities for arable farmers supplying the inputs for cultured meat production, but

arable production itself would be under pressure if livestock were removed from the landscape so there was an over-reliance on artificial fertilisers as a result.

In summary, many of the farmers expressed that big, system-level change in food production was needed to secure a more sustainable and healthy future. While some saw potential in developments within the farming sector with emerging practices such as regenerative agriculture, others shared doubts that such approaches were simply "fiddling at the edges". However, they concurred across the focus groups that the farming transition ahead would see some winners and some losers within rural communities. In light of the range of potential impacts that development and scaling up of cultured meat production poses to traditional farming, we highlight farmers as a crucial and critical key stakeholder group that should have greater inclusion in both the decision-making and technological development of cultured meat.

Practical implications

Our study was a first step to assess the views of farmers in the UK towards cultured meat. We were able to show, therefore, that farmers in the focus groups did not dismiss the potential of cultured meat without careful consideration; rather, they displayed complex and considered perceptions of cultured meat and the impact of such a disruption on their businesses, livelihoods, and rural communities.

Theoretical implications

The limitations of this study are the convenience-based sampling method that was employed which means that this study can only be exploratory and does not have powers of generalisation. Future work could seek to engage with a larger study population of farmers not only in the UK but across geo-political regions. There is also considerable scope for social scientists to further explore the potential impacts of cultured meat development at the scale of rural communities and to consider specifically the potential impacts on land use and as a result landscapes.

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Transforming farming systems through green consumerism – exploring the potential growth of organic vegetable farming in Flanders

Louis Tessier[a]

[a] Flanders Research Institute for Agriculture, Fisheries and Food, Social Science Unit (ILVO L&M), louis.tessier@ilvo.vlaanderen.be

Abstract:
With its Farm to Fork Strategy the EU is aiming for a tripling of farmland under organic certification in less than a decade. Multiple observers have warned, however, that if the change in consumer behaviour does not materialize, this ambition risks orchestrating a massive oversupply of organic products, jeopardizing the livelihoods of established organic farmers, and undoing much of the organic farming movement's progress. This paper aims at contributing to this important debate by reflecting on the dynamics at work in the organic vegetable sector in Flanders. Drawing on 17 semi-structured interviews with various stakeholders and a focus group with organic farmers, 12 systemic barriers were identified covering value chain development, public policy, consumer expectations, and technological innovation. A number of opportunities for local action are outlined that are likely to be explored within the framework of the Horizon Europe ENFASYS project. The article concludes by considering the emerging understanding of this transition in Flanders in relation to the 'conventionalization debate'.
Keywords: organic vegetable farming, systemic barriers, conventionalization, Farm to Fork

Purpose

With its Farm to Fork Strategy the EU is aiming for a tripling of farmland under organic certification – from 8.5% in 2019 to 25% by 2030 (EC, 2021). As such it envisions that a move towards more sustainable farming systems could take place through a considerable and voluntary, but publicly supported change in farmers' management systems and consumers' buying behaviour. The European Commission (EC) has encouraged Members States (MS) to implement policy instruments – including those made available in the CAP – to contribute to this objective. While this ambition has been welcomed by organic agriculture stakeholders, observers (S&P, 2020) have warned that if the change in consumer behaviour does not materialize, this ambition risks orchestrating a massive oversupply of organic products, jeopardizing the livelihoods of many organic farmers, and undoing much of the organic farming movement's progress. In Flanders (Belgium) too, a coalition of public and private stakeholders delivered a strategic plan (Bonte & Leys, 2023). The plan aims at almost tripling share in area, animal production value and number of farmers involved in organic farming in the region by 2027. The plan also aims at doubling the share of household expenditures on organic food in this same time

period, as these have so far only grown incrementally year after year. This paper examines how a number of lock-ins hampering the further growth of the organic vegetable sector in Flanders tie in with the overall effort of the EU to expand production and consumption of organic food.

Methodology

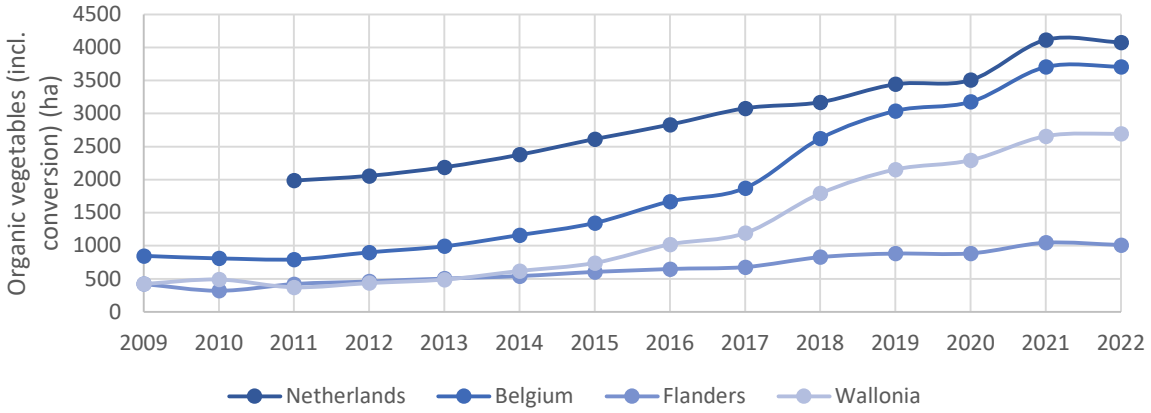
I followed a multi-step protocol for data collection and reporting developed for the ENFASYS project, enfasysproject.eu, to develop a systemic understanding, in terms of underlying actor-relations and emergent social dynamics of the perceived barriers and potential levers for this food system transition (Antier *et al.*, 2023). A first characterization was arrived at based on initial talks with the case study partner Bioforum, the regional organic sector organisation, and a review of publicly available reports on the development of (organic) vegetable sector in recent years and the broader societal developments within Flanders. I conducted 17 interviews with a variety of actors and a focus group with organic vegetable farmers and employees from Bioforum, engaging in total 27 individuals involved in organisations operative at different stages of the value chain: 5 in 'Agro-inputs & Research' stage, 9 in 'Cultivation' stage, 5 in 'Logistics & Processing' stage, 2 in the 'Distribution' stage, and 6 in the 'Governance' stage. Interviewees were asked to share their view on and their perceived role in growing organic vegetable production in Flanders, as well as the main barriers and potential levers they encountered.

During transcription of the interviews, I filled out a reporting template in the form of a spreadsheet, which included classifying mentioned barriers in a matrix by type (technological, financial, market-related, organisational-institutional, cultural-normative, psycho-cognitive, environmental) and by stage in the value chain, and also creating value-network maps to describe the different relationships (goods and services exchanges, money exchanges, influence and representation, knowledge and norms) between the key actors identified. The initial 88 barriers were further clustered and rephrased into a list of more 'systemic barriers' covering the different themes and issues that appeared to form a fundamental obstacle to grow the organic vegetable production in Flanders.

Findings

Trends and structure of the Flemish organic vegetable sector

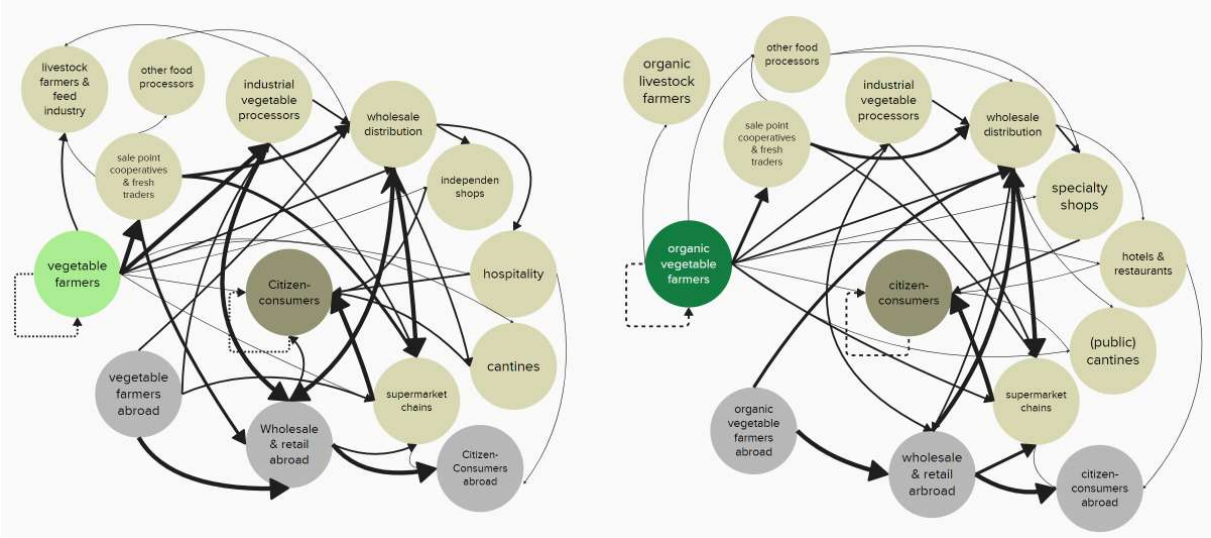
Figure 1 Evolution area vegetables under organic certification (covered and open air, incl. conververison) in Netherlands, Belgium, Flanders and Wallonia) (Timmermans & Van Belleghem, 2023; Biowallonie, 2023; CLO, 2023)



Belgium has seen a considerable growth of the organic area and number of organic farmers in the last two decades, amounting to 103,503 hectares and 2,636 farmers in 2022. This is 7.2% of the total agricultural area and slightly less than the European average of 9.9% in 2021, but most of this area is located in Wallonia, with only 1.6% of the Flemish agricultural area under organic agriculture certification. Belgium is far from self-sufficient in terms of organic production. Only a quarter of the organic products distributed in Belgium come from Belgium (Le Douarin, 2022). For vegetables Italy, France, Germany and the Netherlands are important import countries. The share of expenditures on on organic vegetables is considerable lower in Flanders than in Wallonia (6.3% compared to 11% in 2022) (Timmermans & Van Belleghem, 2023; BioWallonie, 2023). Until 2013, the area of organic vegetables in Flanders and Wallonia was approximately the same (509 ha and 490 respectively). Since then Wallonia recorded more than a fivefold increase to 2698 ha in 2022, while Flanders 'only' showed a doubling of the area (1013 ha) in the same period. Flanders has 156 specialized, organic field vegetable companies, and 25 mixed companies with important horticultural activities. Experience suggests, however, that the large majority of Flemish organic vegetable production is produced by a small fraction of organic vegetable farms, as is the case in Wallonia. While it's not uncommon for organic vegetable farmers to be engaged in both 'short' and 'long' value chains, larger farms are typically organized to sell in wholesale channels, whereas smaller farms are typically oriented towards direct selling and B2B. The majority of organic vegetables produced in Flanders are either packaged fresh and distributed by the sale point cooperatives and independent specialized traders or delivered directly to a wholesaler, supermarket or its service provider. A group of Flemish growers also produces a number of vegetables and herbs for the frozen vegetable industry, a limited portion of which is for export. As is the case for food products in general in Flanders, most of the organic food is sold by classic (47%), neighbourhood (8%), and increasingly hard discount supermarket chains (7%). Specialized organic channels (incl. bakery, butcher, health food store and other general

food stores) have considerable market share (29%). Only 4% of organic sales happen at the farm or on farmers' markets (Timmermans & Van Belleghem, 2023).

Figure 2 Representation of the flows of vegetable productions (left in general, right organic) between actors in Flanders.



Main systemic barriers identified based on a first analysis

Cultivation

- High land prices and strong dependence of conventional farmers on seasonal leases due to competition for land with other farmers, non-farming land users and speculators, along with a lack of nearby leasable organic land hinder conversion and expansion to more extensive vegetable production systems like organic farming.
- High (perceived) conversion costs and production risks in part due to lacking experience with agroecological techniques and steep learning curve form an obstacle for conversion
- Insufficient affordable and quality seasonal labour, specialized wage labour, and affordable mechanization options are a bottleneck for organic and non-organic farmers
- Only a limited share of vegetable farmers are likely to consider converting, as most are at the end of their career or are paying off past investments, while new entrants tend to be financially limited to setting up rather small operations.
- Agronomically, it is very difficult – even with the use of contentious inputs – to meet the rather conventional expectations set by wholesale and retail companies regarding cosmetic quality, price and convenience.

Value Chain & Consumer Demand

- Lack of supply coordination among organic vegetable farmers amplifies market risks for new or less experienced organic farmers who are confronted with an

intransparent and demanding market for 'small crops' (*i.a.* cauliflower, leek, celeriac, fresh herbs).
- Limited (confidence in the) commitment from the local wholesale and retail sector to buy local in the face of growing, cheaper and more secure organic vegetable supply from abroad results in processor's inability to persuade a sufficient number of larger conventional farmers to convert in order to invest processing units for 'larger crops' (*i.a.* beans, peas, sprouts).
- Limited supply and concern for profit margins have led supermarkets to market organic vegetables as a luxury product in supermarkets only to attract a certain type of customers, driving up retail costs and end-consumers prices, with limited price mark-up for producers, depressing on volumes sold in the process (*cfr.* Aertsen, 2011).
- The increasing reliance on input substitution and mechanisation to enable large-scale production undermines the credibility of the organic label to consumers and conventional farmers. This leads value chain actors to develop more holistic and nuanced certification systems instead to enlist farmers in transition and sell 'sustainability' to customers, and it leads smaller direct selling farmers to distance themselves from the organic label by presenting a more radical agroecological approach to concerned customers, thus threatening to drive an ideological wedge in an already bifurcated sector.

Governance & Technological Innovation

- Due to inadequate and trailing public support and lacking commercial models for agroecological innovation, organic farming is losing its distinctive character and sustainability advantage by relying on sustainable technologies such as biopesticides and -stimulants developed for conventional farmers to decrease production costs and risks, and improve cosmetic quality and yields.
- Compared to other regions and countries current regional policies are to weak to stimulate organic growth (particularly on the demand and value chain side) and do not sufficiently discourage the continuation of intensive agricultural models (*cfr.* IFOAM, 2022).
- A vocal and well organized part of farmer community (along with their allies in the agri-food industry and citizenry) question the legitimacy of additional environmental regulation and demands by government and value chain to change towards more sustainable consumption and production practices, undermining the political will to implement sweeping policy reforms.

Practical Implications

This initial analysis suggests that while there is a general interest and ambition of actors throughout the value chain to further expand local organic vegetable production – as has been the case since the 2010s (*cfr.* De Cock et al, 2016) – they are confronted by a number of barriers. Several of these barriers are amplified by the organized push to

expand organic production abroad, leading to a lack of investment in local production and processing capacities, undermining local demand and commitment from retailers, and damaging the credibility of the organic brand overall. If these barriers are not addressed, the organic vegetable sector in Flanders may be in for a recession. It's worth noting that interviewees also mentioned many opportunities and potential levers to mitigate these and other barriers. These include increasing market transparency by sharing price information among organic farmers, organization and bundling of supply for wholesale marketing through a formal cooperative; building long-term partnerships with local retailers, setting a minimum target for the share of (local) organic food in public canteens and developing policy mixes supporting the development of value chains and end-markets for organic products within the apparently limited policy design space available (Howlett & Mukherjee, 2017). It would, however, be premature to discuss the merits of these and other solutions, as this will be the object of upcoming participatory policy and business workshops.

Theoretical Implications

In light of the industrialization of the organic vegetable sector in California, a debate started in the early 2000s essentially on whether the developments observed in the organic vegetable sector in California were universal, and whether these were inevitable. It became generally accepted that in countries with liberalized agricultural policies, the capitalist social structural underpinnings of organic certified agriculture would increasingly undermine the very environmental benefits that are the foundation of organic agriculture (Allen & Kovach, 2000). In the EU, it was argued, however, that the supportive policy environment and the absence of corporate farm structures created a different set of opportunities for farmers. Whereas assessments of structural farm characteristics would indeed suggest that organic agriculture in the EU departs from the agroecological small-holder ideal (*e.g.* Konstantinidis, 2018), Darnhofer *et al.* (2009) found the evidence insufficient to affirm the conventionalisation hypothesis, and therefore called for a more robust assessment of these evolving practices organic farms, and for considering that organic farmers and sectors may engage heterogeneous responses leaving scope potentially for countering conventionalization effectively. With its Farm to Fork Strategy, a new phase has arguably set in for organic agriculture in the EU. The state is actively seeking to expand organic farming beyond the niche market and this putting pressure on existing social relations and norms that had consolidated organic farming as a credible alternative. In the case of Flanders this move appears to be amplifying a number of existing contradictions, effectively locking Flemish farmers out from converting, putting established organic farmers in a defensive position commercially and politically, and even driving value chain actors, consumers and farmers away from the label. Hopefully, this study may invite further exploration of the evolving political economy of organic agriculture and assessments of the evolution of the actual organic farming practices, in order to clarify if, how and where at this historical

juncture the growth of certified organic agriculture may contribute to transforming food systems towards agroecological ends.

A more systematic content analysis of the conducted interviews is planned in order to reconsider and further ground the presented narrative. For the definite identification of systemic barriers and levers, a causal loop diagram will be developed visualizing the dynamics in their interconnectedness. The coming months, this analysis will benefit further from the revision and enrichment from fellow researchers and stakeholders in order to devise a systems-based theory of change (*cfr.* Dentoni *et al.* 2024).

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Understanding the role of health-related attitudes in local beef consumers

Riccardo Testa[a], Riccardo Vecchio[b], Giuseppina Rizzo[a], Francesco Vella[a], Giorgio Schifani[a] and Giuseppina Migliore[a]

[a] Department of Agricultural, Food and Forest Sciences, University of Palermo, Viale delle Scienze, Building 4, 90128, Palermo, Italy, riccardo.testa@unipa.it - giuseppina.rizzo03@unipa.it - francesco.vella09@unipa.it - giorgio.schifani@unipa.it - giuseppina.migliore@unipa.it

[b] Department of Agricultural Sciences, University of Naples Federico II, via Università 100, Portici, Naples, Italy, riccardo.vecchio@unina.it

Abstract:

This study delves into the preferences of Italian consumers concerning local beef, investigating whether consumption is linked to attitudes towards consumer's health, as well as socio-demographic characteristics, habits (i.e., red meat consumption frequency, previous experience with local beef, organic consumption frequency, and place of purchase), and meat involvement. To reach this aim a sample of 1179 participants, representative of the Italian population, was analysed through an online quantitative survey. Findings revealed that participants are willing to pay an average price premium of €3.23/kg for local beef. The majority of local beef consumers are older people with medium-high income and education levels, displaying a preference for purchasing organic products directly from local markets. Furthermore, results indicate that health-related attitudes do not significantly impact the willingness to pay for local beef, suggesting that consumers are primarily motivated by sensorial aspects, such as taste and previous experiences. Finally, the analysis highlights that consumers' weak involvement with meat could favour their reduction in overall meat consumption, encouraging a shift towards more sustainable diets and lifestyles. These findings provide important implications for marketing strategies and policies aimed at promoting more sustainable products and diets.

Keywords: consumer behaviour; Italy; meat involvement; local beef; willingness to pay.

Introduction

In recent years, there has been a global surge in consumers' interest in local food products, driven by perceptions of greater sustainability and improved health benefits compared to conventional options (Skallerud and Wien, 2019). This positive trend has involved also red meat, which has long been a topic of debate due to its potential

association with chronic diseases associated with its overconsumption (de Araújo et al., 2022). However, although red meat leads the debate on its health risk within the WHO discussion (WHO, 2023), it is unclear whether and to what extent the preference for local red meat is also associated with factors related to health, as revealed by the literature on local food (Birch et al., 2018). In fact, existing literature suggests that consumers perceive local food as healthier, primarily due to indirect factors linked to its sustainable production process, encompassing environmental and ethical considerations such as animal welfare, safety, freshness, and taste (de Araújo et al., 2022; Santos et al., 2021). To fill this gap, this study aims to elucidate the relationship between local beef consumption and consumers' health-related attitudes, also considering socio-demographic characteristics, consumption habits and meat involvement. Specifically, the meat involvement can be considered as a sort of consumer's justification mechanism to consume meat as it considered a natural, normal, necessary, and nice food (Roozen and Raedts, 2023; Piazza et al., 2015). By doing so, this research offers valuable insights into a highly debated issue in developed countries—the role of meat in human culture and diet—and whether it is viewed as essential or potentially detrimental to health (Parlasca and Qaim, 2022).

Materials and Methods

In October 2021, data from 1179 Italian beef consumers were collected through an online survey conducted by a professional marketing agency. Participants, 18-aged or older, were responsible for household food shopping and reported consuming beef at least once every two weeks. The questionnaire consisted of four main sections. The first section gathered information on red meat consumption frequency, previous experience with local beef, organic consumption frequency, and place of purchase. The second section aimed at evaluating the premium price consumers were willing to pay for one kilogram of local red meat. Participants selected a value from a range of €15/kg (average price of non-local meat) to €30/kg, with one-euro increments. The third section included two pre-validated scales: the 8-item General Health Interest (GHI) scale (Roininen et al., 1999) to measure health-related attributes, and the 16-item 4Ns (Nature, Necessary, Normal, Nice) scale (Piazza et al., 2015) to evaluate consumers' level of meat involvement. The last section gathered sociodemographic variables such as age, sex at birth, income, education level, number of children under 12 years old in the household, and geographical area.

To analyse the factors influencing willingness to pay (WTP), given interval characteristics of dependent variable, an interval regression approach data (Billard and Diday, 2000) was implemented using STATA 16 statistical software. This analytical approach facilitated a nuanced exploration of the intricate relationships within the gathered data, enhancing the study's ability to discern the variables impacting consumers' WTP for local beef.

Results and Discussion

The findings of the study reveal that participants are willing to pay an average premium price of €3.23/kg (SD = €2.98) for local beef, in line with previous studies (de Araújo et al., 2022; Santos et al., 2021). Surprisingly, this WTP does not appear to be affected by consumers' health-related attitudes as well as for local food consumption (Birch et al., 2018; Kumar and Smith, 2018) (Tab. 1). This could be attributable to the negative perception of excessive consumption of red meat on human health, which has raised controversial public debates and increased consumers' concerns (Parlasca and Qaim, 2022). Specifically, findings confirm that this aspect has involved especially local consumers because they want to fully understand the food origin and the connection between health and diet (Kumar and Smith, 2018). Furthermore, in contrast to findings from previous studies on meat consumers (Roozen and Raedts, 2023; Piazza et al., 2015), Italian local beef consumers show a weak meat involvement, as they do not perceive meat as a natural, normal, and necessary product but are driven by aspects related to local beef taste. This preference is further confirmed by the importance of previous experience with local meat since the higher their appreciation for taste the more they are willing to pay an extra price (Sasaki et al., 2022).

In addition, unlike the findings of Davidson et al. (2003), Italian local red meat preference is not associated to high meat consumption frequency, highlighting that it is not considered as a substitute of conventional red meat. In this context, it is reasonable to suggest that consumers are increasingly inclined to reduce their overall meat consumption, demonstrating a lesser attachment to meat and a greater willingness to adapt their dietary habits and lifestyles toward more sustainable products, such as local food (Peschel and Grebitus, 2023). Consumers, in fact, could perceive local meat as a sustainable food option in environmental and ethical terms (Pirsich and Weinrich, 2019; Telligmann et al., 2017). This could be derived by their engagement in organic food consumption and preference for purchasing red meat directly from local butchers or farmers' markets.

Table 1. Results of the Interval Regression Model

Explicative variables	**Marginal effects**
Frequency of fresh beef consumption	0.143
Consumption of organic products	0.765***
Previous experience with local beef	1.014***
Place of buying (1 if supermarket)	-0.527**
GHI	0.067
Eating meat is *Natural*	-0.024
Eating meat is *Necessary*	-0.301***

Eating meat is *Normal*	0.231
Eating meat is *Nice*	0.338*
Age	0.023**
Gender (1 if Male)	0.238
Area of provenience (1 if North Italy)	1.000***
Income (1 if no difficulty)	0.729***
Education (1 if at least high school diploma)	0.766**
Num. of children under 12 years	0.194
Constant	11.80***

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

As regards socio-demographic characteristics, only age, income, and education level affect local beef consumption (e.g., Denver et al., 2019; Pirsich and Weinrich, 2019). In fact, local beef consumers are typically older individuals with medium-high level of income and education. These consumers predominantly live in Northern Italy, where higher red meat consumption is linked to a continental diet (Farchi et al., 2017). On the other hand, gender and the presence of children do not affect consumption as shown by previous studies (Merritt et al., 2018; Paustian et al., 2016).

Conclusions and implications

The study underscores that, while Italian consumers express a willingness to pay a premium for local beef, their choices are not driven by health-related factors. Moreover, individuals show a limited engagement with local meat, not considering it as a substitute of conventional options but prioritizing previous experiences and taste over perceiving meat as a natural, normal, and necessary product. In this context, although consumer do not explicitly consider local meat as an unhealthy food, their modest level of involvement could favour the reduction in overall meat consumption, encouraging a shift towards more sustainable diets and lifestyles.

This study contributes to enrich the existing literature as it represents the first attempt to clarify whether and to what extent health-related attitudes play a role in the consumers' decision-making process of Italians to purchase local beef. In addition, the study provides recommendations to businesses to realize effective marketing strategies, emphasizing sensorial aspects of their production rather than health benefits. To this end, since consumption of local beef is positively associated with organic consumption frequency and consumers usually prefer to buy at farmers' markets or farm shops, the adoption of alternative food networks together with the organic certification could reach a larger share of consumers. Furthermore, the findings are useful for policymakers in formulating tailored public policies aimed at promoting more sustainable products and

diets, also within the context of short supply chains, thus aligning with the objectives of the Farm to Fork strategy.

However, some limitations can be highlighted. First, survey has not specifically considered whether consumers' preferences are affected by sustainable aspects of production process, such as environmental concern or animal welfare. These aspects could represent dominant drivers of the Italian market of local red meat, which, indirectly, may be associated with a health-related component. Lastly, it should be interesting replicate the study in other developed countries to identify possible changes for different contextual and socio-cultural factors.

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Trade-offs between environmental impacts and human diets in food systems

Benjamin van Selm[a], Ollie van Hal[a], Corina E. van Middelaar[a], Renske Hijbeek[b], Martin K. van Ittersum[b], Imke J.M. de Boer[a]

[a]Animal Production Systems group, Wageningen University & Research, P.O. Box 338, 6700 AH Wageningen, the Netherlands.

[b]Plant Production Systems group, Wageningen University & Research, P.O. Box 430, 6700 AK Wageningen, the Netherlands.

Abstract:
The current global food system is responsible for a multitude of environmental impacts, such as biodiversity loss, global warming, acidification, and eutrophication, with magnitudes depending on the region. It is increasingly clear that food systems must be redesigned to limit the impact on the environment while still providing healthy and nutritious human diets. This study explores the link between mitigating individual environmental impacts and the human diet by minimising either agricultural land-use, greenhouse gas (GHG) emissions, ammonia emissions, or nitrate leaching in a modelled food system, and assesses how food production and consumption patterns change. We took the Netherlands as a case study and used FOODSOM, an agro-environmental food system model which minimises environmental impacts of food production while meeting the dietary requirements of the population. Our results show that minimising methane and nitrous oxide emissions (both GHG emissions) resulted in different diets. Minimising agricultural land use, for example, increased consumption of grains and dairy products while consumption of fruits and nuts reduced due to low yields. Results show how focusing on one specific environmental losses can influence consumption patterns and confirms the existence of trade-offs between various environmental objectives when designing sustainable consumption patterns.

Keywords: Human diets, environmental impacts, FOODSOM

Purpose

Our food system is currently responsible for 34% of global GHG emissions, occupies 40% of the earth's ice and dessert free surfaces and contributes significantly to acidification and eutrophication (Crippa et al., 2021; Foley et al., 2011). This substantial environmental impact largely stems from the high consumption of animal-sourced foods, especially in affluent countries, contributing disproportionately to the environmental impact of the food system (Hallström et al., 2015). Simultaneously, human diets high in animal-sourced foods are associated with negative health outcomes e.g.,

cardiovascular disease (Godfray et al., 2018). It is becoming increasingly clear that the food production and consumption must be redesigned to reduce environmental impacts and improve human health while ensuring society does not surpass planetary boundaries (van Selm et al., 2022; Willett et al., 2019). However, reducing one environmental impact does not guarantee the reduction of other environmental impacts. Trade-offs exist between environmental impacts (e.g., reducing land use increases GHG emissions, van Selm et al. (2023)), and environmental impacts have different levels of urgency, especially when considering local contexts (Richardson et al., 2023). Therefore when redesigning food systems it is important to consider the trade-offs between environmental impacts and how prioritizing different environmental impacts influences the design of the food system. The aim of this study is to understand the link between mitigating individual environmental impacts and the human diet. To this end, we explored reducing land use, GHG emissions, nitrate leaching and ammonia emission.

Methodology

We employed the FOOD System Optimisation Model (FOODSOM) to explore how prioritizing the reduction of different environmental impacts influences food production and consumption. FOODSOM is an iterative linear optimization model of the Dutch food system designed to minimise environmental impacts while meeting the dietary requirements of the population.

FOODSOM

Agricultural land and marine fisheries form the basis of FOODSOM. Within the model, 49 representative crops (one productivity level, based on current management) can be grown on 1.7 million ha of agricultural land (i.e., the total agricultural area in the Netherlands in 2017-18) to produce food crops (for humans) and feed crops (for animals), while marine fisheries only provide a source of food for humans. Crops and marine fish are processed into food suitable for human consumption (e.g., wheat into flour), by-products (e.g., wheat bran) and animal feed. By-products can be used as animal feed or returned to the soil as source of nutrients. In addition, food is lost (e.g., during storage or during processing) and food is wasted (e.g., during consumption or in the supermarket). These losses and wastes are again suitable for animal feed or can be used as a source of nutrients for the soil (e.g., compost). Five livestock systems (dairy, beef, broiler chickens, laying hens, pigs, each with three productivity levels) can consume a select number of crops, by-products and food losses/waste. Following, food suitable for human consumption is produced, together with livestock manure to fertilise crops, and by-products (e.g., blood and bone meal) to be fed back to animals or applied to the soil as fertiliser. Food from crops and animals is consumed by humans to satisfy their nutritional requirements (27 nutrients). Upper and lower limits for consumption are applied to ensure the diet remains feasible. Upper limits of food groups that did not increase the

risk of non-communicable diseases is based on the 95th percentile of current consumption in the Netherlands. The upper limit of food groups that are associated with increasing the risk of non-communicable diseases is based on the EAT-Lancet diet. Finally, a lower limits are placed on food groups with specific minimum consumption recommendations in the Netherlands.

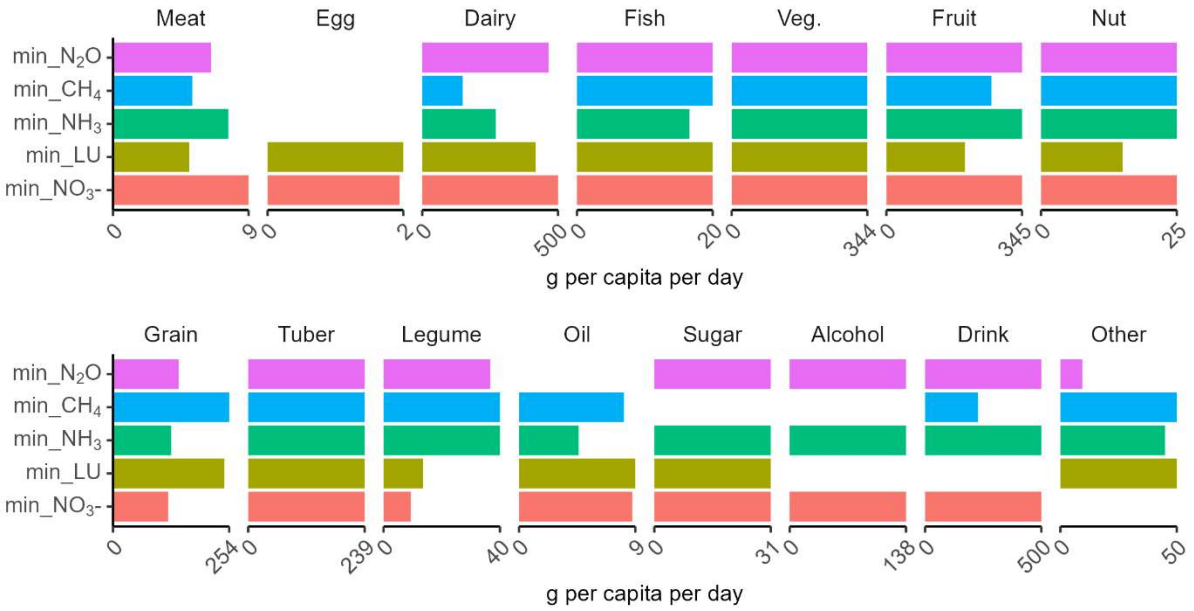
Scenarios

In this study we explore the link between mitigating individual environmental losses and the human diet using five scenarios that only differ in the environmental loss being minimised. All other model parameters remain constant. The following impacts were considered: nitrous oxide emissions (min_N_2O), methane emissions (min_CH_4), agricultural land use (min_LU), nitrate leaching (min_NO_3-), and ammonia emissions (min_NH_3). Specifically for GHG emissions, it is worth noting that a focus on reducing methane will result in immediate reduction in climate warming but could compromise the climate goals on the long run if reductions in carbon dioxide and nitrous oxide are delayed (Allen et al., 2018). An effective climate policy covers both short- and long-term effects. Results of the scenario's min_CH4 and min_N2O provide entry points to set realistic goals, but also points out that focussing on a specific GHGs could compromise the reduction of the other, which could eventually jeopardize the overall effectiveness of the policy.

Findings

Our results show human diets differ when minimising individual environmental losses (Figure 1). Overall, the modelled diets were significantly different to current diets in the Netherlands, consumption of meat, eggs, oils, and sugars decreased, while consumption of fruits, vegetables, legumes and nuts increased (van Selm et al., 2023). Food groups that decreased are generally associated with negative health outcomes while food groups that increased are generally associated with positive health outcomes (Willett et al., 2019). In the modelled diets dairy veal calves and culled dairy cows were the primary source of meat, linking meat and dairy consumption. Consumption of dairy products was highest in the min_NO3- scenario and lowest in the min_CH4 scenario. Dairy cows consumed grassland, which effectively captured nitrogen to reduce nitrate leaching, however, ruminants were the primary source of methane emissions through enteric fermentation.

Figure 1: Human diet composition per food group and scenario.

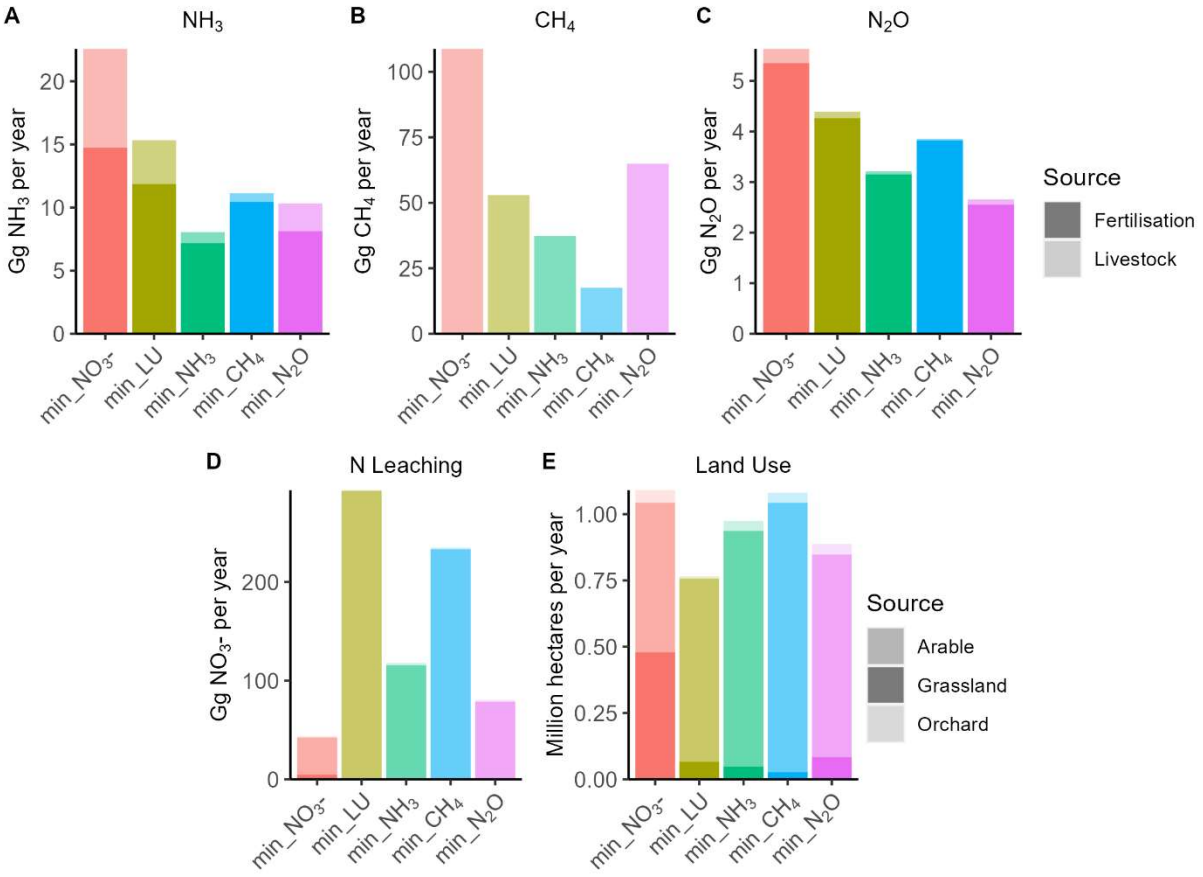


Fruit and nuts were maximally consumed in all scenarios except min_CH_4 and min_LU. The relatively low yield per hectare of fruits, nuts, and legumes increased the required land area. Therefore, consumption of higher yielding crops, e.g., grains, increased in the min_LU scenario to reduce the required land area. Nitrogen fixation by legumes was a source of nitrate leaching, which reduced consumption in the min_NO_3- scenario. In all other scenarios, legume consumption was high. Finally, the alcohol, drink, and other food groups were dominated by food items that produced co-products for animal feed e.g., beer (dried-distillers grain; min_N_2O, min_NH_3 and min_NO_3-), fruit juice (fruit juice pulp; min_N_2O, min_NH_3, and min_NO_3-), and, potato starch (potato pulp; min_CH_4, min_NH_3 and min_LU). This shows the multi-functionality of some crops to produce both food and animal feed, and the importance of applying a food system approach to model food production and consumption simultaneously.

Figure 2 shows substantial difference between the importance of the environmental losses across scenarios. The min_NO_3- scenario resulted in the highest in losses across all categories except nitrate leaching due to the increase in grassland and dairy cows. Fertilisation was the primary source of nitrous oxide (N_2O) and ammonia emissions (N_H3), which meant the min_N_2O and min_NH_3 scenarios were generally linked. However, consumption of dairy products was higher in the min_N_2O scenario (Figure 1), which resulted in higher methane (CH_4) emissions in the min_N_2O scenario. The min_N_2O and min_NH_3 scenarios minimised a form of nitrogen losses which also reduced nitrate leaching. The LU scenario favoured high yielding crops with high

nitrogen requirements, which increased nitrogen losses (especially leaching) but resulted in the lowest land use.

Figure 2: Environmental impacts per scenario. (A) ammonia (NH_3) emissions; (B) methane (CH_4) emissions; (C) nitrous oxide (N_2O) emissions; (D) nitrate leaching; (E) agricultural land use



Theoretical Implications

This study shows human diets varied when mitigating specific environmental losses, which has implications for the design of future food systems. Overall, diets optimised to minimise environmental losses contained less animal-sourced foods and more plant-sourced foods. The precise consumption of animal-sourced food was heavily dependent on the scenario, and often influenced other food groups e.g., alcohol, drink, and to some extent legumes.

If society shifts towards local food systems, food consumption patterns will play a role in reducing local environmental impacts (e.g., ammonia emissions, leaching). For example, if reducing eutrophication from leaching is a priority in the food system, diets will contain comparably more dairy products and less legumes. In a global context, diets

become decoupled from local environmental impacts due to the trade of food products, food items that enhance e.g., eutrophication, can be imported from regions where mitigating eutrophication is not a priority. In reality, future food systems will never be optimised for one environmental objective (e.g., GHG emissions, land use), However, these results provide insights into how altering food consumption patterns, especially animal-sourced foods, can influence specific environmental losses from food production.

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LINKS BETWEEN FARM LEVEL DECISIONS AND CONTEXTUAL PROCESSES

Analyzing sociotechnical barriers and fostering innovation to diversify crop rotations in sheltered vegetable cropping systems in South-eastern France

Mireille Navarrete[a], Marion Casagrande[a,c], Arnaud Dufils[a], Amélie Lefèvre[b], Claire Lesur-Dumoulin[b]

[a] ECODEVELOPPEMENT, INRAE, 84000 Avignon, France, mireille.navarrete@inrae.fr

[b]Agroecological vegetable systems Experimental Facility, INRAE, Alénya, France

[c]Université Paris-Saclay, INRAE, AgroParisTech, UMR SAD-APT, 91120, Palaiseau, France

Abstract:

Despite citizens and public incentives call for a deep reduction in pesticide use, the French market-gardening sector faces difficulties to implement agroecological cropping systems that use less pesticides, and in particular crop diversification, because it requires a deep redesign of cropping systems. How to favor the transition of large specialized farms, occupying main part of the total area, those that could enable a strong reduction in pesticide use? Two case studies were carried out in South–East France. Several actors in the agri-food system were interviewed to identify the current barriers to crop diversification. Six categories of barriers faced by market-gardeners were identified: agroecological inputs not or hardly accessible, lack of specific machinery and land, work-related barriers, lack of knowledge, and commercial difficulties. An outstanding result is that most barriers experienced by market-gardeners are linked to barriers experienced by other actors, which highlights a sociotechnical lock-in around the diversification of crop rotation for managing plant health. This information was later used to devise and carry out multi-actor workshops to co-design coupled innovations that enable farmers to overcome the barriers for implementing diversified crop rotations, with the main actors in the agri-food system engaged in the sociotechnical lock-in.

Keywords: agri-food system; sociotechnical system; actors; diversification; vegetable; market-garden

Purpose

Despite citizens and public incentives call for a deep reduction in pesticide use for health and environment reasons, the European market-gardening sector faces difficulties to implement cropping systems that use limited amounts of pesticides. Among agroecological practices, crop diversification has a large potential to lower pests and diseases damages. Diversified farming systems offer various ecosystem services, such as nutrient and water cycling, soil formation, pest and disease control, pollination, and production variability reduction (Kremen et al., 2012). Plant diversification covers a range of patterns, at various spatial and temporal scales: mixes of species and cultivars or large crop rotations at plot and farm level, agroforestry or agroecological infrastructures at territorial level. A recent literature review demonstrates the high potential of these patterns for controlling pests and diseases (Vialatte et al., 2023). In a study on cash crop farms, Guinet, Adeux et al. (2023) showed that total pesticide use was reduced in crop rotations where functional and taxonomic diversity was higher. Despite public policies aiming to reduce pesticide use (e.g. Green Deal at European level, Ecophyto plan in France), largest reductions in pesticide use are in organic farms or those selling vegetables in short value chains. Transition of large specialized farms is still expected, as they occupy main part of usable area and could enable a strong reduction in European pesticide consumption.

Introducing more biodiversity in market-gardening cropping systems to reduce pesticide use can be done by (i) cropping a larger number of species, especially with resistance genes, to increase the mean crop return time of the most frequent species; (ii) reducing the number of species requiring high levels of pesticide use; (iii) introducing commercial or service species with pest control effects, either during the cropping cycle (e.g. allelopathic effects) or when the crop is buried in soil (e.g. biofumigation). Combining these levers with current practices requires therefore a systemic response and a deep redesign of cropping systems (Altieri, 1999; Morel et al., 2020).

Farm ability to adopt agroecological practices depends on technical, economic and socio-political processes; some of which are in farmers' hands, while others depend on other actors from upstream and downstream value chains. Numerous studies were carried on individual factors determining farmers' intention to adopt sustainable practices (belief, personal preferences, resistance to change, etc.). By contrast, the systematic study of the other actors' impacts is scarcer. Aare et al. (2021) consider that "the transitional path toward more sustainable food systems cannot be addressed at farm level alone, but must include changes in the wider food system(s)". These authors identified several barriers encountered by Danish biodynamic farmers for enhancing biodiversity: national and European legislation, markets, knowledge access, and input supply. Crop diversification was studied by Casagrande et al. (2017) and Morel et al. (2020) on a range of crops, and by Boulestreau et al. (2021) on market-gardening. Four characteristics frame the interactions between vegetable farmers and other actors.

First, as most crop cycles only last a few months, organizing both multi-annual and infra-annual combinations of vegetable crops increases complexity. Second, vegetable crop rotations enable only short fallow periods for service crops. Third, harvesting date is an important criterion in commercial negotiations. And last, distributors' quality standards are very strict when it comes to visual defects. This is why diversifying crop rotation, although being a promising way to control pests, is so difficult to carry out in market-gardening systems.

The aim of the study was to *identify the current barriers to the mass deployment of diversified rotations devoted to control pest and diseases in market-gardening systems*, which depend on the combination of the various actors' strategies in agri-food systems.

Design/Methodology/Approach

System agronomists have long sought to identify the obstacles encountered by farmers when they try to innovate, related to plot characteristics, land or labour force access, knowledge and know-how, etc. (Keating and McCown, 2001). Influence of other stakeholders was more recent studied with for example sociotechnical approaches and multi-level perspective (Gaitán-Cremaschi et al., 2019). Combining agronomic and sociotechnical frameworks enables to take into consideration the complex relationships between upstream chain (mainly genetic selection and input supply), farmers, advisory actors, downstream chain (mainly collection, storage, processing and marketing). Barriers to crop diversification reinforce each other in a systemic way, explaining a systemic lock-in. This was identified on field crops (Vanloqueren and Baret, 2009; Meynard et al., 2018), sugarcane and banana (Della Rossa et al., 2020), and was initiated in vegetable production (Boulestreau et al., 2021). We used the socio-technical inquiry approach (Casagrande et al., Submitted to IFSA symposium) and surveyed different categories of actors likely to hinder the large-scale adoption of diversified crop rotations in market-gardening systems. We started the analysis by surveying farmers, then input suppliers, advisors, vegetable commercial middlemen settled in the territory up to national distributors, to understand how the latter generate or reinforce on-farm obstacles and how they could help to overcome them. After delimiting the system under study (territory, value-chain, problem to be addressed) (i), we mapped the actors involved in the question of crop rotation diversification, based on interviews with key actors and the collection of existing data (ii). Then we organized empirical surveys to understand the determinants of actors' practices in relation to crop diversification (iii), and characterized the obstacles and levers to the innovation process (iv).

The study was carried out in two major French market-gardening production basins: Provence (around Avignon, 43° 56' 57.541" N 4° 48' 19.901" E) and Roussillon (around Perpignan, 42° 41' 19.173" N 2° 53' 41.4" E). In Provence, the focus was on crop rotations devoted to control telluric pests and diseases, which are a major problem there,

and especially root-knot nematodes. 24 semi-structured interviews were carried out in 2021 based on snowball sampling: 6 farmers, 6 cooperatives and shippers, 3 persons working in distribution companies, 4 agri-food processors, the director of a R&D agri-food process network, and 4 agricultural advisers (Michel, 2021). If most actors were located in the study area, a few of them were outside, such as representatives of national distribution companies. In Pyrénées-Orientales, we addressed two Intertwined questions. We carried out an inventory of the major uses of pesticides on vegetables in the area and identified the obstacles and levers to reduce this use, including crop diversification (Bousquet, 2021). We also studied to what extent the commercial channels represent obstacles or levers to crop diversification (Barba, 2021) and to pesticide reduction (Bousquet, 2021; Strand, 2022). We conducted 25 semi-structured interviews in 2020-2021 and 2022. Interviewees were selected based on previous expertise on the territory: 4 farmers, 7 wholesalers, 6 people working in local distribution channels, 7 agricultural advisors and 1 territorial food project animator. The narratives collected in the interviews were first analyzed on each territory separately (Michel, 2021; Bousquet, 2021; Barba, 2021; Strand, 2022) and were then pooled together to map the different types of barriers and assess their genericity in a cross-cutting analysis.

Findings

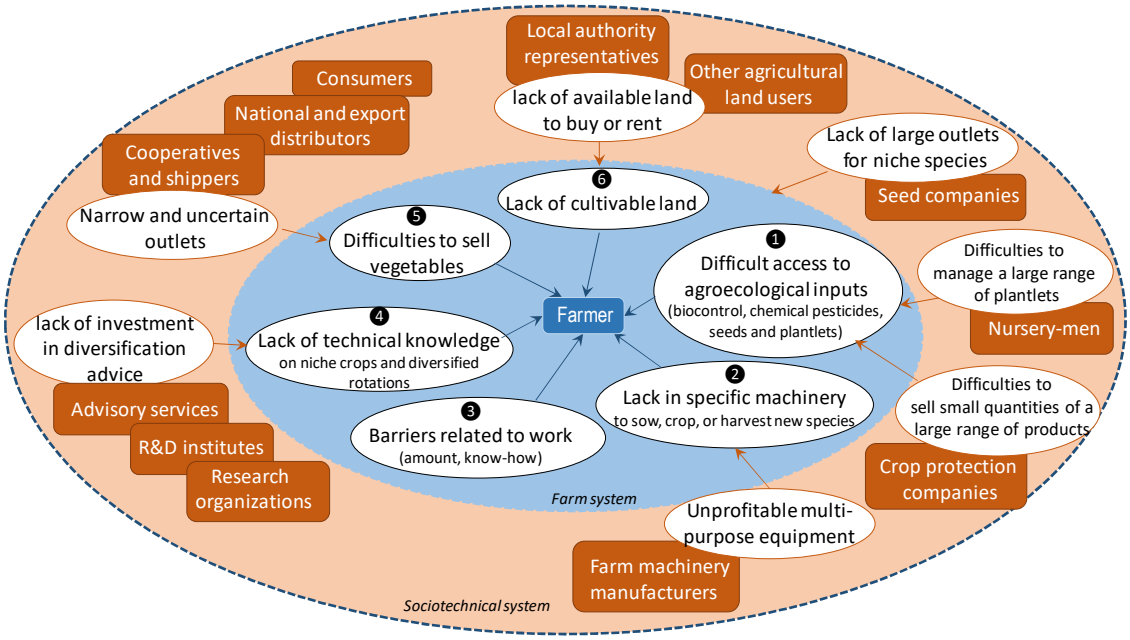
Intuitively, the final decision of crop diversification is first in farmers' hands. This is why we structured results through farmers' barriers and show how they are connected to other actors' barriers. Six categories of barriers were identified based on the two case studies (in the blue oval shape representing the farm system in Fig. 1). The most outstanding result is that most barriers experienced by market-gardeners are linked to barriers experienced by other actors (in the orange oval shape representing the sociotechnical system in Fig. 1), which highlights a sociotechnical lock-in around the diversification of crop rotation for managing plant health.

❶ *Difficult access to agroecological inputs:* several farmers said that high-performance cultivars were lacking for diversification species (e.g., allium spp. against root-knot nematodes). It results in low yields or quality, a lack of profitability and difficulties to find commercial outlets (Cf. ❻). It was linked to seed companies' own barriers which, in the interests of economies of scale, do not develop performing cultivars for niche species due to a lack of large outlets. Methods for plant protection (biocontrol or chemical products for these new crops) were also lacking.

❷ *Lack in specific machinery to sow, crop or harvest new species:* Some farmers were lacking of tools for sowing, planting, harvesting or packaging new species (e.g. a machine for sowing radish, or for bundling stem onions). As these tools are highly specific and these new crops represented a limited acreage on their farms, buying them was not profitable. The difficulty is compounded because, in the study area, there is little sharing of equipment between farmers. In turn, a barrier was experienced by machinery

manufacturers, who were not interested in developing multi-purpose equipment due to high investment and low profitability of current limited markets.

Figure 1. Sociotechnical barriers to diversify crop rotations in sheltered vegetable cropping systems to control pest and diseases. Results from the two case studies.



❸ *Barriers related to work:* Farmers noted that diversifying crop rotations increased working time, mental workload, with more small and diverse tasks to coordinate with workers. These barriers are not specific to plant health challenge, but common in crop diversification (Dupré et al., 2017). Contrary to the others barriers, this one was not linked to the constraints of any other specific actor, apart from overall elements relating to labor market, not been investigated in this study (e.g. labor costs, labor regulations, capacity to find and keep skilled workforce).

❹ *Lack of technical knowledge*: surveyed farmers lacked technical references and skills for specific practices (e.g. push-pull practice) and for cultivating niche crops, and on the best way to associate service and cash crops to manage pests. For example, to control root-knot nematodes, trap crops need to be positioned at the period when the mobile larvae are alive, so that they reach trap crop roots. These barriers to technical knowledge are linked to a lack of investment in technical references on crop diversification from advisory services, R&D institutes and research organizations.

❺ *Difficulties to sell the agricultural products coming from diversified crop rotations*: This was a major brake expressed by most interviewed farmers. Numerous marketing barriers exist, but only two are presented here. First, farmers were faced with a lack of outlets for new species. To control pests and diseases, it may require to opt for cropping

and harvesting periods that do not correspond to marketing expectations. Cooperatives, wholesalers and distributors built their supply and marketing strategies on economy of scale with large volumes. They are thus reluctant to sell a diversity of vegetable species, each with smaller quantities. Second, some interviewed farmers feared losing their commercial relationships on their main crops and the economic consequences.

❻ *Difficulties in land access for cropping new species*: This barrier is strongly related to the preceding issue ❺. Crop diversification reduces the volume to be marketed per species. Some farmers wished increasing the area to be planted with vegetables, either by internal reorganization between productions or by leasing or purchasing new plots. But they were faced to lack of available land near their farms and high cost of land in urban green belts. The actors involved in the land access barrier were diverse: other farmers, local residents, local authority representatives.

Practical Implications

The analysis shows how the impediments coming from the various actors act altogether in a systemic manner to hamper diversification of crop rotations. First, a farmers' barrier is almost always interdependent with another actor's barrier. Second, farm barriers are often interconnected: if a commercial barrier (e.g. reduction in volumes per species) could be overcome by increasing land area, this option is also hampered by other actors' strategies. To develop such crop rotations to manage plant health, it is therefore mandatory that changes occur not only in farms, but also among all actors also involved in the systemic lock-in. This is tricky because only part of the actors is anchored at a local scale, whereas others (e.g., distributors) escape from the local problem. In an attempt to overcome the impediments observed in this analysis, we later carried out workshops with the main actors engaged in the sociotechnical lock-in to co-design coupled innovations capable to unlock the system. They proposed changes at different levels of the agri-food system that could partly help farmers to diversify their crops, as for example coordination among farmers at the territory level, or between farmers, commercial middlemen and distributors to develop new outlets.

Theoretical Implications

Most barriers identified are similar in the two geographical areas and are consistent with findings published in other European countries (Casagrande et al., 2017; Morel et al., 2020). Our results enlarge those obtained by Boulestreau et al. (2021) in one of the two territories studied in this article, and thus gain in genericity. The choice to entry by the farmers' point of view on the lock-in process may have created an asymmetry to understand others actors' points of view. Some actors would merit a deeper understanding, both upstream (machinery companies) and downstream (marketing companies). Another blind spot concerns consumers' eating habits, which also hinder the development of certain vegetables that are difficult to cook or little appreciated.

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Smallholder farming agricultural transformation: implications for environmental sustainability, household dietary diversity and food (in)security.

Ndungu S. Nyokabi 1, Lisette Phelan 2, Henrietta L. Moore 1*

1 Institute for Global Prosperity, University College London, United Kingdom

2 Environmental Economics and Natural Resources Group, Wageningen University and Research, Netherlands

* Corresponding author; email: ndungukabi@gmail.com, n.nyokabi@ucl.ac.uk

Abstract:
This study explores how agricultural sector transformation aimed at increasing productivity and improving farmers' livelihoods and realised through the commercialisation of smallholder agricultural production systems has impacted environmental sustainability, household dietary diversity and food (in)security in the seven counties in the Mau-Cherangany complex in Kenya. Farmers were selected through convenience and purposive sampling by a team of Prosperity Co-learning Laboratory (PROCOL-Africa) network citizen scientists. Data was collected through key informant interviews conducted with 85 farmers. Additionally, data was collected through participatory photography and mapping exercises involving 45 farmers.
Cash crops such as avocado, maize, tea and coffee are increasingly being produced in Kenya. The agricultural commercialisation that has driven this land use change has accelerated biodiversity loss. The use of herbicides to control weeds has led to the loss of native flora and fauna. It has also reduced access to nutritious indigenous vegetables, leading to a reliance on the consumption of purchased foods from the market, and negatively impacted household food security. Holistic approaches to realising food system transformation are required to ensure that the commercialisation of smallholder agricultural production systems is not pursued at the expense of environmental sustainability, socioeconomic inclusion, and rural households' food and nutritional security.

Keywords: Citizen science, food system transformation, food justice, food democracy

Introduction

The global agri-food system is a major driver of climate change; environmental degradation and biodiversity loss; public health problems; and broader societal challenges undermining the realisation of the Sustainable Development Goals (SDGs) (Eliasson et al., 2022). Recognition of the linkages between the global food system and complex wicked problems and societal challenges have led to efforts in the Global North and South to transform food systems and achieve improved nutrition, health, environmental and climate change resilience outcomes (Davis et al., 2022). Food systems also necessitate a transformation to ensure their resilience against climatic and other shorter-term shocks, as evidenced by the recent COVID-19 pandemic (Sanderson Bellamy et al., 2021). In this context, the commercialisation of smallholder agriculture production systems has emerged as a popular approach to promoting rural development and creating livelihood opportunities (Wangu et al., 2021).

Scholars have postulated that smallholder farmers' participation in global value chains can create business opportunities for rural development (Matthys et al., 2021; Wangu et al., 2021). However, participation in these value chains necessitates commercialisation of agricultural production and, by extension, farmers moving from subsistence to intensive production; being dependent on external inputs; and pursuing production that meets market standards (Wangu et al., 2021). Farmers compliance with quality standards forces them to rely on inputs, services, and advice from experts - for example, related to accepted pesticide residue levels and product specification - can increase production costs and reduce profitability (Macharia, 2015; Wangu et al., 2021). It can also expose households to food insecurity, reduce dietary diversity, and increase reliance on purchased foods which may expose households to price volatility (Wangu et al., 2021).

One of the major shortcomings of current approaches to food system transformation and commercialisation of smallholder agricultural production system is that there is insufficient consideration of the potential adverse impacts of market-led policies and interventions on poor rural households' livelihoods, prosperity, and economic opportunities (Davis et al., 2022). To date, the commercialisation of smallholder agriculture has been premised on the idea that the nature and scale of the envisioned changes from food system transformation efforts will automatically lead to improved rural livelihoods. However, there is growing evidence that food system transformation can lead to unsustainable outcomes and perpetuate injustice within social-ecological systems due to information, power, and agency relationships between food system actors (Wangu et al., 2021).

Food systems are shaped by competing interests and uneven power relationships (Ruben et al., 2021; Wangu et al., 2021). Food system stakeholders differ in their priorities and ability to exert agency and influence decision-making processes (Wangu et al., 2021). Consequently, it is imperative that an intersectional approach is taken to food system transformation processes; this will ensure that all actors' interests and goals are accommodated (Davis et al., 2022). Moreover, there is a need for nuanced rather than "one size doesn't fit all" approaches to food system transformation'; this will ensure that

less powerful food systems stakeholders, such as smallholder farmers, are not adversely impacted (Dengerink et al., 2021). Ensuring that livelihoods and socioeconomic inclusion and environmental sustainability are prioritised as outcomes of food system transformation strategies is key to creating just and equitable food systems (Davis et al., 2022).

Although studies in Kenya have explored the commercialisation of smallholder agriculture and participation in global value chains and its impact on income and livelihoods (Wangu et al., 2021), there is a paucity of studies that have explored the implications for environmental sustainability, household dietary diversity and food (in)security. This study therefore explores how policymakers and practitioners can transform the agricultural sector in Kenya by commercialising smallholder agricultural production systems to increase productivity and improve farmers' livelihoods. This will positively impact the environmental sustainability of agricultural production and result in improved household dietary diversity and food security in Kenya.

Study design and methodology

This study was conducted in the seven counties in the Mau-Cherangany complex and included Narok, Bomet, Kericho, Nandi, Uasin Gishu, Elgeyo Marakwet and Trans Nzoia which are important agricultural production areas in Kenya. The study areas were chosen for several reasons: (1) the area is the research area of the Prosperity Co-learning Laboratory (PROCOL-Africa) Kenya citizen science project; (2) agricultural production is the main livelihood and economic activity for the residents of the counties; and (3) the area is undergoing significant land use change which has adversely impacted the integrity of the main water towers and soil fertility in Kenya. The study was conducted across the whole of 2022 across rainy and dry seasons.

Farmers' sampling approach and data collection

The selection of smallholder farmer followed the typology explained by Nyokabi et al., (2021), that classifies smallholder farms based on market quality and farming intensity. The majority of the participating farmers can be considered as rural extensive farms and peri-urban semi-intensive farms. Data collection was undertaken by a trained team of citizen scientists based in the study area who are part of the PROCOL-Africa network in Kenya. Farmers were selected through a convenience and purposive sampling strategy by a team of PROCOL-Africa citizen scientists' network in Kenya. The citizen scientists facilitated data collection. Additional data was collected through key informant interviews with 85 farmers through participatory photography and mapping exercises involving 45 farmers. The participants selected were predominantly smallholder farmers producing cash crops (i.e., avocados, mangoes, tea, and coffee). Some farmers kept bees and livestock such as cattle, goats, sheep, poultry. The questionnaire used in the interview contained questions related to the commercialisation of agricultural production; crops grown; livestock kept; marketing channels; knowledge of environmental impacts of agricultural production; knowledge of socio-economic impacts; and approaches to addressing perceived impacts.

Ethical consideration

This study had ethical clearance from the University College London (UCL) in the United Kingdom and a research permit from the National Commission for Science and Technology (NACOSTI) in Kenya. Informed consent was obtained from all the study participants and participants signed an informed consent form before the data collection activities commenced. Study participants were informed about the expectations regarding their participation in the research study; what kinds of data would be collected; and the overall purpose of the research. Participants were also informed that they could withdraw their participation, consent and/or leave the study at any point if they felt like doing so, without explaining why and with no negative consequences. Participants were invited to ask clarification questions regarding the research approach and purpose and answers were provided to all questions. All discussions and interviews were audio recorded and the audio recordings were stored in an institutional encrypted laptop at the end of each data collection day. Data were also backed up on an encrypted external storage device during the fieldwork. All participants' data were anonymised by attaching a random ID number to each participant and study location.

Data analysis

The recorded interviews and photovoice discussions were transcribed and translated into English from Swahili and other local languages used by farmers including Kalenjin and Maasai. Thematic content analysis was undertaken using NVIVO software. Ideas were identified and grouped into themes. Supporting quotes were identified to support and contextualise these themes.

Findings

Finding reveal that farms in the study area varies on their market quality (access to produce markets and access to inputs) and also on the levels of intensification. Farms in the intermediate rural areas with access to urban markets had intensive production system and used mor farm inputs compared to farms in the far rural areas. In all seven counties, there has been a gradual shift towards the production of cash crops such as avocado, maize, tea, and coffee which have a ready market and can bring more income to farming households. Agricultural commercialisation has driven land use change, creating a homogeneous landscape with new exotic crops, and accelerating the loss of native flora and fauna. A shift away from subsistence to cash crop production has led to a reliance on consumption of purchased foods, which are subject to price fluctuation, and has negatively impacted household food security. The adoption of new farming techniques has led to reliance on external farm inputs such as fertiliser, pesticides, and fuel and exposure to the power asymmetries and vagaries of the market:

> *"The cost of production has increased* [..] *hence low profits, middlemen do not disclose the final exporting price to the farmers"* (Photovoice discussion, Nandi hills)

> *"High cost of farm inputs such as fertilizer, low prices of tea* [farm products] *is a challenge, sometimes the buyers reject our tea bringing us to a loss"* (Key informant 1, Bomet)

Farmers are aware that their production practices can have a negative impact on the environment, as well as human health and well-being:

> *"Farming can cause water pollution when fertilizers and herbicides are eroded to the rivers*" (Photovoice discussion, Nandi hills)

Herbicides used to control weeds have led to the loss of native plant biodiversity and reduced farmers' access to indigenous vegetables previously consumed in households. However, some companies are training farmers on the prudent use and handling of pesticides to mitigate the negative impacts:

> *"Sometimes farmers are also trained on the use of farm chemicals, proper hygiene in farms, first aid* [..] *then they are given certificates*" (Photovoice discussion, Nandi hills)

To protect the environment in which they produce their crop, farmers are also being encouraged by private companies and non-governmental organisations (NGOs) to plant trees so that they can derive additional income and products while, at the same time, reducing their environmental impact:

> *"Tea is mostly planted with Grevilia spp.* [trees] *which conserves the environment and can later be used as firewood, it is also an income source for farmers*" (Photovoice discussion, Nandi hills)
>
> *NGOs usually come in with diversification projects encouraging farmers not to all produce the same crop varieties* [...] *and give training to farmers on the importance of planting trees* [...] and *conserving the environment. [the private companies] there are programs called CSR (Community Social Responsibility)* [...] *protecting catchments* (Photovoice discussion, Kericho)

There was unanimous agreement among farmers that agricultural commercialisation had increased their income and created new opportunities for rural development:

> *"The communities that have planted avocadoes are making a lot of money* [..] *avocado is a high-value tree, they can now pay school fees, buy food and clothing. Youths have got employment in these farms such as weeding and planting. Women are also engaged together with their husbands [..] they get income selling hence improving the living standards of their families while others are even avocado farm owners*" (Photovoice discussion, Bomet)

However, additional costs such as certification costs and increased quality standards requirements increased production costs and limited farmers' access to export markets:

> *"There is certification of farms globally which needs funding [investment in economic resources]"* (Photovoice discussion, Bomet)

Discussion

Transformation pathways that do not consider the needs of local communities may, conversely, have unintended impacts on households' dietary diversity, food, nutrition, and livelihood security, and foster a dependency on inputs such as chemical fertilisers and pesticides, as well as advisory services, which may lead to increased production costs (Wangu et al., 2021). The findings of this research highlight that, as farming systems change towards monoculture production systems, food systems increasingly contribute to wicked problems and societal challenges, such as climate change and biodiversity loss, that are of growing concern to farming communities as well as society more broadly. Similar trends have been observed in Brazil where there has been the expansion of soybeans and meat production has led to environmental degradation and biodiversity loss (Maluf et al., 2022). The findings of this research support calls for redesigning food systems around the adoption of agroecological production practices that ensure agricultural production systems are biodiverse and ecological, economic, and social sustainable (Gliessman, 2016).

This study show a trend towards uniform farming landscapes with low biodiversity and dominated by monoculture production of maize or avocado, and which may be detrimental to environmental sustainability and household food security. Previous research has shown that farm production diversity is positively correlated with indicators of household dietary diversity (Kissoly et al., 2020). It is therefore imperative that policies nudge farmers to biodiverse farm production systems as a way of ensuring food security and attaining sustainability goals.

The results of this study highlight the risks of indiscriminate and overuse of pesticides and other external inputs on the environment and biodiversity, but equally on human health (Macharia, 2015). The use of pesticides can have unintended consequences for the environment including the loss of beneficial organisms such as pollinators and the loss of indigenous vegetables which provide nutritious alternatives to commercial vegetables. In Kenya, indigenous vegetables have been shown to increase household dietary diversity and thus food security (M'Kaibi et al., 2015; Ng'endo et al., 2016; Oduor et al., 2019). Misuse of pesticides creates food safety risks for consumers if the proper withdrawal periods are not observed and/or water resources are contaminated (Macharia, 2015).

The results of this study highlight the imperative for policymakers and practitioners to ensure that food justice is enshrined in food systems transformation that is realised through the commercialisation of agricultural production systems. Increased income derived from agricultural commercialisation can increase access to diversified foods purchased from local markets (Ng'endo et al., 2018; Ruben et al., 2021). The results of this study show that farmers produced food for both home consumption and commercial purposes, but often farmers rely on purchased foods from local shops and markets which is in agreement with the research results of Ng'endo et al., (2018) in western Kenya. There are opportunities for farmers to tap into the increasing and emerging market demands for products such as avocadoes. Moreover, there are opportunities for value addition

associated with agricultural commercialisation that can create local employment, increase the market value of farm produce, and improve rural livelihoods (Matthys et al., 2021; Ng'endo et al., 2018).

Theoretical implications of this study

In this current digital age, the use of participant-led photography in qualitative research has become more commonplace and accessible to a wider section of society (Sanon et al., 2014). One advantage of adopting Photovoice as a research method and citizen science approach is that it invites the public to participate in both scientific thinking and the data collection process (Dickinson et al., 2010). This research approaches acknowledges the agency of the public to be part of finding solutions to the challenges they face in their day-to-day lives (Strasser et al., 2019).

Policy implications of this study

The findings of this research underscore the imperative for policymakers and practitioners to implement holistic policies and intervention strategies that ensure that food system transformation realised through commercialisation of smallholder production systems does not result in unintended, adverse outcomes. Food system transformation should not contribute socioeconomic exclusion, biodiversity loss, food insecurity, environmental degradation, and negative nutritional security of poor rural households. Robust governance mechanisms are needed to reconcile the diverse and competing goals of different food system actors and realise a just and equitable food system transformation processes and outcomes. Power and information asymmetries and policy incoherence need to be addressed to ensure the agenda of transformation is not captured and driven by a minority of powerful individuals and/or business interests.

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Adaptation of viticultural and wine-making practices in the face of climate change in a Geographical Indication: case of the Touraine appellation in France

Annie SIGWALT[a], Faustine RUGGIERI Faustine[b], Cécile COULON-LEROY[c]

[a]Research Unit LARESS, Ecole Supérieure des Agricultures, 49007 Angers, France

[b]INRAE, UMR 1048 SADAPT, AgroParisTech, Université Paris-Saclay, 91120 Palaiseau, France

[c]GRAPPE, Ecole Supérieure des Agricultures, USC INRAE 1422, 49007 Angers, France

Abstract:
It has become necessary to modify viticultural systems to reduce the use of pesticides, adapt to climate change and preserve soils. In France, where 95% of wine production is under Geographical Indications (GI) with practices codified in product specifications, it is interesting to analyze how environmental and climate issues can impact the future of a professional sector in a territory covered a Protected Denomination of Origin (P.D.O.) quality sign, such as the Touraine PDO. This appellation covers an area of about 5000 ha of vines, and gathers 650 winegrowers, mainly around the production of white (59%), and red wines (22%). Our study approach combined interviews first with experts of this wine sector, then with 34 winegrowers. We also organized wine workshops to determine the PDO stakeholders' collective point of view about the actual and future typicity of their wines. Our results highlight potential solutions applicable in terms of technical management of the vine and in the cellar, as well as their impact on the organization of work on the wine estates. It is also necessary to anticipate market developments, especially in terms of the typicity of the wines produced, and in communication strategy, to maintain competitivity of the Touraine PDO.
Key words: wine production, agroecological transition, Loire Valley

Purpose

Since the promulgation of the 2014 law for the future on Agriculture, Food and Forestry in France, it has become necessary to modify current agricultural systems by developing sustainable practices to meet the global challenges of economic, environmental, and social performance. The agroecological transition is thus defined by Piraux et al (2010) as a socio-territorial innovation, which not only involves technical changes, but also social and institutional changes anchored in the territories where it takes place. In viticulture, the challenges of reducing the use of phytosanitary products, adapting to climate change, and preserving the soil, are particularly significant (Macary et al, 2020). Therefore, agroecological practices are widely promoted by institutions and production actors themselves (Lempereur and Herbin 2023; Ruggieri et al. 2023). Despite public policies launched by the French government aiming at an agroecological transition, pesticides remain widely used in viticulture and their sales have so far stayed stable. In addition, the

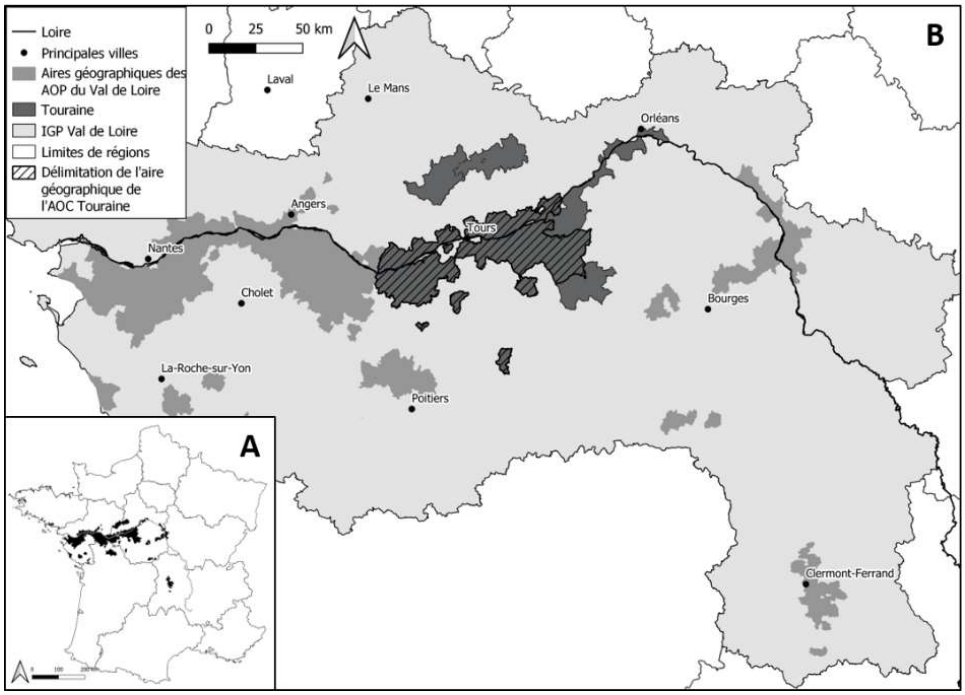
effects of climate change are already very noticeable, affecting both the progress of the vine's physiological stages and the composition of the grapes, even in a wine-growing region with an oceanic climate such as the Loire Valley (Neethling et al, 2012). Moreover, in France, 95% of wine production is under Geographical Indications (GI) with practices codified in product specifications, whether Protected Geographical Indications (PGI) or Protected Designations of Origin (PDO) (INAO, 2023; 2021 data). However, the production of a wine under a Geographical Indication is directly linked to the notion of terroir. The definition we use here is the one proposed by Prévost et al (2014) because it considers sociological aspects and emphasizes value creation. More precisely, the terroir is seen as a local productive and cultural system, linking a territory with physical and natural specificities to a human community, which knows how to enhance it thanks to local skills and know-how, and through the implementation of an adapted local governance, to produce and enhance a typical product. It therefore does not focus solely on the physical criteria of the territory, but also highlights the viticultural and oenological practices deployed by the winegrowers, within the framework of a set of specifications defined for each local product linked to a Geographical Indication. As a result, the typicality linked to the terroir is the result of a particular social construction concretizing the effect of the terroir for a given product, it corresponds to a property belonging to a type, distinguished and identified by a reference human group with knowledge distributed among the different actors in the sector: knowing how to establish, knowing how to produce, knowing how to evaluate and how to appreciate (Casabianca et al, 2006). Therefore, for this study we adopted an interdisciplinary approach, interdisciplinarity being understood here as the joint use of different disciplinary knowledge to understand a complex reality (Lenoir, 2015). In our case, we used concepts coming both from the agronomy of viticultural systems and from a comprehensive sociology approach. Our conceptual framework is based on the notion of "localized sociotechnical systems of production", a concept that refers to a specific geographical territory, often delimited from a legislative point of view by the area of a GI, in which an agricultural or agri-food production good is produced. We seek to analyze how environmental and climate issues can impact the future of a professional sector in a territory covered by a GI and more specifically by a Protected Denomination of Origin (P.D.O.) quality sign. In this article, we present the study we conducted for and with the body management of the Touraine PDO in 2022-2023, to answer the following questions: How do winemakers perceive climate change in their vineyards? What practices do they implement to deal with it, within the framework of the specifications of their PDO? How do they anticipate their wines' typicity evolution? The objective is to help the management body of this PDO to address future strategies for its development, considering both the impacts of climate change on viticultural itineraries and on wines produced by its adherents.

Methodology/Approach

Our study was based on the request of representatives of the Organisme de Défense et de Gestion (ODG) of the Touraine PDO (director, administrators): they wanted us to

highlight the possible technical options to define the vineyards and wines of tomorrow in Touraine PDO, considering the climatic and environmental issues and the economic constraints of winegrowers. A study agreement was thus established in advance, to clarify the expectations on both sides, and to present the research methodology, notably including the participation of fifth-year agronomist students in the collect of field data.
The field of study corresponds to the geographical area of the Touraine PDO, in the Loire Valley wine area, one of the 364 French wine PDOs. It covers an area of about 5000 ha of vines, between Chinon and Blois, in Loire Valley (France). It gathers 650 winegrowers, mainly around the production of white wines (59%), and red wines (22%). This PDO includes 5 complementary geographical names (DGC), with even more quality oriented codes of practices such as DGCs Touraine-Amboise, Touraine-Mesland, Touraine-Azay le Rideau, Touraine-Oisly and Touraine-Chenonceaux. In addition, winegrowers located in the Touraine appellation area can choose to promote their wines under the Protected Geographical Indication (PGI) Val de Loire, or under the label “wines from France”.

Figure 3: Location of the geographical area of the AOC Touraine (source: authors' work based on Agreste and data.gouv.fr data)



We conducted a study in three steps, while training a group of 18 confirmed students from our School of Higher Education in agriculture to research via the different types of interviews and analyze conducted with the Touraine PDO stakeholders.
A first data collection was built to interview 6 actors of the wine sector in the PDO area whose contacts were given to us by the director of the ODG so as to get a wide range of professional profiles. The objective was to interview people who were familiar with this PDO, to identify the challenges that the Touraine PDO must face in a context of climate change. Results were synthetized into a SWOT (Strengths-Weaknesses-Opportunities-Threats) table.

The second step of the study involved conducting semi-directive face-to-face interviews with 34 Touraine PDO producers. After a presentation of the respondent and his winery, the interview guide focused on the characterization of his plots and on the wines produced under AOC, IGP or wines of France, whether white, red, rosé, or sparkling wines. The winemaker had to explain why he chose to produce a particular wine under a certain quality label. This made it possible to characterize the production and marketing profile of the farm. The winemaker's practices in terms of soil, foliage and disease management were then detailed while taking stock of the plant and technical material at his disposal and the innovations put in place, particularly in response to his perception of the impact of climate change on his vineyard. The next part focused on the winemaker's network of knowledge and the information available to him, in order to measure with whom the winemaker was discussing the evolution of his practices in a privileged way. Finally, we invited the winemaker to talk about his prospects, first at the level of his farm and then at the level of the entire AOC Touraine, while collecting his expectations with regards to the ODG. The survey material was subject to thematic and cross-sectional content analysis by the students, giving them the opportunity to use a qualitative interview analysis method.

The third highlight of our study was the organization of a half-day workshop with Touraine stakeholders on the typicity of wines produced today, and those which are likely to be produced in 10-15 years' time, given the impact of climate change on the vine. Two workshops, bringing together 17 participants, were conducted, in parallel, one on white wines, the other on red wines from Touraine. Participants were first asked to define what characterized the identity of today's Touraine wines, by answering with post-it notes. These ones were classified by the students to distinguish sensory criteria from other possible criteria, relating for example to the territory and landscapes, to the management of the vines, to the processes used in the cellars, to notoriety, to the evocation of the area history and heritage. In a second phase, the participants had half an hour to blind taste and enjoy 5 different wines (white or red depending on the table), chosen to represent present typical Touraine wines or to be similar to the Touraine wines of the future, given climate change (higher degree of alcohol, lower acidity, different aromatic notes). Participants were then asked to rank these wines on a scale ranging from "very bad example" to "very good example" and then to explain their assessments. A synthesis of all collected data was then performed to obtain writings and oral presentations to give the results to sponsors.

Findings

Winegrowers are aware of the impacts of climate change

Surveys show that winegrowers are aware of climate change and its effects on the vine cycle: they note an earlier start to vegetation of the vine in spring, with associated risks of spring frosts, a weakening of the vine due to periods of more intense heat and

drought, rippening and early harvest dates. As a result, they are wondering about the evolution of pest cycles and potential emerging diseases. In terms of quality of the grapes, they note a decrease in total acidity and an increase in the potential alcohol content, which they analyze as positive points to produce Touraine red wines, but as a risk of loss of freshness for Sauvignon-based white wines.

Three types of innovation to adapt to climate change at farm level

The analysis of their responses regarding the changes in practices to be implemented to adapt to climate change shows that at the scale of their wine estates, three types of innovations are listed: on the technical viticultural itineraries, in the cellar and in the design of future plots.

The winegrowers first mention short-term changes in practices in the management of the vines: later pruning or in several passes to minimize the risk of frost, and acquisition of anti-frost devices for the most frosty areas; tillage to promote deep root implantation; grassing or mulching to conserve soil moisture; reduction of trimming and leaf thinning to prevent the grapes from "roasting" at the end of summer; harvest at night to preserve the quality of the grapes. It should also be noted that some are thinking about new techniques such as agroforestry or eco-grazing for soil maintenance. It appears that these technical adaptations are consistent with the current specifications.

In the winery, they mention the possibility of using new fermentation yeasts with a lower alcohol yield to minimize the alcohol content of the wines, or even the use of a wine dealcoholizing process. Faced with declining yields, they turn to buying grapes or must from fellow winegrowers in the production area to compensate for volume losses. More generally, in a reflection towards reduction of environmental impacts and a better use of resources, some mention projects for the reuse of cellar water, the installation of photovoltaic solar panels or heat pumps, or the implementation of deposits for bottles.

Finally, longer-term developments, relating to the development and establishment of new plots, are mentioned. These new plantings should favor more north-facing plots, avoiding drought-sensitive soils (limestone) and preferring deep soils with more clay for water retention. Many winemakers wonder about the plant material (rootstocks, grape varieties, clones) to use. In addition to rootstocks that should be more resistant to drought, they highlight old grape varieties (Orbois, Grenouillet, excluded from the specifications because they previously gave grapes that were too acidic). They also highlight traditional grape varieties of the Loire Valley vineyard (Grolleau, Chenin, Pineau d'Aunis) or new grape varieties resistant to fungal diseases (VIFA - varieties of interest for adaptation purposes), and the reduction of the use of Gamay, which is too sensitive to drought. However, changes in production areas or the introduction of new varieties would in all cases require a change in the AOC's specifications, in consultation with the INAO.

It should also be noted that the technical innovations mentioned above sometimes also lead a reflection on the estate’s work organization, either to limit the exposure of staff to high temperatures (staggered schedules, adapted equipment), or because winegrowers

are noticing shorter periods for intervention in the plots, requiring an increased workforce, in a context of strong competition for the vineyard workforce.

Food for thought at the appellation level

In view of all these developments, some of which are underway and some of which are yet to come, the enhancement of wines leads to important thinking subjects for winegrowers, which can take three directions. Namely: i) on the desirable balance between the marketing of wines by winegrowers and by the specialized trade, the latter tending to be more present with the creation of large-scale wine-growing structures at the expense of family wineries, illustrating what Purseigle and Hervieu (2022) define as corporate agriculture; ii) on the typicity of the wines (with perhaps a higher proportion of red wines and the introduction of new grape varieties to compensate for the difficulty of the Sauvignon Blanc grape variety in preserving the freshness and thiol aromas currently sought by consumers in white wines) and iii) on the communication to be put in place to improve the reputation of the Touraine PDO, which, it seems, has so far given little value to the tourist potential of its region (Loire Valley, architectural heritage) or the possible taste association with regional cheeses.

During the final restitution of the results to the sponsors, given the time allotted and the associated resources, we perceived a certain frustration among some of them at not having results at the scale of the farms as a source of information for technical adaptations and possibly an evolution of the AOC's specifications. However, the project has made it possible to identify both current and future avenues to the PDO management body, and to give a picture of the existing winegrowing domains which use a wide range of production methods, laying the foundations for possible additional characterization work. Moreover, the sponsors raised the need to also develop a complementary analysis by mobilizing consumers' perception of the wines expected in the future, the consumer being a contributor of "know-how" in the construction of typicity.

Practical Implications

Our results highlight potential solutions applicable in terms of technical management of the vine and in the cellar, as well as their impact on the organization of work on the wine estates. Some of these technical changes are part of the on-going evolutions that winemakers introduce in their viticultural systems, others are thought as middle-term or long-term changes, such as new ways of implanting vines or low carbon cellar design. In any case, the interviews show the winegrowers' attachment to their PDO quality sign, given the fact they could choose to shift to another regional GI. They favor the Touraine PDO notoriety won over time by their wines’ typicity. Such result underlines the social dimension of terroir, beyond its agronomic and technical aspects. On a collective level, it is also necessary for the Touraine PDO management body and winegrowers to anticipate market developments, in terms of market distribution between traders and winegrowers, in terms of the typicity of the wines produced, and in communication

strategy, so that consumers (and their prescribers) maintain their attachment to wines that are always competing on the French and world markets.

Theoretical Implications

The framework established in this study demonstrates its commitment to supporting the management bodies of PDOs in shaping their strategic directions in relation to agroecological transition and climate change adaptation. Although it has been implemented in the context of a wine producing PDO, it has the potential to by applied more broadly to other GIs and localized food systems using a multi-phase approach that focuses on the actors and elements specific to the terroir of GI systems. While our current research has utilized the framework of socio-technical systems, there is value in considering a shift towards the socio-ecological systems framework developed by Ostrom (2019), particularly as it has recently been adapted to the context of a wine producing GI (Ruggieri et al, 2023).

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The evolution of Solidarity Purchasing Groups: changing preferences and patterns

Rosalia Filippini[a,b], Marianna Guareschi[a], Micaela Sini Scarpato, Maria Cecilia Mancini[a]

[a]Department of Economics and Management, University of Parma,

rosalia.filippini@unipr.it; marianna.guareschi@unipr.it; mariacecilia.mancini@unipr.it

[b]UMR Territoire, INRAE, (France)

Abstract:

This study explores the food supply and demand changes among three Solidarity Purchasing Groups (SPGs) in Parma, Emilia Romagna, Italy, by examining their orders from 2015 to 2022. It found that the pandemic led to a surge in SPG orders. Over the eight-year period, a notable trend emerged: a shift from certified organic to uncertified organic foods and those associated with social assistance projects. The analysis also uncovered differences in food demand patterns between urban and periurban SPGs and identified a growing interest in products from Parma and distant areas like Sicily. Conversely, there was a reduced interest in products from Emilia Romagna farmers and those in Northern Italy. These insights can help SPG members to reflect on their purchasing habits and support sustainable food supply chains. Furthermore, this research enriches to scholarly discussions on SPGs by offering a first-of-its-kind analysis on the specifics of SPG orders and their supplier selections.

Keywords: Short Food Supply Chains, temporal analysis, Italy

Purpose

The purpose of this analysis is to study the evolution of Solidarity Purchasing Group (SPG) demand and supply in a time span of 8 years. The analysis covered the entire catalogue and 2 set of products, namely cereals and fruits.

Design/Methodology/Approach

The analysis is based on a descriptive statistic of data on the 3 SPGs' purchasing orders from 2015 to 2022. The purchasing orders represent both the demand requests of families and the actual supply of farmers that are contacted by families. The analysis covered: the diversification of products purchased, their quality labels, their provenance. The three SPGs are from the province of Parma (Italy). Parma is the main urban center in the province of Parma, in the Emilia Romagna region (Italy). They 3 SPGs were chosen for their localization, thus representing different typologies of consumers: Pallacorda GAS involved 29 families living in the city center of Parma; GASteropodi grouped 31

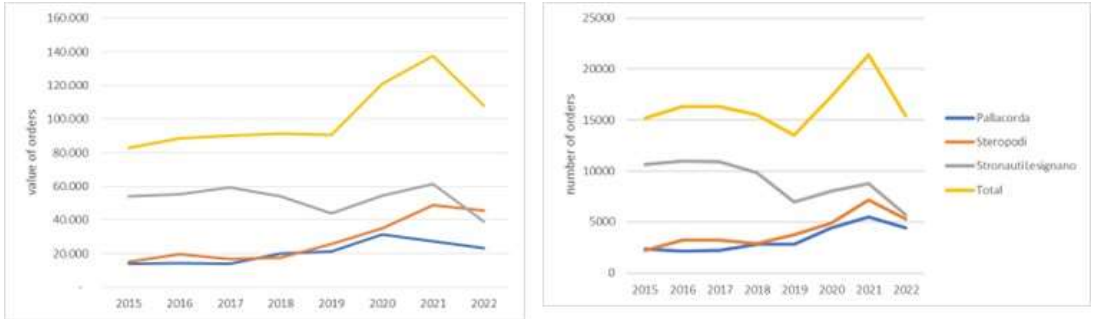
families from Alberi, a village localized 6 Km from the city of Parma, thus in the periurban area; GAStronauti include 72 families from Lesignano, a village 25 Km from Parma.
The analysis covered the entire catalogue of products and then it deepens 2 categories of products: cereals and fruits. They were chosen because they represent two different consumption patterns. Fruits are mostly fresh products, while cereals are mainly processed products. Moreover, in both categories there are local, regional and national suppliers. In literature, a clear definition of local and regional food is missing. Local products usually refer to those that are produced and consumed within a defined geographical area (Kneafsey et al., 2013). For the purpose of this contribution and considering the case study we identify the local suppliers as the ones from the Province of Parma, while regional suppliers are those from the region Emilia Romagna.

Findings

A general overview: evolution of purchasing, suppliers, and quality signs for the three SPG in the period 2015-2022

A first aspect analyzed concerns the overall purchasing performance of the three SPGs for all product categories with respect to the amount spent and with respect to the number of orders placed in the period 2015-2022. Both values and number of purchased products increased in the period observed (Fig.1). Especially it seems that the year 2020 represents a moment of further engagement in SPG. The value of purchasing increased on average 24% from 2019 to 2021, while the number of orders increased on average of 26% in the same years. This raise seems to stop with 2022 when both the number of purchasing and the value spent have decreased even though with different percentages. Nevertheless, the value spent in 2022 was higher than what was spent before 2020, while the number of purchasing is the same than the average number of orders in the pre-pandemic period (around 15,380 orders). From these data we can deduce that the increase in value in 2022 compared to the average of the years 2015-2019 is due to an increase in product prices or a shift in the type of products purchased. As it is possible to see the 3 SPGs show the same dynamics.

Figure 1: Values and number of orders of all categories by the three SPGs in the period 2015-2022



Concerning the analysis of suppliers, results show an increase in the number of suppliers by 58% in the period 2015-2022. Regarding the provenance of the products, while

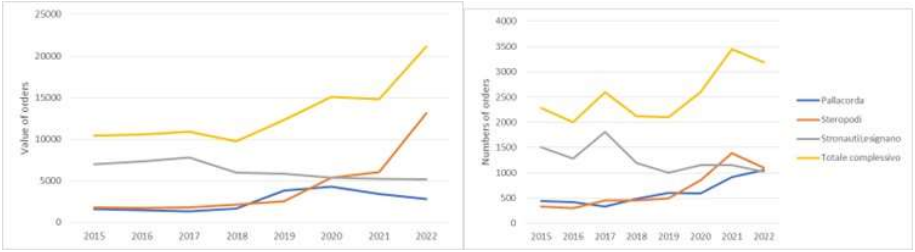
suppliers from Emilia Romagna represented the 49.3% in 2015, they dropped to 36.7% in 2022. However, considering the total number of regional producers, local suppliers raised from 67.6% in 2015 to 72.5% in 2022. In terms of number of orders demanded to suppliers from the Province of Parma, it represented the 58% of total orders from Emilia Romagna in 2015 and the 90% in 2022. This corresponds to an increase in the value spent within the province of Parma, representing 56.5% in 2015 and 90.3% in 2022. At the same time, the demand for products not locally cultivated have increased, such as olive oil and citrus fruits. These results show that SPG members are more and more interested in local food suppliers at the expense of regional suppliers. At the same time, SPGs members have increasingly sought to cover their food requirements through SPGs', looking for producers localized outside the regional borders. In fact, there is an increase in the number of producers in the Central and Southern regions by 260% and 66.7% from 2015 to 2022, respectively.

Regarding the quality signs used by suppliers, the percentages of suppliers with organic certification and PDO-IGT remains stable along the period, representing 29% and 17.4% respectively. Producers adhering to Participatory Guarantee Systems (PGS) increased slightly from 10 to 12.3%, as well as producers that follow natural and organic farming practices but do not have the organic certification, who increased, representing the 15,5% in 2015 an the 20,3% in 2022. Moreover, data show an increase from 8.8% in 2015 to 19% in 2022 in the number of suppliers with social commitment, such as fairtrade and mafia-free lands, demonstrating the political and ethical commitment of SPGs.

A look at two specific categories: fruits and cereals products

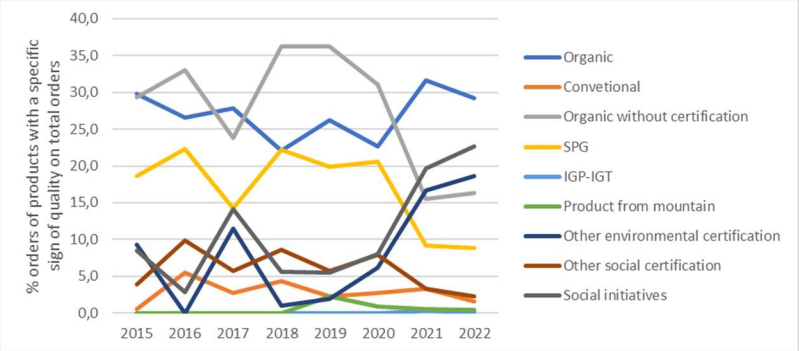
The analysis of the cereal-products category shows that the value spent by the three SPGs increases on average by 22% in the period 2019-2021 and by 43% in 2022 compared to 2021 (Fig.3). This increase is due to the growth in the value spent by GASteropodi by 116% in 2022 compared to 2021, while Pallacorda and GAStronauti Lesignano show a decrease by17.6% and -1.2% respectively in 2022 compared to 2021, following the general trend (Figure 4). Even if the number of orders is considered, general trend is respected: the number of orders for cereals raised on average by 28% in the year 2020-2021, while decrease by -7.7% in 2022. However, the number of orders in 2022 (3,185) is 43% percent higher than the average orders before 2020 (2,222 orders), due to the increase of orders by GASteropodi members.

Figure 3: Values and number of orders of cereals products in the period 2015-2022



In the overall period, SPGs demanded mainly dry products (pasta, rice and other cereals such as oats, millet, spelt, barley grains - 12,000 orders). Snacks and bakery products (8,084 orders) were used more than flours (5,411 orders). In addition, while dry products increased by 92% over the period and snacks and bakery products by 114%, flour decreases by -39%. Especially Pallacorda increased dry products of about 360% and decreased flours by -28.5%. Pallacorda has started to demand for snack and bakery products since 2018, registering a rise of 30% in the years 2018-2022. GASteropodi increased all categories of products especially snack and bakery products (+560%) and dry products (+223%). On the contrary, GAStronauti Lesignano registered an overall decrease of orders of -32%, especially for flours that drop to -60% (Fig.3).
Considering the location of the suppliers of the products ordered, a decrease of 42% is observed for number of orders demanded to Emilia Romagna suppliers; in fact, Emilia Romagna's percentage weight in total orders decreased by -53%. However, the percentage weight of orders from Parma Province on all regional orders shows an increase of 29%. In general, all regions supplying cereal products throughout the period experience a decrease in the number of orders, due to greater regional diversification of suppliers.
Regarding the quality signs, shows that while the incidence of organic products remained almost constant over the period, representing 29% of total orders, products without certification and PGS decreased. Instead, there is an increase in orders toward products with other environmental certifications and social initiatives.
At the same time, we notice an increase in orders for dry products which come mainly from outside the region, and the drop of flours, which mainly come from the Parma Province. In other words, the local products have decreased, while products from out of the region have increased. These last products have organic certifications. This result seems to suggest that when SPG looks for products produced outside the region, they prefer formalized certifications.

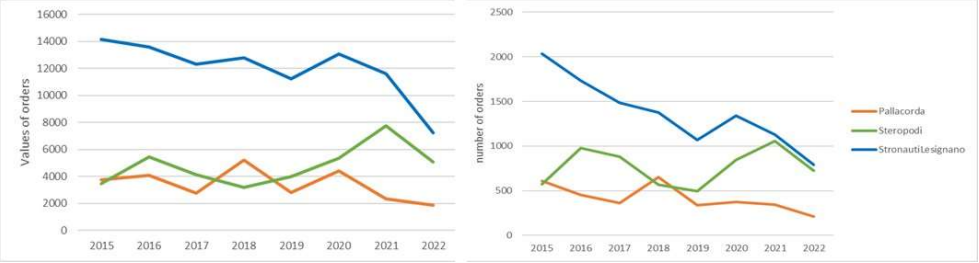
Figure 4: percentage of orders of products with a specific quality sign on total orders



Considering the Fruits category, SPGs show different dynamic (Fig 5): for Pallacorda and GAStronauti Lesignano the number of orders decreased on average more than the value spent in entire period, respectively about – 48% and – 67%, consistently with the general

dynamic. On the contrary, the SPG GASteropodi has increased both number of orders and value of product, respectively by 26% and 46%. Comparing Pallacorda that is located in the urban area and GASteropodi which is localized in peirurban area, the two show opposite dynamics: while GASteropodi engagement generally increases, Pallacorda seems more and more less attached to SPG orders of fruit.

Figure 5 Values and number of orders of fruits in the period 2015-2022



In the overall period, SPGs were used more for fresh products (15,697 orders) than processed products (only 4,705). Nevertheless, fresh products decreased more than the processed ones, respectively 56% and 20%. Especially Pallacorda decreased fresh products of about 77% and processed products only 20%, while on the contrary Steropodi increased both categories of products, 15% of fresh products and almost 80% for processed products.

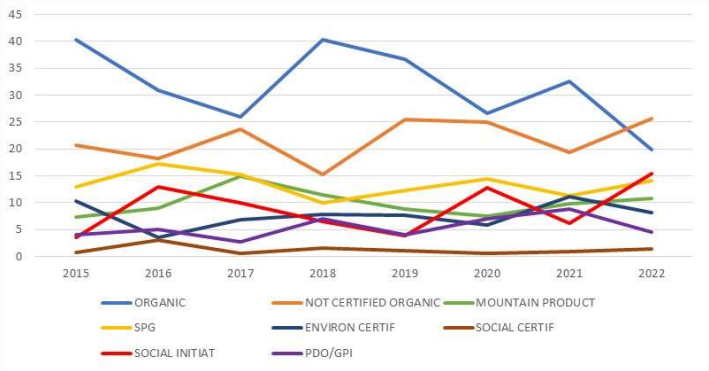
This dynamic is interesting since it shows a less interest of consumers in fresh products, especially the ones who lived in the city. This can be probably due to the fact that it is not always convenient, for consumers the provisioning through SPGs: usually orders are made 1 or 2 weeks before, and families need to wait to consume fresh food. Being also more perishable, costumers may prefer to order less for a product that it cannot be immediately consumed. At the same time, alternative outlet for “sustainable” foods have emerged in the city along the years, such as small shops, other alternative food chains, or even supermarkets are more engaged in alternative and local foods. Thus, the modalities of supply of SPGs seem less convenient for fresh and quality products.

Considering what kind of fruit is more demanded through SPGs, it is notable to mention that the ones more ordered in 2022 were oranges (267), apples (254 orders), strawberries (173), lemons (129). These are all fruits that are not locally produced, and mainly come from North (Trentino region) and South of Italy (Sicily and Calabria). At the same time, considering the entire period, the fruits that record the higher decrease are mostly locally produced fruit, such as melon (-90%), watermelon (-88%), apricots (62%), cherries (-57%). Again, this is probably due to the fact that since 2015 several initiatives in the city of Parma have emerged to supply locally food produced.

Consistently, at the regional level the number and the value of orders decreased more for the region Emilia Romagna (- 53%), than for the region Sicily (-17%), but inside the region of Emilia Romagna, the number of orders from suppliers in Parma Province increased by 50%. This result is consistent with the increasing interest for local producers as analysed before.

On quality signs, Fig. 6 shows that while in 2015 organic products represented 40% of the products purchased, in 2022 they represented only 19% of it. On the contrary, the products without any certifications increased from 20% to 26%. This result is consistent with the fact that for local suppliers the organic label is less necessary. It thus seems that SPGs is considered as a guarantee of quality of the food product, even when formalized certification is not provided. A significant increase it is registered also for products that are sold in the framework of social initiatives (+ 15%).

Figure 6 Number of orders and quality sign in fruit category



Practical Implications

The analysis allows members of the SPGs to observe their own purchasing dynamics, considering the location of suppliers, preferences with respect to product categories, and signs of quality and in general, how their members' interests shift. Such an analysis can be a tool for the SPGs to be able to discuss strategies to put in place to strengthen themselves.

Data show the pandemic period led to an increase in total orders in the period 2020-2021. Thereafter, there is a return to pre-pandemic levels in the number of orders and higher levels in the value spent, possibly due to an increase in prices. In addition, an increase in the number of producers from other geographic areas is observed over the entire period, suggesting an interest in products which come from other regions. But at the same time, and considering the regional suppliers, the local farmers have increased, showing that the GSP' pillar of product proximity is maintained and strengthened. In addition, a shift from buying fresh or raw products to products that can be stored more easily or are already finished is observed. Thus, this study can be an opportunity for SPGs members to reflect on the social and cultural values they share and support through the purchase of food coming from specific economic activities. It is interesting for example that the interest on organic certified products decreased while the interest on local food has increased.

Theoretical Implications

Short Food Supply Chains (SFSCs) are advocated for their capacity to improve the sustainability of the agro-food system. A unique definition of SFSCs is missing since the

way they are established is affected by the specific socio-ecological relationships in each case study. Renting et al., (2003) had proposed three main categories of SFSCs: Face-to-face SFSCs, Proximate SFSCs and Extended SFSCs. The three kinds distinguish themselves on the decreasing importance of geographical and temporal proximity between consumers and farmers, while their social proximity is central.

In Italy, Solidarity Purchasing Groups (SPGs) were born by groups of consumers to get control over the food supply chain and the food quality (Brunori et al., 2012). Studies have been especially focused on how consumers and farmers personally approach to SPGs (Barbera et al., 2020), than on what is demanded by consumers in a systematic way. Understanding the evolution of their food demand is important to understand the changing importance of SFSCs attributes such as the geographic proximity, quality labels, food diversification, commitment to sustainability. To the best of our knowledge, this is the first time that such data were systematically collected and analyzed. In general, SPGs supply is more and more diversified. Results show that there is a difference in the preference between fresh and processed products. While fresh products decrease, processed products decreased less or even increased. The competition with other emerging AFNs is one of the causes, since this is especially true for the SPG localized in the city center. In peri urban areas, where the alternative food outlets are few, SPG has increased the number of both fresh and processed products. This result opens research questions about the competition and/or integration of AFNs and SFSCs and thus the resilience of the overall alternative food system (Filippini et al., 2020).

The analysis shows that SPGs are more and more SFSCs (Renting et al., 2003). By the one side, they are more and more supporting local farming system, more than the regional one. By the other side, they are more and more supporting agriculture that it is not proximal but it provides food quality (Goodman, 2003). The food quality here is less based on certifications, such as organic one, and more and more based on trust, and social implications.

Still, processed products are niche products, such as biscuits, jams with special flavors. This indicates a certain preference for products that are less available in conventional food chains, such as supermarkets, where the food supply is more standardized. These products are also products that are less integrated in the daily diet of a household.

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GOVERNING TRANSITION TO CIRCULAR BUSINESS MODELS

Role of nutrient requirements in the design of circular food systems – the case of older adults

Shiksha Adhikari[a,b], Ollie van Hal[b], Thom Huppertz[a,c], Imke J.M.de Boer[b]

[a]Food Quality & Design group, Wageningen University & Research, 6708 WG Wageningen, the Netherlands;

[b]Animal Production Systems group, Wageningen University & Research, 6708 WD Wageningen, the Netherlands;

[c]FrieslandCampina, Research and Development, 3818 LE Amersfoort, the Netherlands

Abstract
Recent studies show that redesigning food systems on the basis of circularity principles can bring environmental benefits. It has been argued that protein requirements used in these food systems studies underestimate the actual protein requirements, especially for older adults. We aim to assess the effect of adopting higher protein requirements of older adults on environmental impacts and modelled diets of circular food systems. We used the agro-ecological model FOODSOM that meets the human nutritional requirements while minimizing the environmental impact (i.e., land use and greenhouse gas (GHG) emissions). A scenario with current protein requirements was compared with a scenario where protein requirements for older adults was increased. Implementing new requirements increased average protein requirement of Dutch population by 8%. Minimum land use and GHG emission were found when 25 to 30% of the required protein came from animal-source foods. We found that an increase in protein requirements of the older adults increased the environmental impact (i.e. land use with 6% and GHG emissions with 9%), but also resulted in a notable shift from calorie-rich to protein-rich plant-source foods (e.g., inclusion of legumes, replacing oil with nuts). This study clearly demonstrates, that we should acknowledge age-specific human requirements in the design of sustainable food systems.
Key words: Food systems; Land use; Greenhouse gas emissions; Protein; Dietary changes

Purpose

The global food system has a major impact on the environment. Recent studies show that redesigning food systems on the basis of circularity principles can bring significant environmental benefits, of which adopting a circular diet is most effective. Circular food systems consider the interactions that occur between plant and animal-source food production to achieve the lowest possible land use and GHG emissions. *In circular food*

systems biomass is prioritized to produce food for human consumption, unavoidable food losses are recycled as, for example, compost or animal feed, and animals convert mainly biomass inedible to valuable food for humans (van Zanten, Van Ittersum, & De Boer, 2019). Thus, a diet that meets all human nutritional requirement is generated with minimum environmental impact and referred to as *circular diet*. *A circular diet is primarily plant-based diet with only a moderate amount of animal-source food needed to meet human requirements at the minimum possible environmental impact*. It has been reported that, by shifting from the current to a circular diet, land use could reduce by 43% whereas GHG emission could be reduced by 52% (van Selm et al., 2023).

Thus far, these food systems studies are based on current human protein requirements. These current dietary protein intake requirements, however, are believed to underestimate the actual requirements, especially for the older adult population. The current recommendation of 0.83 g protein per kg body weight per day for both genders is 49-55% lower than suggested by some studies. For instance, it is reported that protein requirement for females above 65 years old is 1.29 g per kg body weight per day (Rafii et al., 2015), whereas for males above 65 years old it is 1.24 g per kg body weight per day (Rafii et al., 2016). Inadequate protein intake is associated with scarcopenia in older adults (Coelho-Junior et al., 2022). Therefore, it is crucial to focus on protein requirements of older adults to ensure that their dietary protein intake is adequate.

With the growing life expectancy and increasing population of older adults, it is important to take into account their nutritional requirement while redesigning sustainable food systems. Here, we aim to assess the effect of adopting higher protein requirements of older adults on the suggested circular diets while minimizing land use or GHG emissions. *Additionally, we aim to analyse the dietary changes required to meet the increased protein requirements*. In this way, we also highlight the influence of changes in nutritional guidelines applied on the outcome of the food systems models.

Methodology

We used FOODSOM model to assess scenarios that differed in terms of protein requirements. FOODSOM is an agro-ecological optimization model for the Dutch food systems and has been described in detail by van Selm et al. (2023). It is able to assess how agricultural resources can be used optimally to meet the nutritional demand of the Dutch population, with minimal environmental impact. In brief, the model selects the combination of crop and animal production systems that meets human nutrient requirements, while minimizing environmental impacts (i.e., land use or GHG emissions). Crop production includes 49 representative crops which can be grown on available arable land, grassland, and orchards or in mushroom sheds and greenhouses. The area of land available and crop yields are based on national statistics or survey data and vary depending on soil type. Crop residues, compost, artificial fertilizer, and animal manure are used to fertilize the crops. Animal production includes five common livestock systems (i.e., dairy cattle, beef cattle, broiler, laying hen, and pigs), considering their entire life cycle. For the food producing animals, three productivity levels (low, medium, high)

are included. Catches of marine fisheries are based on current landings and also contribute to food supply. For this study, a circular food system is assumed with no import or export of nutrients.

Dutch demographics (CBS, 2019) were used to calculate total human nutrient requirements for different gender and age categories. Human nutrient requirements, categorized on the basis of gender and age group, were calculated as recommended by the European Food Safety Authority (EFSA, 2017). These requirements are complemented with amino acid requirements *per g protein per day* based on FAO recommendations (FAO, 2013) - adjusted to fit gender and age group categories. To answer our research question regarding the influence of increased protein requirement on circular food systems, two scenarios were compared: in the CURR scenario we assumed currently recommended protein requirement (0.83 g per kg body weight per day for older adults of both gender) *that is used in most food systems studies* and in INCR scenario we assumed increased protein requirements (1.24 g per kg body weight per day for male (Rafii et al., 2016) and 1.29 g per kg body weight per day for female (Rafii et al., 2015)) for the part of population that was 70 years and older. These protein and amino acid requirements are set to be met by digestible amount of protein and amino acid provided by the diet formulated by the model.

FOODSOM formulates diets that meet human requirements with minimum environmental impact. 140 food sources are available in FOODSOM to formulate the diet. These food sources are categorized into food groups namely: cereals, dairy, eggs, fish, fruits, legumes, meat, nuts, oil, tuber, and vegetables. The dietary changes observed as a result of increased protein requirement was assessed by comparing the diet from CURR scenario with INCR scenario. These changes (increase or decrease compared to CURR scenario) were assessed at the level of food groups.

For both scenarios, FOODSOM was employed with the objective of either minimizing land use or GHG emissions. For all four scenarios (CURR scenario and INCR scenario while minimizing for land use or GHG emissions), we explored the environmental impact for a range of animal-source proteins (ASP) as share of total protein requirement in the diet. The share of ASP allowed in the diet ranged from 0-100% of the human protein requirements at intervals of 5%. For the situation where the environmental impact was minimum, to get the precise result, we explored intervals of 1%. For the precise situation in which the environmental impact was minimal, we also investigated the changes in diet as a result of increased protein requirements for older adults.

Findings

Increasing the protein requirements for adults (age group 70 years and older) increased the average protein requirements of the Dutch population with 8%, from 59 g per person per day to 64 g per person per day. Diets with less than 15% of ASP were infeasible as they did not meet all nutrient requirements, especially vitamin B12, eicosapentaenoic acid and docosahexaenoic acid requirements. We found that land use and GHG emission were minimal with a daily consumption of 16 g of ASP per person (between 25-

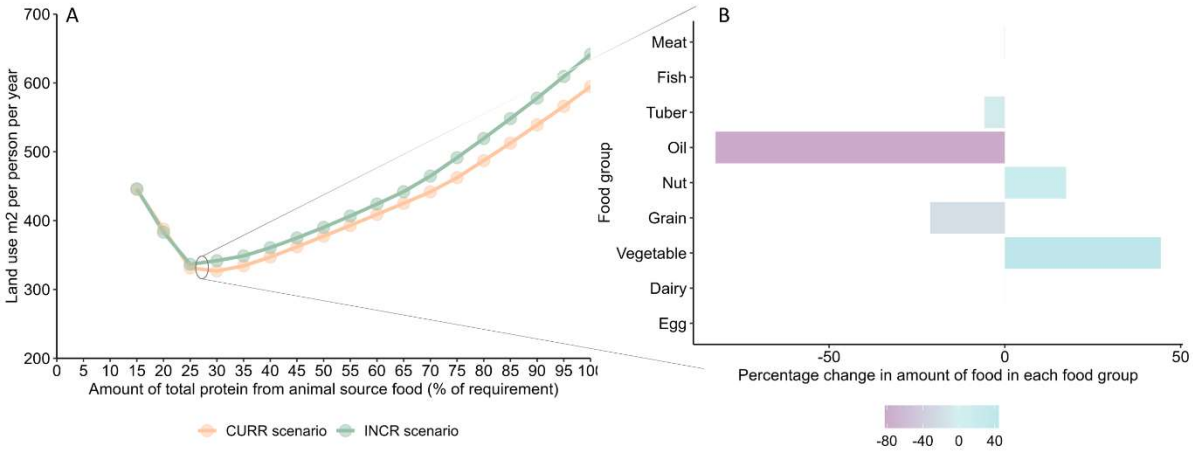
30% of requirement) in all scenarios. Furthermore, land use and GHG emissions increased in diets with less or more than 16 g ASP per person per day.

3.1 Minimizing land use

In both scenarios, land use was minimal around 16 g of ASP in the diet (Figure 1A). In the CURR scenario, minimal land use was 323 m^2 per person per year (Figure 1A), whereas in the INCR scenario this was 337 m^2 per person per year. The increased protein requirement did not influence the land use of CURR scenario compared to that of INCR scenario when the amount of ASP in the diet was less than 30% of protein requirement. Here, the limiting nutrient was not only protein but also other nutrients such as fat, lysine and vitamin B12. Although lysine has a higher requirement in INCR scenario as well as it is one of the limiting nutrients, diets that were constructed met nutritional demand with similar land use. When the amount of ASP in the diet was higher than 30% of protein requirement, however, the land use increased proportionally with the share of ASP. Land use was higher for INCR scenario than for the CURR scenario when the ASP was higher than 30% of protein requirement. Since the total protein requirement in the INCR scenario is higher, the share of ASP is automatically higher as well. This is reflected in the number of livestock required (up to 15% more livestock was required to meet the increased protein requirement).

Increasing the protein demand of adult also changed the composition of food groups in the diets. Here, we only report dietary changes for the situation with minimum land use (Figure 1B). We observed changes in 5 out of 12 food groups. The increased protein requirements resulted in a diet with less oil and more protein and fat rich nuts. Moreover, the amounts of tubers and grains decreased while the amount of vegetable increased. No changes in the amounts of animal-source foods was observed, as the amount of ASP in the diets with minimum land use was similar (16 g) for both CURR and INCR scenario. Interestingly, it was seen that calcium and vitamin B2 were the limiting nutrients for CURR scenario but not for the INCR scenario at minimum land use.

Figure 1: (A) Land use (in m^2) for diets varying in the amount of animal-source protein (ASP) for two scenarios, the current protein requirements (CURR) and increased protein requirements (INCR); (B) Changes (in percentages) in food groups for the diet with minimum land use when moving from current protein requirement to increased protein requirement of older adults

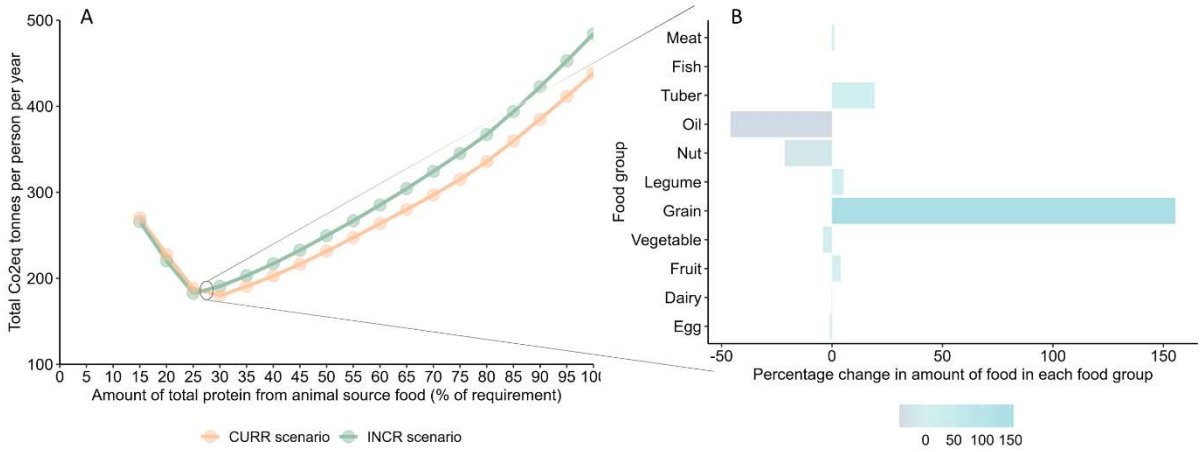


3.2 Minimizing GHG emissions

In both scenarios, GHG emissions was minimum around 16 g of ASP in the diet (Figure 2A). In CURR scenario, minimal GHG emissions was 176 kg CO_2 eqv per person per year, whereas in the INCR scenario this was 182 kg CO_2 eqv per person per year. Similar to minimizing land use scenarios, increased protein requirement did not have an influence in the amount of GHG emission when the share of ASP was less than 30% of protein requirement. Calcium and protein were limiting nutrients, irrespective of the share of ASP in the diet. This is different compared to scenarios for minimizing land use, which allows higher number of livestock (including dairy cattle whose products are a major source of calcium, and other animal products which have higher digestible amount of protein) compared to when the objective is minimizing GHG emissions. When minimizing land use, the bio-mass available for animal productions cannot be used for plant production, however when minimizing GHG emissions every resource has a cost. When the amount of ASP in the diet was higher than 30% of protein requirement, however, GHG emissions increased proportionally with the share of ASP and was higher in INCR scenario.

Similar to minimizing land use, increasing the protein requirements of older adults also changed composition of food groups in the diets. We observed changes in 7 out of 12 food groups (Figure 2B). Although amounts of many food groups were changed to meet the increased protein requirement the relative change in amounts were small (ranging from maximum 40% reduction to 20% addition). However, grain was included in relatively high quantities in the diet when the protein requirement was higher. Interestingly, although fat was one of the limiting nutrient, the amount of oil in diet was reduced and replaced by other food groups to meet the increased protein requirement.

Figure 2: (A) GHG emissions (in CO_2 eqv) for diets varying in the amount of animal-source protein (ASP) for two scenarios, the current protein requirements (CURR) and increased protein requirements (INCR); (B) Changes (in percentages) in food groups for the diet with minimum land use when moving from current protein requirement to increased protein requirement of older adults



The circular diet with minimum environmental impact, consist 25-30% of ASP in the diet for our study while (Simon et al., 2023) concluded this can be achieved with 40% ASP in the diet. However, when looking at absolute amount of ASP in the circular diet with minimum environmental impact, our study suggests 16 g ASP in the circular diet and (Simon et al., 2023) suggest 18 g of ASP. On this account, it is important to investigate both absolute amount as well as the percentage share of ASP in diet before deriving conclusions.

Theoretical Implications

In this work, we illustrate that a change in a single nutrient requirement of one age group results in an increase of average nutrient requirement of the entire population. This, in turn, changes the diet with minimum environmental impact. For example, we observed that an increase in protein requirement results in a notable shift from calorie-rich to protein-rich plant-source foods (e.g., inclusion of legumes, replacing oil with nuts). An increase in protein requirement not only changed the diet but also increased the overall environmental impact. To our knowledge, the impact of changes in nutritional requirements has been greatly understudied so far in food systems modelling. This study emphasizes the importance of including appropriate human nutrient requirements in determining the outcome of food systems modelling.

We also discovered that the environmental impact (land use and GHG emissions) of a diet minimal at one specific amount of ASP (i.e., 16 g) in the diet. The increased protein requirements of the adult population are met by eating more and different plant-source proteins. The increase in environmental impact associated with the higher and different plant-source food intake is negligible. In case we consume more than 16 g of ASP, however, the environmental impact is remarkably higher when the total protein requirement of the population is higher.

Furthermore, we observed that a change in the requirement of one nutrient also influences the availability of other nutrients in the modelled diets. The increase in protein requirement, for example, increased the total amount of food needed in the diet. This in turn increased the amount of other nutrients in the diet. For example, vitamin B2 was one of the limiting nutrient in the CURR but not in the INCR scenario. This was a result of the increased amount of food rich in vitamin B2 and protein that was needed to meet

the increased protein requirement. Some nutrients, however, are limiting both in CURR and INCR, such as vitamin B12, fat and lysine. Hence, we suggest to explore the consequences of the age-specific nutrient requirements of other nutrients on the outcomes of the food systems modelling.

In agreement with van Selm et al. (2023), we also found that the environmental impact chosen to be minimized had influence in the modelled diets. For instance, compared to minimizing land use, minimizing GHG emissions resulted in different diets. For example, modelled diets while minimizing land use had more grains and no legumes whereas GHG had notable amount of legumes. Furthermore, when the objective was to minimize GHG emissions, variation in diet to meet increased protein requirement was more pronounced. For example, while minimizing GHG, to meet the increased protein requirement amount of all plant-source food groups were changed however while minimizing land use only 5 food groups were changed. Therefore, this study highlights the need for future studies to consider the relationship of different input parameters with the objective employed before drawing conclusions.

Finally, we observed that a small change in input parameters can significantly influence final model outcomes. We therefore emphasize on the importance of communicating the underlying assumptions of the food system studies. Here, we demonstrate that we should acknowledge differences in human requirements among specific age and population groups (e.g., older adult, pregnant and lactating women) in designing healthy diets with specific environmental objectives for outcomes of food systems model to be generalized.

Data Availability: The data presented in this paper can be made available upon request.

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Circular business models in and across agriculture, forestry and aquaculture

Mikelis Grivins[a], Emils Kilis[b], Pia Piroschka Otte[c], Ieva Leimane[d], Alberts Auzins[e]

[a]Baltic Studies Centre and Riga Stradins University, mikelis.grivins@bscresearch.lv

[b]Baltic Studies Centre, emils.kilis@bscresearch.lv

[c]Ruralis, pia.otte@ruralis.no

[d]Institute of Agricultural Resources and Economics, ieva.leimane@arei.lv

[e]Institute of Agricultural Resources and Economics, alberts.auzins@arei.lv

Abstract:

This presentation discusses circular business models in and across agriculture, forestry and aquaculture, and the contextual factors affecting these business models. The presentation raises two research questions: (1) How circular business models are structured? How closed loops of bioresource use are linked to particular business models? (2) What collaborative and governance arrangements and conditions enable and strengthen circular business initiatives?

The presentation answers these questions by synthesising evidence from 12 case studies of circular business initiatives from four countries - Latvia, Estonia, Lithuania, and Norway (three case studies per country). In this study case is both a circular business initiative (CBI) engaging with bioresources and a closed loop of the bioresources the CBI is part of. The analysed cases were selected based on the following criteria: (1) Scope of the case; (2) Scale of the case; (3) Kinds of bioresources involved; (4) Areas of bioresource utilisation; (5) Sectors covered; (6) Links with the final consumer. The case studies were conducted in the period between September 2022 and August 2023. For each case study desk research and a set of interviews were conducted.

Keywords: circular economy, bioresources, business models, comparative research

Purpose

This presentation discusses circular business models in and across agriculture, forestry and aquaculture, and the contextual factors affecting these business models. The presentation raises two research questions: (1) How circular business models are structured? How closed loops of bioresource use are linked to particular business models? (2) What collaborative and governance arrangements and conditions enable and strengthen circular business initiatives?

Methodology

The study assesses circular practices, social-material structures enabling circularity and performance of enterprises in closing bioresource loops on the level of

cases. It uses case study approach to do this. The study uses the following definition of a case: **case is both a circular business initiative (CBI) engaging with bioresources and a closed loop of the bioresources the CBI is part of**. Each case represents two things simultaneously – the CBI (circular business initiative – a set of strategies that among other things allow valorising some bioresource residues and by-products) and a closed loop of bioresources that allows valorising the bioresource residue. The study is built on the results of 12 case studies from four countries – Latvia, Estonia, Lithuania, and Norway (three case studies per country). Each of the case studies simultaneously analyse the circular business models and examine conditions and collaborative and governance arrangements that allow to make use of bioresources in a sustainable and efficient manner.

The analysed cases were selected based on the following criteria: (1) Scope of the case; (2) Scale of the case; (3) Kinds of bioresources involved; (4) Areas of bioresource utilisation; (5) Sectors covered; (6) Links with the final consumer. The case studies were conducted in the period between September 2022 and August 2023. To support a joint approach for the partners representing the four countries engagement with cases and comparability of the cases, a common methodology for the case studies was developed. For each case study desk research and a set of interviews were conducted. Some case studies might have benefited from other, case-specific methods. The collected information was used to fill the case study template (that requested authors to present the data according to the main comparative categories). In each partner country, after the case studies were completed, a workshop was conducted, to discuss the findings emerging from the conducted cases.

The analysis of the cases consisted of three large blocks – analysis of the context (described using the STEEP approach); analysis of the business models (described using the Business Model Canvas); analysis of structural arrangements allowing business model to be set up. The STEEP (Social, Technological, Environmental, Economic and Political) analysis addresses three relevant aspects for thinking about the context and business ecosystem in which CBIs operate. These are 1) contextual factors and trends characterising the AFA (agriculture, forestry, aquaculture) sector and bioeconomy, 2) factors and trends enabling the CBI, 3) factors and trends limiting the potential of the CBI.

In this study a business model (BM) is a set of activities and internal organisational arrangements envisioned for and implemented by the enterprise as well as the common practices associated with these activities and arrangements. While in general one would expect that a business model would also generate profits, the cases illustrate that not all of them do that and not all of them are expected to. To analyse CBMs a simplified Business Model Canvas is used. To discuss CBMs, this study is structured in three sections: (1) value creation, (2) value capture, and (3) value proposition.

Findings

STEEP analysis

- Social factors

One of the primary social factors affecting the development of knowledge-intensive CBIs that rely on cutting-edge technology and are based in more peripheral regions is *access (or lack thereof) to skilled labour*. Indeed, the depopulation and ageing of rural areas is an important obstacle to regional development, and it appears that is also a common barrier to building CBIs further away from the main population centres. One can also observe countervailing trends vis-a-vis *consumer acceptance* of circular and sustainable products. Several case studies note growing demand for sustainably produced products. The case studies also indicate a cautious and sometimes sceptical attitude on the part of consumers. This can take many forms. Fear of greenwashing was a common theme, but there is also a generally cautious attitude towards the products of different startups and the extent to which these companies will be sustainable. Certain practices are looked upon with suspicion, despite their generally resource efficient character. These anxieties, however, should be analysed in a contextually sensitive manner as they may reflect local developments in the sectors in question, and the cultural imaginaries surrounding these sectors, rather than broader trends in the sector as a whole.

The last point highlights the cultural dimension of circularity and the *traditions, beliefs and routines* that both novel and traditional forms of circularity must mesh with. The use of waste in the production of consumer goods is seldom received positively by consumers. However, waste should be regarded as a cultural category that is much broader than the legal definition, meaning that a wide variety of products may face challenges when entering the market.

- Technological factors

Our cases indicate that there are several background factors that shape the technological dimension of circularity. In addition to technological developments that have facilitated the introduction and implementation of loop-closing practices in particular, *digitalisation and automation* more generally featured prominently in the responses of our informants. This suggests that, unsurprisingly, the digital transformation has raised the overall level of technological sophistication and development across various industries and serves as the foundation for complex solutions that are specific to CBIs. CBIs are also affected by countervailing trends with regard to innovation and the *ability to benefit from innovation*. On the one hand, several case study reports note that specific initiatives and products are made possible by recent technological advances that have made certain production practices more feasible, though still expensive. Our cases also illustrate certain *synergies between circularity and the region* (Nordic-Baltic). The region is believed to be a good environment for

technological experimentation, a testbed of sorts for various technological solutions. Likewise, our cases suggest the need to consider the importance of various *entanglements between technologies and between technological and policy development*. There are vulnerabilities and risks associated with strong interdependencies between different technological processes. Logistical processes can be both expensive and tightly regulated if the materials that are being used can be environmentally harmful, when not managed properly. Furthermore, our cases suggest that the level of technological development frequently outpaces the legislative framework. Finally, our cases suggest that technologically speaking circularity is a *heterogeneous playing field*. Specifically, we note that there are both technologically advanced and novel solutions and more mundane and incremental innovations that depend largely on routine circular practices and waste-avoidance.

- Environmental factors

Unsurprisingly, it was noted that environmental factors play a crucial role in relation to CBIs. *Climate change* and public discourse about the influence of AFA sectors on the environment provide the necessary impetus for innovation (acting as a driver), while simultaneously limiting what can be achieved by specific CBIs (acting as a barrier). While recent advances and shifts in demand have increased the *availability and variety of environmentally friendly solutions,* this does not necessarily mean that such innovations are widely adopted. Indeed, our respondents note that linear practices remain entrenched, despite the general waste aversion of businesses. What is more, even if a company adopts a particular environmentally conscious solution, it should not be assumed that this decision is driven by environmental values. In general, these shifts towards sustainability can be regarded as a response to hybrid challenges encountered by businesses. These challenges involve a combination of policy, environmental and economic factors, so looking at the environmental dimension in isolation is seldom informative. Stringent regulations, environmental conditions and volatilities in global markets force entrepreneurs to look elsewhere for resources that they had previously relied upon. Indeed, unpredictable changes in the global market because of sudden shocks (be they environmental or geopolitical), potentially compounded by adverse weather conditions in the local market were common factors that our respondents mentioned when talking about the way environmental factors shape their work. Thus, we see a combination of higher prices due to a scarcity of resources (e.g. mineral fertilisers) and *production difficulties* (e.g. due to floods or droughts). Finally, we note that, while CBIs frequently characterise their practices as environmentally friendly, it is important to stress that the *environmental impact of particular innovations* is dependent on whether they are appropriately implemented. However, there is often insufficient research and data to assess the environmental impact of specific solutions beforehand.

- Economic factors

From an economic standpoint, circularity can be seen as a form of *risk management*. Firstly, it is a way for businesses to diversify their activities, even if their primary focus is on linear production. Likewise, the implementation of circular principles and loop-closing practices can be a response to *increased costs and expenditures*. By using and re-using previously undervalued resources, companies can extract additional value or even develop new products that replace increasingly expensive materials (e.g. mineral fertiliser). This is especially relevant to respond to changes and volatilities in global markets (e.g. increased energy prices, lack of imports from Russia and Ukraine). Finally, circularity can be seen as a future-proof business strategy to address the burdens of *legal requirements* or the expectation of increasingly stringent regulations. At the same time, it is important to note that CBIs face *competition from competitors* that sell cheaper alternatives. This is both a positive and a negative. While it encourages innovation to make products cheaper, it also reduces demand. However, in certain contexts there is increased consumer willingness to choose and pay for circular products (e.g. Norway). Nonetheless, the identification of *new distribution channels and markets* is key. Simultaneously there is an issue associated with the *pricing of products* – it is not always clear what it should cost. An important challenge for CBIs is the lack of certification for circular products. The CBIs we have looked at primarily draw on *private capital,* while public support (e.g. tax exemptions, subsidies) is limited. This suggests that CBIs benefit from private initiative, rather than public support.

- Policy factors

From a policy perspective, it should be noted that the environment for CBIs is shaped by broader *European policy developments*. These range from the Green Deal and the EU circular economy action plan to various sector-specific initiatives and strategies and other more specific regulations (e.g. European Commission's regulations regarding the production of food using waste products). Furthermore, there are *national policies* that synergise with EU policy developments and attempt to implement these principles in local legislation. Subsequently we must consider the role of local governments. Specifically, the *support (or lack thereof) from line ministries and municipal governments*. We observe that country reports reference incentives from which CBIs can benefit, but this is not a universal phenomenon that is equally available to all sectors. *Legislation and formal requirements* can function as an impediment to entrepreneurship organised around the use of bioresources. Indeed, our cases paint a complex picture of the role of legislation. Finally, there is a key difference between rhetoric and practical measures. In other words, governments may have goals, ambitions and guidelines supportive of increased circularity across different sectors.

Business Models Canvas

Value Creation

While in public discourses closing the resource loops is often framed as an environmentally responsible thing to do (even by the cases considered), during the interviews the enterprises engaged in the circular use of bioresources mainly presented the circular practice as a pragmatic/ economic choice. From 12 cases included in the study, only two clearly expressed environmental concerns as a key motivator to engage with these practices. From the cases, we can identify four key considerations that motivate enterprises to look for ways to close bioresource loops. These are: (1) creating new products; (2) reducing costs; (3) optimising the use of resources; and (4) implementing solutions due to regulatory demands. The cases also illustrate that none of the four is exclusive – however, it seems that in each case there is usually one that dominates the decision-making. It can also be suggested that the motivations that push enterprises to close bioresource loops affect their openness to various technological, social and legal solutions.

- Creating new products

Some of the enterprises across the four countries became engaged with circularity because they saw an empty market niche that they could penetrate with a new product. For example, an enterprise producing insect protein – saw that there is a demand for new sources of protein and that waste could be used to produce the product taking the niche. Another case noticed that the existing practices for closing residual wood loops could be made more efficient. There are several other examples. All of them had to make sure, that the new product can be successfully integrated into the existing market. Primarily, this means that the product must be in a competitive price range. Several of the enterprises explained that they would need to substantially increase the processing capacity to cut the costs of the final product. Also, some of the built solutions were highly energy intensive.

- Reducing costs

Some of the enterprises claim that they have been motivated by the possibility of reducing input costs and becoming more independent from the global supply chains. Especially with the recent spikes in fertiliser and energy prices, some enterprises were looking for ways to use the bioresource residues to increase independence from upstream suppliers. Enterprises producing energy and digestate from slurry and other biomaterials fall into this category. However, there are also cases developing biogas-powered vehicles, allowing farm operations to function without fossil fuels by utilising manure as a source of biofuel production.

- Optimising the use of resources

There are also those enterprises that engage with bioresource residues because they are looking for a way to use the resources available to them more efficiently. For

this group, it is not the goal to develop a completely new product. These enterprises have a well-functioning business model and can, in fact, function without additional engagement with leftovers. Enterprises representing this group perceive the residues as a potential opportunity to improve the efficiency of the enterprise and as a possibility to ensure some additional profits.

- Engaging regulations

Regulatory demands are a strong motivator for many of the enterprises. At least one of the enterprises explicitly stated that the future fines were a key motivator to introduce solutions that allow closing bioresource loops.

Value Capture

While there are different ways enterprises are trying to benefit from the circular use of bioresources, the principles that allow them to do so and the issues that they encounter are somewhat similar across cases and across the four partner countries. From the 12 cases that have been analysed, the following 6 key factors of value capture have been identified: (1) collaboration efforts; (2) inter- and intra-organisational structure; (3) availability of knowledge and experience; (4) steady resource flow; (5) developing technologies and infrastructure; (6) and multifunctionality. The relations between the factors and groups of CBM are illustrated in Table 1.

Table 1. Factors of value capture and their importance for the different groups of CBMs.

	Benefiting internally	Business to Business		Business to consumer
		Service	Product	
Coordinating efforts	Not important	Crucial	Somewhat important	Somewhat important
Inter- and intra-organisational structure	Important	Important	Somewhat important	Important
Availability of knowledge and experience	Important	Important	Important	Important
Steady resource flow	Not important	Not important	Crucial	Crucial
Developing technologies and infrastructure	Important	Important	Important	Important
Multifunctionality	Not important	Important	Important	Important

Value Proposition

The role of the circular use of bioresources differs from one case to the next and is strongly linked to the overall strategic significance of the circularity in the CBI. The significance of these practices is linked to the target groups the enterprises are working with and the perceptions of the optimal strategy to monetise their practices.

Benefiting internally. There is a clear group of enterprises that has been motivated to introduce circular solutions to support their internal needs and visions. *Providing services to other businesses*. There are two general ways enterprises are presenting their services to other actors. On the one hand, the cases collaborate with potential upstream partners presenting the latter with an opportunity to deal with or even benefit from their bioresource leftovers. This offer goes hand in hand with the increasing legal pressure on enterprises to introduce more sustainable production practices. On the other hand, several of the enterprises are working with very novel solutions. Their engagement with new practices, technologies and organisational solutions puts them in a unique position where they can offer knowledge to other actors interested in potential benefits from closed loops. *Providing products to other businesses*. Most of the enterprises were providing some kind of products to their consumers. These most commonly were – biogas, electricity and fertilisers. The enterprises were benefiting from the public financial incentives (allocated through various mechanisms explicitly linked to circular practices). However, when talking about working with business partners, none of the cases indicated that the circularity was an additional selling point allowing to secure deals. *Providing products to consumers*. Only some of the enterprises were selling their products directly to consumers. None of those were explicitly communicating to consumers the circular production practices adopted by the enterprise.

Circular Economy Indicators in the Sicilian Agri-Food Sector

Agata Matarazzo[1], Silvia Zingale[1], Massimo Riccardo Costanzo[1], Salvatore Ingenito[1], Carla Zarba'[2], Alessandro Scuderi[2]

[1]Department of Economics and Business, University of Catania, Corso Italia, 55, 95129 Catania, Italy.

[2]Department of Agriculture, Food and Environment, University of Catania, Via S. Sofia, 100, 95123 Catania, Italy

Abstract:
The transition to a circular economy represents an interesting opportunity for Sicily, as it could allow the island to exploit its natural and agricultural resources sustainably, while promoting economic development and environmental protection. strategies and business models based on the circular economy, New business models are proposed to companies. Sicilian companies can optimize their resource use, reduce waste, and promote the creation of long-term value, thus transforming environmental challenges into opportunities for growth and prosperity. This paper aims to present the current business panorama of eastern Sicily and to provide the results deriving from a survey on the diffusion of the circular economy among the agri-food sector's stakeholders. Based on the findings, some key suggestions emerged that could help promote relational networks, new best practices to reduce waste of matter and energy, and sustainable styles for the corporate world. Firstly, examples of the circular economy on the island are presented; secondly, the adopted research methodology is described, with a focus on the specific questionnaire for the different Sicilian food supply chains involved; and finally, the results and suggestions aimed at businesses are provided.

Keywords: Sicilian food sector, environmental performance indicators, economic and social impacts, sustainability, circular business models

Purpose

Food production has contributed to crossing as many as four thresholds that determine planetary limits, that is, those values within which humanity must move to maintain a state of equilibrium of the biophysical systems that support its existence [1]. Climate change, loss of biodiversity, alterations to the nitrogen and phosphorus cycle, and changes in land use are examples of impacts associated with agricultural production. Current agricultural systems are responsible for about one-third of greenhouse gas emissions [2]; consume around 69% of water resources globally [3]; use between 10 and 30% of the amount of energy consumed in industrialized countries [4]; and contribute heavily to soil, air, and water pollution. The current food production model is based on intensive agronomic practices, monocultures and excessive use of manure and fertilizers. Carbon dioxide, methane and nitrous oxide are emitted directly and indirectly

throughout the value chain of agri-food supply chains, thus contributing to climate change. Not only agricultural production but also processing and distribution need to be optimized to lower the impact on food systems. Indeed, as stated by a recent study published in Nature Food, in 2015, CO_2 emissions related to food systems reached 18 billion tons, accounting for 1/3 of the total (34%), and of these, 29% come from distribution, processing, consumption, and end-of-life [5]. Concerning packaging, the emissions produced by the food sector reach nearly 1 billion tons of CO_2 [6].

At the same time, the food sector is also one of the most vulnerable economic sectors exposed to climate change's effects. The scarcity of water resources, alterations in rainfall regimes, and frequency and intensity of extreme weather phenomena represent conditions the agribusiness sector must adapt quickly. Studies conducted by the FAO show that, due to severe pressure on natural habitats, 75% of the varieties of agricultural crops have been lost, with severe consequences on food diet diversity worldwide [3]. This paper aims to illustrate the potential for the Sicilian agri-food system of the transition from the current linear economic model, in which resources are used as if they were unlimited, to a circular model, which considers growing environmental issues [7,8].

Among the new emerging business models in the agri-food sector are those concerning digital agriculture, in particular the use of digital technologies is used to optimize agricultural production and improve efficiency. The personalised supply of food is also a new business model that offers tailored foods based on dietary needs and individual consumer preferences. Blockchain traceability technologies that ensure the transparency and safety of food throughout the supply chain are increasingly relevant as business models. Other models include indoor and vertical agriculture, the use of alternative plant-based products and food preservation and processing technologies that revolutionize the food industry, extending the shelf life of food and maintaining its freshness and nutritional value.

By transition to a circular economy country can benefit increasing sustainability, creating jobs, protecting the environment, and reducing emissions. At the same time, there are different assessments of the benefits and possible risks, the ratio and structure of which necessitate the differentiation of approaches to the implementation of this concept in countries with different development levels. In the field of food production, in turn, there are also specific risks and challenges associated with food safety: food shelf life, strict storage rand packaging requirements, standards and norms of production, various geographical zones of origin of raw materials, national characteristics and traditions of consumption, etc. And these factors should be taken into account in the course of expanding the practice of using circular models in food production [9].

Methodology

This paper presents the results from a survey conducted on agribusinesses in eastern Sicily, aimed at assessing the degree of diffusion of the circular economy. The sample, to which the questionnaire was administered, consisted of 10 companies. As the data

collected highlights, the heterogeneity of the companies did not affect the responses in some cases, while in others, it amplified the differences, especially in terms of the performance of activities and planning of future expectations.

Findings

This section illustrates the results of a survey on agri-food enterprises in eastern Sicily, aimed at assessing the extent of the circular economy. The sample, to which the questionnaire was administered, consists of 10 companies. As the collected data show, the heterogeneity of the companies has however found in some cases unanimous answers, while in others it has amplified the differences above all in terms of development of the activities and programming of the future expectations.

The first thematic macro-area of survey (1-6), which is purely descriptive, aims to gather information on companies' characteristics; although the companies interviewed remain anonymous, a distinction by business sector, number of employees, and average annual turnover is of interest.

The second part of questionarry (7-11) aims to investigate the efforts already implemented by companies on environmental sustainability and circular economy. In particular, companies were asked to indicate voluntary certifications acquired, the presence of professional figures dealing with sustainability and circularity, medium- to long-term projects inherent to the circular economy, and the activation of training actions aimed at their employees, designed to share the principles of the circular economy.

All of the companies surveyed have at least one certification, which denotes a particular sensitivity to environmental sustainability and food safety (Figure 1). Some certifications mentioned in the "Other" category include BRC Food certification, ISO 50001, ISO 22000, IFS Food, Viva, and SOStain.

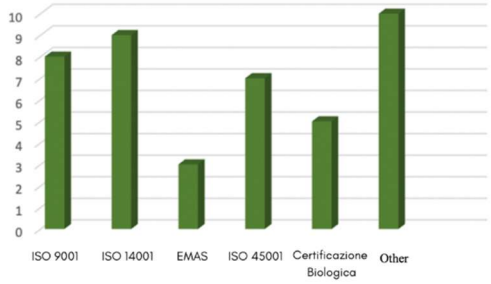

Figure 1. Voluntary certifications acquired

In almost all of the cases examined, there was not any professional figure with specific skills in the field of environmental and social sustainability. Only one figure, the Chief Sustainability Officer, gave a positive response. All the surveyed companies have taken or intend to take actions to limit their environmental impacts in the next two years. The third macro area (12-13) analyzes the future prospects that the surveyed companies

envision. Specifically, companies were asked whether they plan to acquire certifications in the circular economy and what the impacts of a transition to a regenerative economy will be in their business sector (Figure 2).
All the agribusinesses plan to acquire additional certifications in the circular economy.
Regarding the impacts of a transition to a regenerative economy, all companies believe that it can lead them to limit the waste of resources; 90% of them believe it can lead them to improve their reputation and, given the growing consumer awareness of environmental issues, strengthen their relationship with their customers.

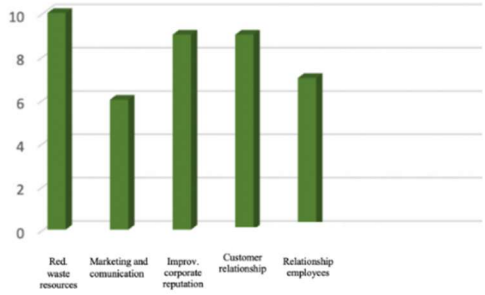

Figure 2. Impacts of a transition to a regenerative economy

The fourth macro area (14-20) analyzes the circular approach implemented by the agribusiness ecosystem surveyed, forming the core of the questionnaire.
Regarding the new best practices to reduce waste of matter and energy, implemented, the following ones were collected:

- an extensive photovoltaic system, capable of powering the production plant, guaranteeing the production site a flow for energy sustenance entirely self-generated from renewable sources;
- a complex system of purification of processing water, reused to irrigate the company's vegetable garden;
- a packaging that is fully compostable or made of recyclable materials to allow proper disposal of packaging;
- a "just in time" production system that produces small quantities based on sales, i.e., the quantity ordered in advance, and thus allows the company not to create surplus or leftover stock and to minimize waste;
- the reuse of a food product that is slightly overcooked at the end of the cooking process as a semi-finished product for the production of another product, considering it illogical to discard a good, fresh product for aesthetic reasons;
- the adoption of sustainable agricultural practices, such as organic farming and the rational use of pesticides and fertilizers, which allow the company to preserve soil fertility, protect biodiversity and reduce pollution from chemicals.

It is specified that for macroarea it is meant part of the questionnaire, not productive areas.

All the companies report they are impacting the environment due to their energy consumption (Figure 3).

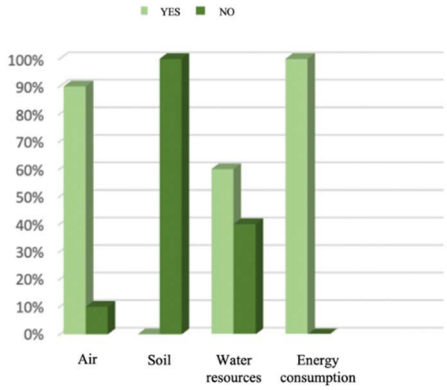

Figure 3. Environmental impacts

Although there are some barriers, including lack of financial resources and too long processes to acquire certifications, all the companies interpret the circular economy as a great opportunity and have undertaken and/or planned projects to implement the circular economy. The concluding question, to which all the companies surveyed positively answered, closed the survey on a positive note, demonstrating a growing interest on the part of the Sicilian business ecosystem in the circular economy and its applications. The companies interviewed constitute a very heterogeneous set both in terms of organizational structure and dedicated staff, as well as in relation to the circularity practices adopted. This heterogeneity is evident because the companies belong to different market sectors and are distinguished by their business histories, which differ in terms of time; in fact, some of them were founded a few years ago or have recently started a transition to the circular economy, while others are long-lived companies on both fronts. Moreover, these companies possess entrepreneurial projects with divergent perspectives and goals. Despite these differences, the responses obtained were more than positive and, in some cases, showed particularly significant trends. The survey of Sicilian agribusinesses on environmental sustainability and circular economy provided valuable information on possible improvements that can be made by companies. Based on the responses obtained, some key suggestions emerged that could help promote circular economy principles. First and foremost, the priority aspect to consider is resource optimization. Companies should adopt practices that minimize waste by implementing more efficient production processes and recycling materials. Introducing advanced technologies and automation can help optimize processes and reduce environmental impact.

In addition, the survey highlighted the importance of promoting sustainable supply chains. Agribusinesses should forge partnerships with suppliers who adopt sustainable practices such as, for example, organic farming and responsible use of water resources, while ensuring food quality for their customers.

Another key aspect concerns waste management. Companies in the industry should adopt policies on waste reduction, recycling and composting, helping to reduce their environmental impact.
Finally, the survey emphasized the importance of staff training and awareness. Companies need to invest in training their employees to promote environmental and social awareness and develop specific circular economy skills. This will result in all members of the organization being involved in adopting sustainable practices and actively contributing to achieving corporate goals. It is clear that the current system, based on a rigidly linear logic, does not work, and that a shift to a circular and regenerative economy would bring enormous benefits, enabling businesses to reduce their dependence on foreign countries while contributing to the achievement of Sustainable Development Goals 12 and 13 (SDGs), which are of crucial importance to humanity and the planet (Oliveri et al, 2022). Specifically, Goal 12, "Responsible Consumption," aims to halve global food waste, make the food supply chain more efficient, significantly decrease the amount of waste produced and improve its management; Goal 13, "Combating Climate Change," aims to strengthen resilience and capacity to manage environmental disasters affecting Planet Earth (Falzarano, 2020).

Practical Implications

In Sicily, implementing the circular economy is still in its infancy. Despite the bureaucratic complications, the regulatory environment characterized by complex and rigid rules, and the lack of or poor knowledge of the topic, there are many virtuous cases in the agri-food sector. This has long been engaged on the front of reducing food waste and, for some years now, on initiatives to reduce the use of packaging. Some Sicilian companies can enjoy the title of "pioneers" or "forerunners." Being ahead of the curve, especially in the corporate world, can be a crucial advantage over the competition and thus represent a huge opportunity.
The survey conducted on the Sicilian business ecosystem on environmental sustainability and circular economy provided valuable information on possible improvements that companies can make, contributing to the promotion of circular economy principles and relational networks between virtuous companies, institutions and civil society. It also found awareness of companies with reference to the benefits of a transition to a regenerative economy, including reduced resource waste, improved corporate reputation and, considering consumers' growing awareness of environmental issues, improved customer relations. As a major contributor to environmental degradation, the agri-food sector can be transformed into a valuable ally in combating climate change and creating an economy that respects the natural balance. Therefore, it is necessary to rethink the agribusiness sector that provides nutritious, healthy and accessible diets for all while fostering the ecological transition, following the path set by the European Union, from field to table.
The suggestions come from the experiences of other companies in similar industries.

Food companies should pass eight steps to provide a transition of a circular economy. They include: (1) design and market new products; (2) change production to fit a sustainable model; (3) profit from smart distribution; (4) consumer choice impacting circular economy; (5) availability of re-usable products; (6) recycling agricultural and food waste; (7) preventing food losses with actionable results; (8) raise more awareness towards a circular economy [10].

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Analyzing coupled innovation processes between public collective catering and agriculture in France to support agroecological transition

Juliette Migairou-Leprince[a,c], Marie-Hélène Jeuffroy[a,c], Caroline Pénicaud[b,c] and Margot Leclère[a,c]

a Université Paris-Saclay, AgroParisTech, INRAE, UMR Agronomie, 91120 Palaiseau, France juliette.migairou-leprince@inrae.fr / marie-helene.jeuffroy@inrae.fr / margot.leclere@inrae.fr

b Université Paris-Saclay, INRAE, AgroParisTech, UMR SayFood, 91120 Palaiseau, France, caroline.penicaud@inrae.fr

c IDEAS, initiative for Design in Agrifood Systems

Abstract:
This study highlights the main traits of coordinated innovation processes between the agricultural and catering sectors. From a case study, we identified several successive innovative practices implemented by local farmers and actors from public nurseries, and we especially unraveled their coordination during their innovation process. Based on interviews, we analyzed the coupled innovation process using two scientific frameworks: action logic and step-by-step design. We identified three main traits of coupled innovation processes: (i) the building of an inclusive multi-actor network strengthened by exchange arenas, (ii) the progressive alignment of stakeholders on a shared desirable unknown, and (iii) successive phases of coherence of the network and ongoing learning of conjoint explorations for innovation design. We shed light on the importance of creating dedicated exchange structures and forums for sharing ideas, knowledge, and standards between actors. We also demonstrated that the call for proposal and the public procurement process can allow actors to align on a shared aim. We finally affirm that coupled innovation processes are complex, iterative and dynamic and can be composed of a range of various innovations.

Keywords: food systems; public food procurement; reconnection; practice change, coupled innovation

Purpose

Agriculture and food sectors have to innovate to reduce their environmental impacts and support the transition towards more sustainable and healthier agrifood systems (Béné et al., 2019). Public collective catering and the associated supply chains are considered as levers to enhance the agroecological transition from the consumer to producer levels (Swensson and Tartanac, 2020). For instance, public catering demand

may foster legume farming (Magrini et al., 2021) or support farms implementing agroecology (Gaitán-Cremaschi et al., 2022).

In this context, French public authorities enacted several regulations to support this role, especially by setting ambitious objectives for catering structures to improve sustainability (laws: “EGALIM” 2018, and “Climat et Résilience”, 2021). However, these objectives are not reached by most public catering structures (Ministère de l’agriculture et de l’alimentation, 2023). Meanwhile, a recent French study showed that some catering services changed their practices to improve sustainability, especially by reconnecting with agricultural actors (Martin et al., 2022). These changes challenge the relationships between actors in the different sectors of the food system: agriculture, collective catering, food processing, logistics, suppliers, and local authorities (Gaitán-Cremaschi et al., 2024).

Coupled innovations is a recent research concept that defines novelties designed in coordination by actors from sectors that used to innovate separately, like the food and farming sectors (Meynard et al., 2017). Accordingly, a coupled innovation process can be defined as a multiactor design process that leads to designing various innovations toward sustainability, thus reconfiguring social relationships (Salembier et al., 2020). Our study aimed to understand the main traits of a coupled innovation process between the food sector (with catering services) and agriculture. We studied a French case study in which the practices of the various actors changed coordinately for more than 15 years (2006-2024) in the various steps of growing, processing, stocking, and preparing potatoes.

Description of the case study

We studied several successive innovative practices regarding potatoes, implemented by (i) public collective catering services managed by a French urban local authority, (ii) a private supply company,
(iii) a farmers’ cooperative, and (iv) potato producers. Every weekday, the catering service studied provides lunch to around 20,000 children from 0 to 3 years old, spread over 300 sites. On each site, one or two people cook lunch (including daily homemade “purée”) with more than 80% organic ingredients. While the cooking function is self-managed by each structure, the supply function is contracted out: a private company writes menus, contracts with the suppliers, prepares the exact daily amount of each raw ingredient that is needed, and delivers it to each site two times a week. Before 2013, only about half of the sites had this atypic organization, while in the others, the supply function was self-managed by the local authority: cooks directly placed orders with a panel of suppliers. In 2013, all sites adopted the organization with contracted-out supply and self-managed cooking functions. The same company has been winning successive calls for tender since 2006 and has purchased some vegetables, especially potatoes, in local short supply chains.

Methodology and conceptual frameworks

In the first step of our approach, we identified innovative practices regarding potatoes in this area; then, we traced back to identify designers and concerned actors by these changes. To understand the successive practice changes, we conducted 20 semi-structured interviews with 12 actors who played a determinant role in the design or its coordination (4 farmers, 3 employees of the cooperative, the operation director of the dedicated platform of supply company, the dietician of the local authority and 3 cooks) between September 2023 and February 2024. We elaborated a narrative explaining the global trajectory of change involving all actors, a list of successive practices changes, and a chronological cartography of the actor's network. Then, we focused on each actor's individual action logic and design process, drawing on the step-by-step iterative design loops and traits proposed by Meynard et al. (2023). An in-depth analysis of coordinations between these processes led us to highlight some traits of this multi-actor, multi-sectorial innovation process.

Findings

Overview of the significant practice changes over time among the various actors

Our analysis showed that the practices changed in a coordinate manner for more than 15 years (2006- 2024) in the various steps of growing, processing, stocking, and preparing potatoes. Two dynamics of change have been identified: the first occurred periodically within public calls for tender of the supply

function, and the second laid out continuously during contracts when structures and individuals were committed to working together for several years.

The same supply company has been winning, since 2006, the successive calls for tender by proposing a range of products that have co-evolved in line with the demand from the local authority and that integrated direct-selling and local concerns (organizational innovation). Since 2009, organic potatoes have been required in successive calls for tender in response to elected representatives (councillors) demand to prioritize children's health. Indeed, for sanitary reasons and workload concerns, the type of potatoes delivered changed in almost every public contract of the studied period (successively raw potatoes, peeled and pre-cooked potatoes, then frozen potatoes). Several innovations in farming, processing, cooking, storage, and delivery were required to match the demand. During the contracts, every two months, forums gather local authority staff, representatives of cooks, and a representative from the supply company to discuss the supply, recipes, and adjustments to be done. These meetings allow these actors to share knowledge and lead to practice changes, such as introducing new recipes (processing innovation) or modifying the delivery schedule (organizational innovation).

Simultaneously, over the last fifteen years, local organic producers have taken the opportunity presented by the demand from the catering sector to organize themselves collectively. They first set up a producers' association in 2011 to centralize products and plan production (on volumes and temporality) between producers so as to be able to supply adequate volumes on time (partly for the public demand mentioned above) and decide on the selling price (organizational innovation). The supply company has signed contracts with this producers' association since its creation (particularly for the supply of potatoes) and not as usual with food wholesalers (organizational innovation). The annual demand for potatoes is more than a hundred tons, which requires the seven farmers to be organized (although this only represents around 5 ha). This regular demand in large quantities supported recent (less than ten years) conversions of existing conventional farms to organic farming as outlets were secured (farming innovation). In 2014, the producers' association changed its legal status to become a cooperative community-oriented enterprise (SCIC), gathering farmers, processors, and customers on the governing board. This new status was chosen as it enabled investments in expensive processing equipment (organizational and equipment innovations) and kept the majority voice in the hands of farmers. The catering sector's demand, and specifically from this local authority, was for pre-prepared vegetables (either peeled, cut, or cooked) to ease the cooking step. Thus, the cooperative met the local authority’s demand by adding a potato processing line to the vegetable factory (processing innovation). This demand for ready-to-process potatoes has led to agronomical innovations on farms. For instance, producers have diversified the varieties grown by introducing some that are better adapted for processing and have different characteristics than those for table use (particularly regarding storage properties) (farming innovation).

Main traits of the coupled innovation process

1st trait: The building of an inclusive multi-actor network strengthened by exchange arenas

The network of actors described is the outcome of a progressive building for several years. Various exchange arenas were created for actors to coordinate by sectors and between sectors. We identified that the occurrence of internal efficient dialogues was a condition for large-scale structures to act and decide coherently and to be able to coordinate with other structures. The almost 600 cooks have daily exchanges with administrative agents of the local authority, sometimes directly and sometimes by representatives, about their practices. Moreover, every two months, forums gather representatives of cooks from different sites to share their recipes, work habits, and observations with pairs, administrative agents, and a supply company representative. For instance, when the potatoes changed from pre-cooked to frozen, cooks discussed the new recipes they were experimenting with on their own site. These exchanges facilitated the building of shared satisfaction criteria (like the ideal packing size) that were reported to the present supply company representative. Concurrently, farmers

were also connected and regularly exchanged knowledge on their farming practices (potato variety, storage feature, etc.) during cooperative meetings to build a homogeneous offer to the catering sector.
In this network, actors from the various sectors do not discuss with all the others. It appeared important for good interactions within the system that the various types of actors involved in the innovation process belong to structures of similar scales. Administrative agents of the local authority represented cooks during exchanges with the supply company, which in turn exchanged information with representatives of farmers (i.e., farmers' cooperative employees). The local authority, the supply company, and the farmers' cooperative were intermediaries' actors, ensuring links between the farming and the catering sectors in different exchange spaces to share specific knowledge. Indeed, during forums gathering representatives of cooks, administrative agents, and the supply company representative, they exchanged knowledge regarding practical cooking issues. Meanwhile, in farmers' cooperative forums, farmers explain their practical farming or processing issues to the farmers' cooperative and the supply company employees.
2nd trait: The progressive alignment of the actors on a shared desirable unknown

During the coupled innovation process, actors aligned on a shared aim, even if they did not mention or formulate it clearly. Indeed, practice changes and exchanges between actors on their own satisfactory criteria progressively drew the shared direction towards which to work. Since 2006, councillors and administrative agents prioritized health for children, thus ordering organic products in public procurement. In 2011, farmers created an association to control selling prices and ensure a new outlet for their organic products. The supply company started providing potatoes from the farmers' association in order to boost local enterprises and increase its impact on the territory.

Councillors and cooks were satisfied by the products of this new supplier and the consequent support to farmers. So, even if there was a disruption between the local authority and the suppliers every four years during calls for tenders, from a global view, they continuously act in the same direction and adjust their respective goals towards supporting organic potato producers with public procurement and providing local and healthy food for children. Public procurement processes even serve as a forum for facilitating collaboration among stakeholders, allowing them to converge their efforts and harmonize their satisfaction criteria. All actors' sharing of common ambitions and changes in this direction appeared essential for designing coupled innovations.

3rd trait: Successive phases of coherence of the network and ongoing learning of conjoint explorations for innovation design

In some phases, exchanges between actors were frequent and fueled innovation design, while in others, these exchanges were entirely stopped. During contracts, the local authority (and so cooks) and the supply company frequently exchanged to improve

products and the supply offer. On the contrary, during the calls for tender periods, they reduced their dialogue as much as possible to avoid favouring this company over other candidates. When new contracts were signed, exchanges resumed for actors to coordinate their efforts over the next four years. Thus, phases of dialogue breakdown do not necessarily stop the process.

Most innovations resulted from an intra-sectorial individual exploration of ideas during the design process (disjoint exploration). However, they participated in the global coupled process by mobilizing knowledge and standards from other sectors in the design process, a condition to be accepted by other actors. One example is the adoption of the contracting-out system with the supply company on all sites in 2013. This organizational innovation resulted from a will to simplify the administrative workload of agents from the local authority. However, they also considered the expectations of other actors to be sure that some suppliers would tender and commit to more extended volumes. This change in practice for a single actor has impacted various sectors. The supply company had to deliver twice as much volume as before the change, which increased the demand for vegetables from the local farmers' cooperative. This demand, added to the overall demand for potatoes from the cooperative, supported farmers in increasing the surfaces grown with potatoes and investing in on-farm storage equipment.

A turning point occurred in 2017, during the response to the call for tenders for the public market, where it was requested that the holder be attentive to the cook’s working conditions (by limiting the handling of products, etc.). This call for tenders’ period was an intense phase of exchanges between the supply company and the farmers' cooperative to design the best offer possible for the tender. They answered with the proposition of peeled and pre-cooked vacuum-packed potatoes and were selected. This contract required changes in the cooking practice (deleting the peeling task) and supported the building of the project vegetable factory of the farmers' cooperative. Resulting innovations in farming practices also occurred: farmers started to grow varieties with different traits than for usual raw selling. This diversification, feeding farm agroecological transition, was designed thanks to securing cooperative outlets by the supply company contracting with public procurement.

During the following contract, a new exchange arena was created to initiate discussions on possible solutions between the local authority, the supply company, and the farmers’ cooperative. These exchanges created a conjoint exploration of ideas between these three actors and led to the implementation of frozen potatoes as a trade-off between all actor’s satisfaction criteria. Some limits of this process might be discussed in the scope of agroecological transition. Although this decision process is relevant to achieving a social trade-off between stakeholders, it may fail to account for environmental stakes.

Practical Implications

Producing scientific knowledge from a success story of coupled innovation processes can support future designers to implement multi-actor approaches by stimulating the exploration of new concepts, creating new knowledge, and building new types of relationships, as already proposed by Boulestreau et al. (2022) for vegetable value chains. More specifically, the in-depth analysis of a coupled innovation process through the formalization of its main traits provides information on the conditions for the success of this type of complex process. From this case study, we can conclude that aligning all the involved actors on the same view of transition and creating specific spaces for intra and inter-sectoral dialogues to build this goal and share their specific knowledge were successful conditions for a coupled innovation process. More generally, this case study illustrates the feasibility of supporting local production (thus developing environment-friendly and profitable agriculture) while respecting regulations concerning public procurement by working with intermediaries who have seized this shared objective, which is still unusual (Mazin and Da Cunha, 2024).

This case study allowed us to explore the concept of coupled innovation at the interface between agriculture and food (Meynard et al., 2017) involving collective catering. A long-term coupled innovation process was implemented in a large network of actors (more than four “sectors of activity”, involving several hundred people, including cooks) compared to those previously analyzed (Salembier et al., 2020 ; Boulestreau et al.,2022). We developed an original analysis method based on the explication of the action logic of each actor and their connections (rather than based on components of the design process), resulting in highlighting traits of the coupled innovation process. Similar analysis of other cases of coupled innovation could confirm these traits or identify new facets of these complex processes. These traits also raise questions for research on the means to support actors in step-by- step coupled innovation processes.

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Governance of circular economy transitions in the agri-food sector: from conceptual frames to the action
The case of Reunion island

Siqueira T.T.S.[a b], *Jacquet C.*[a b], *Kouadio K.*[a b], *Choisis J-P*[a c]

[a] CIRAD, UMR SELMET, F-97410 Saint-Pierre, Reunion, France

[b] SELMET, Univ Montpellier, CIRAD, INRAE, Institut Agro, Montpellier, France

[c] SELMET, INRAE, Univ Montpellier, CIRAD, L'Institut Agro, Montpellier, France

Abstract

Our study aims to propose and test an original conceptual frame to analyse the governance of circular economy (CE) transitions in the agri-food sector. It is based on three main dimensions (*ideal, material and institutional*) and was tested in the context of Reunion Island, where resources are scarce and the interdependence between uses very strong. Our field research was carried out in 3 steps: stakeholders' mapping, individual interviews and collective thematic workshops. From May to July 2023, we carried out 44 interviews of stakeholders from agri-food sector (farmers, cooperatives, public agencies, etc). The content was analysed in view of the 3 above mentioned dimensions. To confirm, correct and complete our analysis, we organized a full-day workshop with 25 stakeholders. Analysis revealed that there is no shared frame about the CE. Rethink, Reduce, Reconvert and Reuse were in descending order the most cited R principles. We identified 40 initiatives classified in 3 CE strategies: replacing imported material by local material sourcing or more renewable material, replacing imported food by increasing the consumption of local products, promoting organic matter recycling and recovery. Our study also shows that even if agri-food sector stakeholders' do not directly link institutional measures to a specific support to CE strategies, public agencies, policies and territorial authorities play an important role on the governance of the CE transitions. They provide funds for the projects, work for coordination between actors and promote CE transitions trough individual or collective CE strategies. Finally, the stakeholders state that the concept of CE is vague and not adapted to the agri-food sector. Moreover, they criticized the lack of adapted references of directives to the local context and call for the construction of a shared frame to define and develop CE transitions in the agri-food sector.

Purpose

Circular economy (CE) is a concept that is gaining an increasingly important place in public policies at the European (e.g. The Europe Action Plan for the Circular Economy as part of the European Green Deal, 2020) and national levels (eg. In France *Loi Garot*, 2016). Even if the evidence remains vague (Giampetro and Funtowicz, 2020), the promise of reducing environmental impacts and contributing to economic development through

circularity seems to appeal agri-food sector stakeholders' attention (Leipold et al., 2021). Consequently, we observe collective and individual initiatives emerging at different scales of agri-food sector (suppliers, farmers, local authorities, etc.).

CE initiatives face different governance issues related to internal organizational specificities and to external coordination between actors. Governance issues related to the coordination between actors in the sharing of resources at territorial level can sometimes be conflicting. This is even more true in island agri-food sector, such as Reunion, where resources are scarce and the interdependence between uses very strong (Kleinpeter et al., 2023).

Furthermore, population and urbanization growth reinforce the pressure in scarce local resources (Russeil et al., 2023). Our study therefore aims to propose and test an original conceptual frame to analyse the governance of CE transitions in the agri-food sector. We also provide practical insights about the governance of the transition to a CE trough an analysis of emerging initiatives in the Reunion Island agri-food sector.

Design

Inspired by transition's studies, mainly Pachoud et al. (2022), and in circular economy literature, we propose and test an original conceptual frame to analyse the governance of CE transitions through three main dimensions (*Figure 1*):

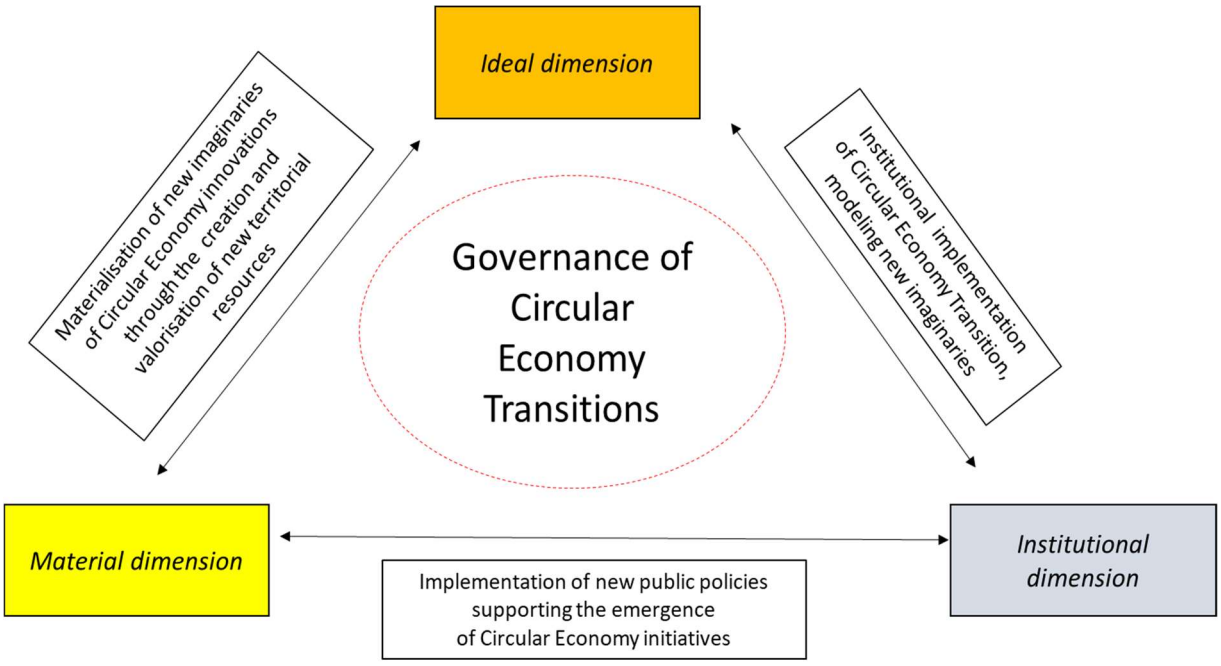

Figure 4: Analytical framework of the governance of circular economy transitions
(Source: Adapted from Pachoud et al., 2022).

(i) the *ideal* dimension reflecting actors believes, representations and comprehensions. Here we focused in the better understanding of stakeholders' CE conceptual frames through the lens of "9R principles" (Potting et al., 2017; Kirchherr et al. 2017): Refuse,

Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.
(ii) the *material* dimension concerning local material and intangible innovations which directly or indirectly integrate the circular flows of natural resources to meet stakeholders' needs.
(iii) the third so-called *institutional* dimension includes public policies represented by the directives to follow and the rules to respect in both national and specific territorial contexts. Furthermore, this dimension also includes informal norms.
Three mains steps guided our field research: stakeholders' mapping, individual interviews and collective thematic workshops. First, we carried out a pre-mapping of the players in the agri-food sector based on previous research work carried out with numerous stakeholders of the agri-food sector. Then, we bring together 8 researchers, and use the collective intelligence to identify the main stakeholders in the agri-food sector carrying out innovative circular economy projects. The stakeholders' mapping step allowed us to identify a diversity of agri-food sector actors to be interviewed. The resources considered were biomass from agriculture or recoverable in agriculture: whether sugar cane straw which can be used for animal feed or burned to produce electricity, livestock effluents used for soil fertilization or potentially for methanization, wood chips used as animal bedding or burned to produce electricity, green waste used for composting or as mulch for market gardening.
Second step, from May to July 2023 we carried out 44 semi-structured interviews with a variety of stakeholders from Reunions' agri-food sector: farmers, organized civil society, cooperatives, public agencies, agricultural suppliers, interprofessional structures, farmers' and cooperatives' unions, local authorities, agri-food consultancies and advisory organizations, agri-food industries, research and development agencies, waste treatment organizations, energy producers and supermarkets. The interviews ranging from 1:30 to 2 hours. We fully transcript the interviews and realized a thematic analysis of its content based in the three above mentioned dimensions: *ideal*, *material* and *institutional*.
Third, we organized a full-day workshop with a team of 8 trained facilitators and 25 stakeholders divided in 4 thematic groups. The main objectives of the workshop were to confirm, correct and complete our analysis of governance dimensions related to CE transitions in the agri-food sector. The workshops also aim to identify and debate the main levers to unlock governance issues of CE initiatives in the agri-food sector.

Findings

First, considering the *ideal* dimension, stakeholders discourses analysis revealed that there is no shared frame about the CE in the agri-food sector. "Rethink" was the most cited R principle and was mainly associated with local consumption of resources but also coordination, reorganization of actors among themselves. Then, "Reduce", "Reconvert" and "Reuse" were respectively the most cited R principles. Moreover, they believe that there is a lack of skilled jobs and structured channels to recycling and recovery materials

channels limiting CE implementation (e.g. According to ADEME, 2018, more than 27,000 tons of waste per year were sent to Europe and India).
Second, related to the *material* dimension of the CE, we identified 40 emergent initiatives that directly or indirectly integrate the circular flows of natural resources to meet stakeholders' needs. We identify 3 CE strategies:

- (1) replacing imported material by local material sourcing or more renewable material (eg. Biodegradable mulch; bedding the animals with local products; using local biomass instead of imported coal to energy production, implementation of local hatchery to avoid chick imports, collectivising forage production and storage to better use local biomasses and avoid imports of forage, etc).
- (2) replacing imported food by increasing the consumption of local products (e.g. territorial planning for scholar canteens food supply, increasing consumers' accessibility of local animal products through special subsidies and taxes mechanisms allowing reduction of prices, etc.).
- (3) promoting organic matter recycling and recovery (e.g. implementation of biogas unit, creation of composting units and multi-actors exchange groups to develop organic matter recycling, etc.).

Third, related to the institutional dimension, as mentioned above, CE policies are growing fast at European and National levels. However, the stakeholders state that the concept of CE, as presented in this public policy, is vague and not adapted to the agri-food sector. That is the case for the FREC "The roadmap for the circular economy" (DEAL, 2021) developed in the Reunion Island. That is basically a declination of the European Green Deal Policy coordinated by the local Department of Environment, Planning and Housing (DEAL). The FREC establishes more than 50 measures and few objectives to be reached to 2030, but only one measure considers local biomasses. Furthermore, according to interviewees, this roadmap did not sufficiently consult agri-food stakeholders.
However, even if agri-food sector stakeholders' do not directly link institutional measures to a specific support to CE strategies, our study shows that public agencies, policies and territorial authorities (the Reunion Island Region and Department authorities) are important in the governance of CE transitions. The institutions are not only providing funds for the projects, but also playing a role in the coordination of CE transitions trough individual or collective CE strategies.
The CE strategy 1 seems to be mainly supported by public research players (e.g. trough the Inventory of available biomasses and identification of potential new uses) and delocalized local public agencies (e.g. Agency for the Environment and Energy Management, Regional Direction of Agriculture and Forestry) thanks to public policies to promote energy or ecological transitions. They can also be initiated by individuals' private actors or their collective action. The CE strategy 2 seems to be mainly supported by territorial authorities (The Reunion island Region and Department authorities) in line with the local structured cooperatives and retailers to promote local food supply with

affordable prices. The CE strategy 3 is mainly leaded by the waste treatment actors and we observe both public and private initiatives. These initiatives can be coordinated by local authorities like in the case of a consortium of municipalities for green waste treatment. Or still public initiatives, leaded for instance by the Regional Direction of Agriculture and Forestry, for the creation and coordination of multi-actor arenas to exchange and find out common solutions avoid water and soil contamination trough adapted agricultural organic matter recycling. We also observe, individual emerging initiates like on-farm effluent composting or the implementation of biogas units that can be funded by local authorities.

Finally, the interviewees also criticized the lack of adapted references of directives and laws to the local context. This seems to be the case of livestock effluents spreading regulations[1]. According to certain stakeholders, this law is adapted neither to the pedoclimatic conditions of the island nor to the structures of the farms (small size, intensive indoor breeding). They also mentioned the difficulty of implementing alternative solutions that are often too expensive (composting platform mechanization). The regulatory complexity and rigidity also seem to slowing down the implementation of solutions.

Practical Implications

In the island context, such as the Reunion, where resources are limited and ecosystems are fragile, the adoption of CE principles in the agri-food is perceived as a mean to replacing imported material by local material sourcing or more renewable material, replacing imported food by increasing the consumption of local products, promoting organic matter recycling and recovery. Moreover, CE strategies is perceived as a mean to stimulating local economy through the creation of new jobs. By individual and collective initiatives, supported or not by public policies and regulations, agri-food sector stakeholders try to implement the transitions to a CE.

Moreover, institutional support to individual or collective strategies does not seem to provide any guarantee on the success of CE initiatives (and even when many actors are on board). CE transitions in the agri-food sector seems to face many governance issues. These governance issues were mainly associated to the low interest in collective actions, public administration obstacles as well as the lack of dialogue between actors, potentially due to historical tensions. Governance issues were largely related to the establishment of socio-technical lock-ins, which sometimes lead to projects being abandoned. Conversely, when the CE is based on regulatory issues and strategies are funded the projects seems to have more chance to succeed. For private actors' strategies, it seems that more than public fund the existence or creation of a market seems an important key to the success.

However, the interviewees also mentioned levers to unlock governance issues of CE initiatives in the agri-food sector. The local construction of a shared frame to define and develop CE in the agri-food sector seems to be a first step. The adoption of a territorial frame of reference with local agri-food actors would be important for the development of a genuine territorial circular economy. It can be done through a territorial planification process where the stakeholders and civil society can participate without an oriented circular use of biomasses like in the case of Regional Biomass Plan resulting from the National Strategy Biomass for energy production (Decree No. 2016-1134 of August 19, 2016).

Theoretical Implications

The literature on the governance of CE transitions in the agri-food sector is under developed. This lack of adapted references encouraged us to draw a conceptual framework adapted to the agri-food sector, inspired by the work on governance of territorial transitions developed by Pachoud et al., (2022) and the literature on CE. The proposed framework allowed us to carry out a relevant diagnosis on the three dimensions of governance (ideal, material and institutional) impacting transitions. However, this work remains unfinished and deserves to be further developed to better integrate certain specificities of the diversity of transitions in the sector. Furthermore, the construction of an adapted definition of the circular economy in the agri-food sector seems to us to be a good starting point. Indeed, this concept, well developed and integrated in the industrial sector, is still unknown and vague for actors in the agri-food sector.

The three main steps guiding our study (stakeholders' mapping, individual interviews and collective thematic workshops) also seems relevant for the study of governance of CE transitions in the agri-food sector. Starting with a collective stakeholders mapping allow us to enlarge our perspective of actors and to identify the suitable interview contacts. The following steps allow us to identify, to confirm, correct and complete the collected information. Furthermore, we also were able to analyse and debate how the dimensions composing the governance of CE transitions can encourage or lock the development of CE initiatives in the agri-food sector. Otherwise, we also identified and debated the main levers to unlock CE initiatives and enlarge the perspective of the development of a CE transition at the regional level.

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RETHINKING SOLUTIONS AVAILABLE TO FARMERS

Lupins Unleashed: overcoming challenges, vision and design of innovative products to enhance agrobiodiversity.

Sonia Massari[a], Francesca Galli[b], Luca Colombo[c]

[a]University of Pisa, PAGE and ISIA Rome Design, sonia.massari@unipi.it

[b]University of Pisa, PAGE, francesca.galli@unipi.it

[c] FIRAB, l.colombo@firab.it

Abstract:
This study explores innovative idea generation among design students, with a particular focus on the uses and characteristics of white lupin. Based on data on consumption, production methods and agroecological practices, the aim is to generate ideas for new products that valorise neglected and underutilised crops (NUCs) in different market segments, such as restaurants and distribution channels. The process falls within the domain of food design, an emerging field with significant potential in contexts such as agroecology that are still outside mainstream consumption. Designers use creative techniques such as emergent scenario design and agile prototyping to envision both the concept and its real-world application. Future-thinking is crucial in today's rapidly changing environment, with design thinking and scenario-based design methods serving as key methodologies. These processes allow for the exploration of potential futures, helping to understand the consequences of current decisions and actions in shaping sustainable food systems.
Keywords: NUCs, agroecology, Design methods, transdisciplinarity, creativity

Introduction/Purpose

In this era of sustainable food systems transformation, our research addresses the under-explored area of neglected and underutilized crops (NUCs) and legume consumption, with a specific focus on lupins, highlighting their untapped potential as nutritious and ecologically sound protein sources (Annichiarico et al., 2014). Despite their agroecological properties, lupins are still relatively overlooked for human consumption. This results in farmers neglecting the crop for its limited marketing potential (Lucas et al., 2015).
On the production side, the limited research and development focused on lupin varieties, disease resistance and cultivation techniques does not result in their widespread agricultural adoption. Investment in research is thus essential to enhance their agronomic and nutritional properties. The biggest barriers to white lupin development at present are anthracnose disease in cold-humid environments and an often too high alkaloids content for food processing, reducing their attractiveness to

farmers compared to other major grain legume crops with stable market demand and established value chains (Annichiarico et al., 2014).
On the consumption side, there is a lack of public awareness of lupins as a food source, which hampers their acceptance and market demand. Unlike other pulses such as beans, lentils or chickpeas, lupins are not integrated into global cuisines and their importance in the traditional diet is limited to certain regions (e.g. some Mediterranean areas) and to few processing options making consumption less pronounced than in the past (Böhme et al., 2020). Secondly, cultural habits and preferences strongly influence food choices, and the introduction of a new and unfamiliar food may encounter some resistance[2]. The limited availability of diverse and appealing lupin-based recipes as well as the bitter alkaloids that require extensive processing to remove (Signorini et al., 2018; Ortega-David and Rodriguez-Stouvenel, 2013) further limit their culinary appeal, which is crucial for widespread adoption.
Overcoming challenges on both the production and the consumption sides of the market will require a collaborative effort involving farmers, researchers, policy makers, the food industry, as well as designers and creative professionals (Frow et al, 2015; Hagy et al 2017; Massari et al, 2023). Investing in agricultural research, raising awareness of the nutritional benefits of lupins, developing innovative and palatable lupin-based products, are all crucial steps towards reducing their neglect and promoting their cultivation and consumption, with a great potential in a sustainable diet framework.
The aim of this paper is to describe a process for the rapid generation of innovative ideas to bring NUCs to market and stimulate their consumption. The idea stems from the DIVINFOOD project[3], funded by the European Union's Horizon 2020 research programme, which aims to develop food chains valorising underutilised agrobiodiversity to halt its loss and meet growing consumer expectations for healthy, local products that contribute to sustainable food systems.
In this study, which focuses on innovative idea generation with design students, the white lupin was particularly emphasised and considered. Based on the uses and characteristics of white lupins (data on consumption and production methods, agroecology), the aim was to generate ideas for new products valorising NUCs, to be launched on the market (in restaurants, distribution and elsewhere) and/or new eating experiences. The idea generation process falls within the realm of food design, an increasingly important discipline in the agri-food landscape that has great potential, especially in contexts such as agroecology that are still far from mainstream consumption.
Designers use creative processes that employ a variety of techniques, including emergent scenario design and agile prototyping, to envision not only the concept, but

[2] as debated in the 6th edition of Nutrition Day, organised in 2023 by the Food and Nutrition Centre, Nutrinformarsi: understanding Italians' food consumption. (https://www.crea.gov.it/-/ancora-basso-il-consumo-di-legumi-frutta-e-verdura-secondo-l-indagine-crea-sui-consumi-alimentari)
[3] The project, which involves 26 partners in 7 countries and is based on 9 Living Labs (Hossain et al 2019) for participatory research, aims to structure and stabilise territorial networks for collective management of agrobiodiversity to promote a commons economy that values the ecosystem services provided by NUCs.

its real-world application in current and future contexts (Arce et al, 2022; Youbin and Jaehwan, 2019). Future-oriented thinking has become increasingly important in today's society, where uncertainty and rapid change are omnipresent. A key methodology in Futures Thinking is Design Thinking techniques and Scenario-Based Design methods, creative processes that enable the imagination of possible futures to understand the implications of current decisions and actions (Allievi et al, 2021;Audretsch & Belitski, 2013). The basic premise of this paper is rooted in a salient observation regarding the dynamics of innovation within European project frameworks. Specifically, there is a conspicuous gap in the integration of creative and design expertise, a deficiency that compromises the effectiveness of innovation efforts. This observation catalyzes a strategic imperative to explore novel methodologies conducive to agile prototyping that enable the rapid translation of research findings into tangible artifacts and service solutions. Given the nascent stage of these envisioned products within the market environment, scenario-based approaches emerge as indispensable tools for envisioning and iteratively refining prospective trajectories. Consequently, the methodological orientation of this study is meticulously crafted to reconcile the exigencies of scientific inquiry with the imperatives of practical application, thus advocating a paradigmatic shift toward interdisciplinary collaboration. In essence, the cultivation of a transdisciplinary ethos underpins the conceptual framework of this research endeavour and serves as a linchpin for fostering synergy across disparate domains of expertise.

The methodology

The methodology used in this study was a collaborative classroom design involving a team of 25 students divided into three groups. The process began with a presentation by one of the authors, in the role of a fictitious "client," who provided an overview of white lupin, NUCs and the concept of living labs as part of the DIVINFOOD project.

The initial presentation was followed by a project briefing, which explained the characteristics of white lupins and outlined the objectives for bringing NUCs to market through innovative business models. This phase involved aligning the learning objectives with the project's expectations and establishing a clear understanding of the project scope. Students were tasked with researching the pulse and lupin markets to develop new scenarios. Unlike traditional approaches, students were not given restrictive briefs, but were encouraged to construct emergent scenarios based on their research findings and identified use scenarios (Massari, 2017). The use of creative briefs is a standard practice in product and service design, although there is no 'standard' creative brief. They can be structured in different ways, with multiple briefs often being developed to replace previous ones, leading to significant variations in format and purpose, depending not only on the data provided, but also on the use scenarios identified by the students (Koh et al, 2015).

This scenario-based design approach facilitated creativity and ideation, allowing students to explore a wide range of possibilities and develop diverse future scenarios. In the context of the lupin valorization, the scenario-based design technique is applied

while adhering to fundamental principles. First, reasonableness dictates that scenarios must be based on a thorough understanding of future influencing factors. This requires the creation of narratives that accurately depict potential developments arising from existing trends, technological advances, and societal shifts to ensure plausibility and feasibility. Diversity is another key principle, underscoring the importance of exploring a wide range of future scenarios. By considering different possibilities, including positive, negative and neutral outcomes, as well as extreme and transitional scenarios, the approach allows for a comprehensive exploration of potential futures, thereby increasing the robustness and adaptability of the proposed solutions.

Furthermore, the relevance of the scenarios to the specific context and objectives of the analysis is paramount. Each generated scenario must provide valuable insights for decision making and policy development, tailored to the objectives of the project and the unique characteristics of the lupin valorization initiative. This will ensure that the scenarios are not only insightful, but also directly applicable to the project's goals. Finally, the internal coherence of the scenarios is essential for their effectiveness. Scenarios need to be logically consistent, with different components and dynamics linked together in a coherent way. This ensures that the scenarios are internally consistent, enhancing their credibility and facilitating a convincing presentation of causal relationships and potential impacts within the context of lupin valorization.

The limited time frame of the course required a pragmatic approach to data collection and analysis. Instead of in-depth qualitative methods such as field interviews and ethnographic research, primary and secondary sources were used, supplemented by tools such as interviews, surveys, and web context analysis. In addition, field observations were conducted to gain insight into existing scenarios relevant to the project.

In the next phase, the students created user experience maps using various systems design techniques and design thinking tools. Through iterative brainstorming and co-creation sessions, the groups generated concepts and produced initial prototypes (Lloyd 2017). Once innovative scenarios were identified, the students proceeded to define naming conventions, visual identities, system maps, and stakeholder connections, culminating in a presentation and validation with stakeholders.

In summary, the methodology involved a comprehensive process of collaborative ideation, research, and prototyping tailored to the constraints of the classroom environment and the goals of the project, combining scenario-based design with agile prototyping.

Results

The workshop produced three “food design concepts” that showcase innovative approaches to sustainable food systems and consumption patterns (Massari, 2021; Ebel et al 2020). The integration of the three conceptual frameworks stems from their shared effort to identify everyday urban environmental scenarios conducive to their respective applications. Central to this convergence is the careful delineation of two distinct target demographics: youth and children. This segmentation is based on an astute recognition

of the distinct socio-cultural proclivities and developmental needs that characterize these cohorts. Moreover, the delineation of two distinct contextual milieus - educational institutions and green spaces (including edible gardens, parks, etc.) - serves as a strategic scaffolding for contextualizing the proposed interventions within the fabric of everyday urban life. By anchoring their exploratory trajectories within these dual axes of demographic and contextual specificity, the conceptual frameworks espouse a holistic approach aimed at generating nuanced insights into the multifaceted dynamics that underpin urban life.

The "Loop-ini" project - The *Loop-ini* project introduces a circular food system paradigm through vending machines, engaging stakeholders at the cultivation, production, packaging, distribution and collection stages to promote circularity and resource efficiency. It pioneers a circular snack concept based on lupins, using recycled materials for packaging. The vending machine offers a variety of lupin-based snacks and beverages, targeting diverse demographics and high-traffic locations. Innovative packaging mimics the shape of lupins, providing a unique consumption experience and acting as an educational tool through illustrative puzzles about lupins and sustainability. This holistic design approach aims to transform the retail experience into a sustainable initiative, emphasising environmental friendliness, nutrition and consumer education.

Figure 1 Loop-ini (concept designed by students)

The "LOOPs" project - The *LOOPs* project focuses on designing circular snacks for children to promote sustainable consumption patterns early on. Through engaging product design and packaging, it aims to instill sustainable values in children. The project introduces a circular snack concept emphasizing sustainability and natural food consumption, utilizing waste materials for packaging and local farm-sourced raw materials. Initial distribution targets schools to encourage natural food consumption among children, with plans for collaboration with specialized companies and potential expansion into ice cream production. The project's name "LOOPs" symbolizes its cyclical nature and underscores sustainability from production to disposal, phonetically linking to "lupin" for ethical resonance. A 360° approach, led by mascot "Agustin the Lupin," immerses consumers in lupin integration education. Innovative packaging includes educational elements, such as illustrated puzzles, while cereal varieties reflect chocolate bar flavors for easy identification. Transparent packaging ensures product quality and enhances the consumer experience.

Figure 2 Loops (concept designed by students)

The "APE LUPINO" project - The *APE LUPINO* concept represents a pioneering standard for healthy and environmentally friendly beverage options, integrating nutritional, environmental, and consumer-centric considerations. It combines the nutritional benefits of lupins with honey to create a tasty and healthy drink, inspired by craft beer's use of lupin seeds. Different types of honey, such as lime, dark wildflower, or chestnut, offer various flavor profiles to cater to consumer preferences. APE LUPINO targets 35- to 54-year-olds, addressing the demand for gluten-free and plant-based diets, as well as the rise of teetotalism. Its packaging promotes sustainability, utilizing reusable bottles and a water-soluble honey capsule to eliminate added sugar while encouraging waste reduction. APE LUPINO sets a new standard for aperitif experiences, redefining tradition with a focus on health and environmental consciousness rooted in agroecology and sustainable beekeeping principles.

Figure 3 ApeLupino (concept designed by students)

Practical implications

The study's three design concepts/results illustrate the feasibility of constructing comprehensive scenarios within limited timeframes, fostering stakeholder reflection on project diversity, coherence and significance. Utilizing agile design or prototyping, particularly in participatory design for scenario creation, meets the growing market demand for agile prototyping to contextualize and validate products. Structured scenario-based design and design thinking facilitate stakeholder engagement, innovation and departure from traditional business models within the food system. However, the experiment encountered limitations, notably the absence of transdisciplinary collaboration crucial for skill integration. To ensure thorough scenario elaboration, diverse perspectives from stakeholders representing various communities and sectors are essential. Although limited to dialogue between the lecturer, project provider and students, future validation with external sector stakeholders is planned to enhance scenario accuracy. Additionally, the exercise focused solely on scenarios and concepts, lacking business models and economic feasibility, prompting plans to involve agricultural economics and marketing students in future iterations to address this deficiency.

Concluding remarks

This study highlights the importance of incorporating co-design methods when experimenting with new products. Supporting the co-creation process is fundamental for the long-term success of a project, as it fosters collaboration among stakeholders and ensures the relevance and acceptance of the final outcomes. Theoretical implications suggest that creativity, through innovative and unconventional approaches, can lead to scenarios that challenge expectations and reveal previously unconsidered possibilities,

and should be assessed (Barbot, 2011; Batey 2012). By imagining and developing alternative scenarios, this approach pushes beyond the boundaries of current knowledge and perspectives.
Furthermore, this case study illustrates how design techniques can generate new ideas and explore possibilities beyond current and known limits, particularly useful when new development pathways have to be identified to popularise NUCs and let them sneaking out a too small niche. It demonstrates the potential of university training courses to address the current challenges of global society and strategically develop organizations. This model of learning is transferable from design studies to other disciplines, and serves as an interesting example of synergy between teaching and research, promoting integration between disciplinary knowledge and cross-cutting skills. Ultimately, this study underscores the significance of interdisciplinary collaboration and innovative methodologies in addressing complex societal challenges and fostering strategic development.

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Identifying Walloon (Belgium) dairy farms optimising sustainable food security using Multiple Criteria Decision Making methods with a multi-actor panel

Caroline Battheu-Noirfalise[a,b], Alexandre Mertens[a], Arno Faivre[b], Catherine Charles[b], Thomas Dogot[b], Didier Stilmant[a], Yves Beckers[b], Eric Froidmont[a]

[a] Walloon Agricultural Research Centre, Department Sustainability, systems and prospectives, B-6800 Libramont-Chevigny, Belgium

[b] University of Liege, Faculty of Gembloux Agro-Bio Tech, B-5030 Gembloux, Belgium

Abstract:
Dairy systems can contribute positively to food security but their sustainability is questioned, stressing the need to study farms reaching optimal "sustainable food security". Stakeholders representing the upstream milk sector (6 advisers, 5 farmers' unions, 5 researchers, 4 environmental organisations and 4 feed enterprises) participated to the optimisation by defining weights for 17 sustainability metrics calculated on FADN-data, using the Analytical Hierarchy Process, and the respective optimal farm(s), using ELECTRE III on 209 Walloon specialised dairy farms through an online application (https://shinyapp.cra.wallonie.be/optimilk/). Agglomerated weights per stakeholder type showed differences between types but rather low consensus rates within each type. Agglomerated weights for the Walloon upstream dairy sector were the highest for both the economy and the contribution to food security (0.28), followed by the environment (0.21) and the social pillar (0.1). Using the weights for the dairy sector, ELECTRE III identified two optimal farms, which were both organic with one intensive and one extensive farm, illustrating the interest of organic systems in the frame of sustainability. This work illustrates the feasibility and interest of a sustainability assessment using a mixed methodology coupling ELECTRE III and AHP on the basis of FADN-data.

Keywords: Participatory approach · Livestock systems · Production systems · Multidimensional sustainability · Farm Accountancy Data Network (FADN)

Purpose

The increasing human population and demand for animal food products raises the issue of impacts of animal systems on food security caused by their use of human-edible feed and tillable land (Mottet et al., 2017). However, dairy systems are found to have the highest potential of different animal productions for contributing positively to food security as they can transform non-human-edible resources (forages and by-products) into human food (milk and meat) with high conversion efficiency (Wilkinson, 2011). Nonetheless, the economic profitability and resilience of European dairy farms is uncertain, notably due to the end of milk quotas (Schulte et al., 2018). Moreover, dairy

systems are increasingly criticised concerning their multiple impacts on the environment such as greenhouse gases emissions or nitrate leaching (Steinfeld et al., 2006). On social aspects, dairy farms are triggered by e.g. the high workload (Hostiou et al., 2017). The objective of this study was to identify and describe dairy farms reaching optimal "sustainable food security". The case study is the Walloon region, whose high diversity of dairy systems allowed us to evaluate sustainability on a wide range of farm characteristics.

Design/Methodology/Approach

Using farm accounting data (mean of 2018-2019-2020) of 209 Walloon specialised dairy farms (Belgium), we calculated 27 metrics proposed by a previous review on sustainability metrics. The data covered a large diversity of dairy systems with milk production ranging from 3500 to 10300 l milk / cow / year and with a fodder composition ranging from fully grass-based to 68% of maize silage. The metrics represented the social (4 metrics), environmental (11 metrics) and economic (12 metrics) pillars of sustainability (Lebacq et al., 2013). Six metrics defined in a previous work were added to represent the contribution to food security (Battheu-Noirfalise et al., 2023). Those results were presented to dairy stakeholders, which, in this case, are the Walloon milk upstream sector as their members have a high knowledge of dairy farms' structure and management. The following members participated: researchers (n=5), environmental organisations (n=4), technical advisors (n=7), feed enterprises (n=4) and farmers' union (n=5). One environmental (agro-environmental measure) and one economic (net margin) metrics were added to the analysis as they were specifically asked by the stakeholders.

Table 1. Name, description and units of the sustainability metrics used in the optimisation together with their optimisation objective (maximise or minimise). Abbreviations: CP, Crude Protein; DC, Dairy Cow, FWU, Familial Working Unit; GHG, GreenHouse Gases; HDP, Human Digestible Protein; LU, Livestock Unit; TWU, Total Working Unit.

Main criteria	Secondary criteria	Description	Units	Objective
Contribution to food security	Net productivity	Net amount of produced HDP (produced – consumed) per ha	kg HDP / ha	Max
	Net efficiency	Amount of HDP produced / Amount of HDP consumed	kg HDP / kg HDP	Max
	Tillable land use	Tillable land area (crops and temporary grasslands) per produced HDP	m^2 / kg HDP	Min

Economy	Production costs per litter of milk	Variable + fixed costs	€ cents / l milk	Min
	Share of variable costs	Variable costs / Total costs	%	Min
	Net margin	Revenue (milk + meat) – Total costs + Subsidies – salaried working unit – rent – amortization – financial costs	1000€ / FWU	Max
	Transmissibility	Capital excluding land / FWU	1000€ / FWU	Min
	Economic efficiency	Gross operating surplus / Revenue	%	Max
Environment	Nitrogen surplus	Incoming nitrogen (feed, fertilizers, seeds, animals) – outgoing nitrogen (milk, meat, farm fertilizers)	kg N / ha	Min
	GHG emissions	GHG calculations were performed using the software DECIDE [4]	kg CO_2eq / l milk	Min
	Stocking rate	LU as defined in the Walloon law of nitrogen management	LU / ha	Min
	Herd costs	Veterinary costs, medication, reproduction	€ / DC	Min
	Pesticides use		€ / ha	Min
	Agro-environmental measure		€ / ha	Max
Social	Total working units		TWU	Max
	Familial workforce	FWU/TWU	%	Max
	Employment rate		TWU / ha	Max

[4] The local tool DECiDE has been used to perform GHG balance (https://www.decide.cra.wallonie.be/fr). DECiDE is based on the Life Cycle Analysis methodology. All indirect and direct emissions of greenhouse gases (GHG) supporting the farm's activity (CH4, N2O and CO2) are expressed in CO2-eq and related per hectare and per litre of standardized milk. The data used in DECiDE originated only from accounting data: buildings were not taken into account, and assumptions were made about the type of livestock and the types of storage and spreading of farmyard manure.

In September 2023, we organised stakeholder meetings by stakeholder type in order to facilitate discussions. Metrics' weight were determined by each stakeholder individually using the Analytical Hierarchy Process (AHP) (Saaty, 1987) method, which takes the form of a questionnaire and establishes weights based on pairwise comparison of importance between metrics (with the pillars of sustainability as main criteria and the sustainability metrics as nested secondary criteria). Metrics that were correlated at more than 60% were excluded to keep the simultaneous comparison of criteria at maximum 7 (Table 1). We implemented Electre III (Roy, 1991), a Multiple Criteria Decision Making method, in an online application using the R package shiny (Chang et al., 2023): https://shinyapp.cra.wallonie.be/optimilk/. This method classifies the possible alternatives (the dairy farms) from "best" to "worse" based on maximising or minimising weighted criteria. Stakeholders were asked to fill in their individual weights resulting from the AHP in the online application and could modify their choice if needed. The co-defined weights by stakeholder type were then obtained by using a geometric mean between stakeholders. The aggregated weights at the level of the milk sector were obtained by using the same procedure on the weights per stakeholder type. Consensus rate was represented with the consensus indicator (Tastle et al., 2007), based on Shannon entropy, an indicator of diversity already used in the frame of AHP. This indicator varies from 0% (no consensus) to 100% (full consensus).

Findings

Stakeholders' preferences

Feed enterprises and advisers showed similar priorities concerning sustainability pillars with, in order of preference, the economy (average weights of 0.38 and 0.25, respectively), the contribution to food security (0.19 and 0.20, respectively) the environment (0.17 and 0.11, respectively) and the social pillar (0.07 and 0.10, respectively ; Figure 1). Environmental organisations, researchers and farmers' unions preferred the contribution to food security in the first place with respective average weights of 0.26, 0.22 and 0.27. While the environmental organisations preferred the environment (0.24) in second place, researchers and farmers' unions had the economy in second place (0.19 and 0.25, respectively). For those three types of stakeholders, the social pillar also showed the lowest average weights similarly to feed enterprises and advisers. Consensus rates within stakeholder types were ranging from 9% (Feed enterprises – pesticide costs) to 71% (Researchers – production costs per litter of milk and stocking rate). Aggregated weights for the Walloon dairy sector, considering all stakeholders, were the highest for both the economy and the contribution to food security (0.28), followed by the environment (0.21) and the social pillar (0.1). In total, the net margin was the most important economic indicator (0.10). The net efficiency was the most important indicator for the contribution to food security (0.12). The N surplus was the most important environmental indicator (0.05), followed closely by the GHG emissions (0.04). In total, the

most important social indicator was the employment rate (0.07). Consensus rates for the dairy sector ranged from 45% (production costs per litter of milk) to 62% (total working units).

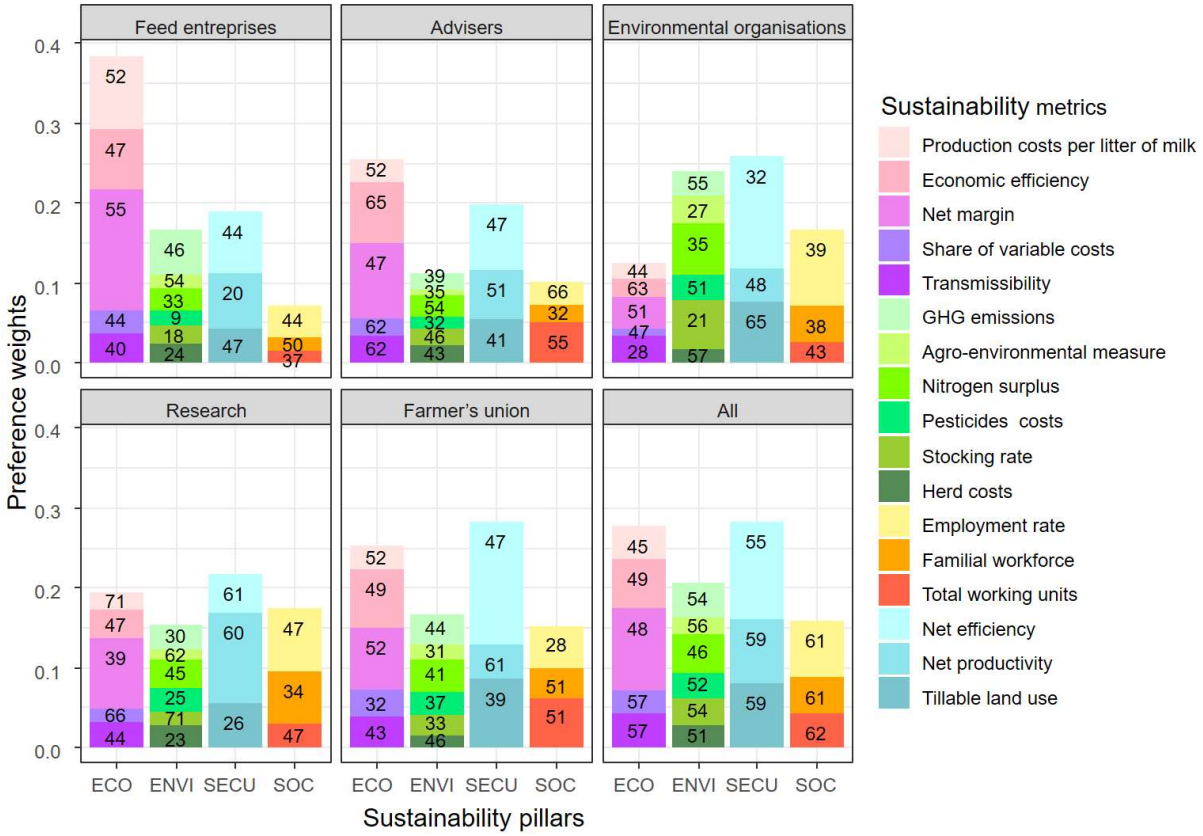

Figure 1. Agglomerated metrics' weights (metrics' weight multiplied by their respective sustainability pillar weight) per stakeholder type and the dairy sector with the associated consensus rate (figures in the graph).

Description of the optimal farms

Using the aggregated weights of the Walloon dairy sector, two farms were equally identified as "best" in the farm sample by ELECTRE III (Table 2). Those two farms were named organic intensive (OI) and extensive (OE). Indeed, the OI-farm had a higher milk productivity per cow (7750 l / cow / year) and number of LU (95) compared to OE. The OI-farm also used higher amounts of concentrates (2.0 kg DM / cow / day) and reached a lower age at first calving (26.6 months) than OE. None of the farms was using maize silage and they both had a herd size below the median. The OE-farm reached the maximum net efficiency (80.9 kg HDP / kg HDP) and the minimum tillable land use (0.9 ha / kg HDP) in the farm sample. However, its net productivity (193 kg HDP / ha) was lower than the value presented by OI (295 kg HDP / ha) due to a lower stocking rate (1.5 LU / ha) and milk productivity per cow (4690 l / cow / year). In term of net margin, both

farms were above the median of the farm sample. The production cost per litter of milk was close to the minimum for OE (0.194 € / l milk) and close to the median for OI (0.278 € / l milk). The economic efficiency was close to the maximum for both OI (63.0%) and OE (68.6%). The OE-farm showed a transmissibility close to the minimum (80000€ / FWU), while the value of OI was closer to the median (300000€ / FWU). Concerning environmental aspects, OE reached the minimum values for the N surplus (-25 kg N / ha). The OI-farm showed a higher N surplus (40 kg N / ha) but lower GHG emissions (1.09 kg kg CO_2-eq / l milk) than OE (1.23 kg kg CO_2-eq / l milk). The veterinary costs were below the median for both farms. The OE-farm did not declare any agro-environmental measure, while OI showed a value of 8.3 € / ha. Socially, OE had an employment rate (0.029 WU / ha) and total working units (1.0 WU) lower than OI but its familial workforce almost reached 100%. The OI-farm had 2.0 WU with the half of familial workforce.

Table 2. Minimum, median, maximum values and performances of the two optimal farms, organic intensive (OI) and organic extensive (OE), for the sustainability metrics used in the optimisation as well as for dairy farm characteristics. Abbreviations: CP, Crude Protein; DM, Dry Matter; FWU, Familial Working Unit; GHG, GreenHouse Gases; HDP, Human Digestible Protein; LU, Livestock Unit; TWU, Total Working Unit.

Sustainability metrics	**min**	**median**	**max**	**OI**	**OE**	**units**
Net efficiency	1.5	7.9	80.9	23.9	80.9	kg HDP / kg HDP
Net productivity	90	248	371	295	193	kg HDP / ha
Tillable land use	0.9	9.7	42.9	7.1	0.9	ha / kg HDP
Production costs per litter of milk	0.187	0.292	0.547	0.278	0.194	€ / l milk
Economic efficiency	18.6%	45.4%	71.4%	63.0%	68.6%	€ / €
Net margin per FWU	-39000	45000	128000	77000	-6400 0	€ / FWU
Share of variable costs	0.347	0.576	0.749	0.583	0.428	€ / €
Transmissibility	50000	320000	316000 0	30000 0	8000 0	€ / FWU
GHG emissions	0.34	1.22	3.88	1.09	1.23	kg CO2-eq / l milk
Agro-environmental measure	0.00	9.86	215.38	8.33	0.00	€ / ha
N surplus	-25	130	398	40	-25	kg N / ha
Pesticide costs	0	8	140	0	0	€ / ha
Stocking rate	0.41	1.96	4.12	1.76	1.53	LU / ha
Herd costs	32	202	539	121	99	€ / LU

Employment rate	0.009	0.023	0.064	0.037	0.029	WU / ha
Familial workforce	18%	54%	100%	50%	97%	FWU / WU
Total working units	1.00	1.68	5.00	2.00	1.01	WU
Use of concentrates	0.3	3.4	9.7	2.0	0.3	kg DM / cow / day
Age at first calving	22.9	28.9	40.7	26.6	28.2	months
Milk productivity	3520	7560	10260	7750	4690	l milk/ cow / year
Share of maize silage	0	11	68	0	0	%
Herd size	31	140	650	95	54	LU

Practical Implications

This work identifies and describes two optimal dairy farms in terms of sustainable food security. As a result, it presents a strong basis to discuss with stakeholders and decision makers about sustainability issues, future objectives and pathways of transition in the Walloon dairy sector. Using real data of commercial farms, our results present individual and realistic values as clusters of farms can mask individual farms specificities. The two optimal farms described in this work were both organic, illustrating the interest of organic systems in the frame of sustainability. However, the analysed data are from 2018 to 2020 and, in 2023, organic milk price decreased due to the lack of consumption. Thus, the economic resilience of the organic market should be further analysed. Further analysis will also describe the gradient from optimal to less optimal farms in function of their characteristics. The farmers of the two optimal farms will be interviewed to better understand their posture and management. Last, stakeholders' reflexions about the possibilities of generalizing the optimal farms in the Walloon region will be analysed. This work leaves an open access decision tool, allowing other scientists, technical advisers, teachers or students to reproduce the methodology with their own weights. As a result, it helps diffusing a way of thinking in terms of "optimisation" in the place of "maximisation", inducing reflexions about sustainability and its inherent trade-offs.

Theoretical Implications

This work illustrates the feasibility and interest of a sustainability assessment using a mixed methodology coupling ELECTRE III and AHP on the basis of FADN-data. Such methodology enables an interactive optimisation, which is found to be the most effective way to integrate stakeholders in the optimisation process (Kaim et al., 2018). Indeed, stakeholders can, in the same meeting, obtain their preference weights (using the AHP), determine the corresponding optimal farm (using ELECTRE III) and modify their assessment if needed. This methodology also enables to integrate a sustainability assessment into a scientific frame, having both a quantitative (FADN-based sustainability metrics) and qualitative (sustainability metrics' preferences) approach,

giving value and coherence to the results. Further, the integration of a large panel of stakeholders, representative of the Walloon dairy sector, into the sustainability assessment allows a high support and mutual agreement from the stakeholders to the results. However, in order to be successful, we highly recommend anticipating the time and support needed to explain clearly the used metrics because a good comprehension is key to consistent results and sustainability assessment considers a high number of metrics, which can easily induce confusion. Moreover, our results showed low consensus rates amongst stakeholder types, highlighting the importance of integrating a high number of representatives per stakeholder type.

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What new business models and digital innovations can really support small-scale farmers in the Mediterranean region? A Living Lab approach to explore potential innovations for small-scale fruit and vegetables producers

Paolo Prosperi[1,2,], Laurick Collewet[1,2], Dimitrios Aidonis[3], Mohamed Ait Hou[4], Chrysanthi Charatsari[5], Marcello De Rosa[6], Reem El Khechen[1,2], Hager Fouad[7], Martina Francescone[6], Ahmed Ghannouchi[7], Justus Harm[8], Shadi Hashem[9], Evagelos D. Lioutas[3], Anastasios Michailidis[5], Lhoucine Ouahi[10], Ider Ouchna[11], Driss Ouslimane[4], Mohamed Zahidi[12] and Luca Camanzi[13]*

** Corresponding author: prosperi@iamm.fr*

Abstract:
European policies and research programmes are encouraging innovation development for small farms in terms of new business and organisational models - including the application of digital technologies - in supply chains providing sustainable production and consumption of healthy and nutritious foods. In the PRIMA-funded "Med-Links" project, we co-create and co-develop – with value chain stakeholders – new business models, voluntary sustainability standards and a digital platform to increase market profitability and linkage of five fruit and vegetables (small-scale) supply chain systems in the Mediterranean area. Building on a three-step Living Lab approach we observe that the co-development of a set of three innovations leads to potential improvements regarding the coordination among farmers and with their economic and social partners. Innovations also provide producers with effective strategies to enhance the outcomes of certification processes and to communicate more effectively about product quality and growing practices. Support needs have been identified and are provided through a digital platform offering training materials, information sharing and financing tools.

Keywords: Food system innovations; Multi-stakeholder approach; Adaptation strategies; Value chains

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Purpose

The Small scale fruit and vegetable (F&V) producers strive to integrate accessible and profitable market channels due to a number of key problems within supply chains such as unbalanced market power dynamics (Berti and Mulligan, 2016), information gaps and asymmetries, low and geographically fragmented production volumes, remoteness and transportation costs and difficulty in meeting high food safety requirements and traceability (Camanzi et al., 2019), as well as low willingness to pay of local consumers for quality produce (Hernandez et al., 2021). Our research develops and assess pathways of

innovation – co-identified with supply chain stakeholders – in order to ease and coordinate the information flow and value sharing within small scale F&V supply chains. In this research, the concept of "innovation" is seen as an "*outcome of a process, rest on two defining characteristics, a degree of newness of a change and a degree of usefulness or success in application of something new*", at multiple potential scale (e.g., world, country, territory, supply chain, firm) (Granstrand and Holgersson, 2020). Through Living Lab activities (Hossain et al., 2019; Leminen et al., 2013), three innovations are co-developed with local stakeholders of small farming-based fruit and vegetable supply chains (short, export-oriented and public) in 5 Mediterranean countries, including 1) pertinent certification schemes, 2) optimised management and business practices, 3) innovative IT tools supporting decision making, transparency, traceability, supply and demand convergence, and transaction management. Our research aims to explore the applicability and effectiveness of co-developed tailored and effective solutions enhancing resilience, coordination, sustainability and fairness along fruit and vegetable supply chains (short, export-oriented and public procurement). The main question that we dig into relates to grasping how and what feasible and effective innovations leading to more resilient, competitive and sustainable small-scale fruit and vegetable production can be co-developed using a Living Lab approach in Mediterranean countries.

Design

In the PRIMA-funded Med-Links project, we have co-created and co-developed – with the participation of value chain stakeholders – new business models, voluntary sustainability standards and a digital platform to increase market profitability and linkage of five fruit and vegetables (small-scale) supply chain systems in the Mediterranean area. The Med-Links Living Lab approach is composed of three phases and allows to 1) validate the current innovation state of the supply chains analysed (exploration phase), 2) shape a vision of an ideal and desired future state to co-develop and test prototypical innovation pathways (experimentation phase), and 3) evaluate the potential impact of the co-developed innovation on the performance and resilience of the supply chains (evaluation phase). In Living Labs, data from knowledge-based synthesis methods is gathered through the organization of participatory activities. Living labs are composed by participants belonging to multiple functional groups of stakeholders such as industry (i.e., farmers, food processors, distributors, etc.), policy, academia, environment, and media/culture (Carayannis et al; 2012).

The Med-Links Living Lab approach consist of testing and demonstrating co-created innovations for Business Models (BM), Voluntary Sustainability Standards (VSS) and a digital platform. According to the European Network of Living Labs (ENoLL, 2022), Living Labs are defined as "open innovation ecosystems in real-life environments using iterative feedback processes throughout a lifecycle approach of an innovation to create sustainable impact". Med-Links Pilot Actions, as Living Labs, are developed through a quasi-experimental approach (Schuurman et al., 2013) which is articulated in a pre-

measurement, an intervention (i.e., the real-life experiment) and a post-measurement. Thus, Living labs are implemented throughout three building blocks, or phases of innovation development, namely: exploration, experimentation, evaluation (Evans et al., 2017).

- Exploration involves "getting to know the 'current state' and designing possible 'future states'";

- Experimentation relates to ""real-life testing" of one or more proposed 'future states'";

- Evaluation belongs to "assessing the impact of the experiment with regards to the 'current state' in order to iterate the 'future state'".

Exploration phase

In Med-Links, this phase corresponds to moving from innovation idea towards concept or prototype of the solution (i.e.: VSS, BM, and digital platform innovations) for users (i.e.: cluster members and Pilot Actions participants, farmers, processors, distributors, buyers, etc.). It is the pre-measurement step before the intervention/experimentation stage. In this step, the main goal is to understand the 'current state' and Pilot Actions in each cluster will identify the problem and fit its solution as good as possible with the problem. Through observation, participation and in-depth interviews, the focus is put on the current problems of the target users while considering the related contexts.

Building on an Open Innovation approach this phase consists of developing purposive inflows of knowledge and technology to capture and benefit from external sources of knowledge (e.g., experts, literature) to enhance current management and technological developments. The exploration phase is crucial to develop and share ideas for VSS strategies, BM optimizations, and the digital platform to the clusters needs, in order to come to concrete innovation concepts. At this stage a benchmark of the 'current state' is provided (i.e., cluster competitiveness, VSS, BM). This 'current state' ex-ante benchmark allows the ex-post measurement of potential impacts and effects of the experimentation phase in order to measure the potential effects of the innovation. As pre-measurement stage, the exploration phase provides the 'current state' in terms of competitiveness, BM optimizations and VSS strategies, and the digital platform technology use throughout the first findings (including first ideas on 'future state' that is initially discussed and tested within LL groups) as well as through the assessment of relevant indicators and project KPIs that are measurable at this stage (i.e., questionnaire in the first meeting).

Experimentation phase

After having materialized specific solutions of future state into concepts (competitiveness conditions, BM optimizations, VSS strategies, initial digital platform design) during the exploration stage, the experimentation stage in Pilot Actions puts these solutions to the test by developing and experimenting with BM, VSS, and digital platform prototypes. The testing takes place in 'real-life settings' (prototypes can be tangible or intangible services, or experience design prototypes, in general with the aim of facilitating testing of the possible 'future state'). Innovation is presented as a prototype to the users in the form of a new solution potentially triggering new habits and new contexts of use.

The main goal of the intervention/experimentation phase in Med-Links is to understand user reactions and attitudes to the proposed prototype solutions (BM, VSS, digital platform). In so doing, it is important to carry out this phase in "as-real-life-as-possible" contexts. These interventions can be considered as 'Proxy Technology Assessments' and 'User Experience Testing'. The experimentation stage simulates an envisioned 'future state' by means of an intervention. In Med-Links the designed solutions are put to the test, as much as possible in real-life context before proceeding to the evaluation stage.

Evaluation phase

"*What advantages is the 'future state' able to deliver in terms of the 'current state' of your envisioned user population?*" (Evans et al., 2017)

The evaluation stage of the Med-Links Pilot Actions consists of evaluating the innovation. Following the initial exploration stage (benchmarking the 'current state' of the end users) and the following experimentation stage (simulating a 'future state'), the final evaluation stage consists of generating a 'post-measurement' of the intervention and compare it to the 'pre-measurement' benchmark, illustrating potential impact and added-value created by the innovation.

Pilot Actions methodological approach

In a first step, data has been obtained through expert-oriented and structured surveys in the five countries with the purpose of identifying the current state regarding the three innovations the project focuses on. In Living Labs, data from knowledge-based synthesis methods is gathered through the organization of participatory activities (see Figure 1). Living labs are composed by participants belonging to multiple functional groups of stakeholders such as industry (i.e., farmers, food processors, distributors, etc.), policy, academia, environment, and media/culture (Carayannis et al; 2012). The number of participants per country can be found in table 1.

Figure 1: Med-Links Pilot Action Dynamics: Knowledge flow and Timeline

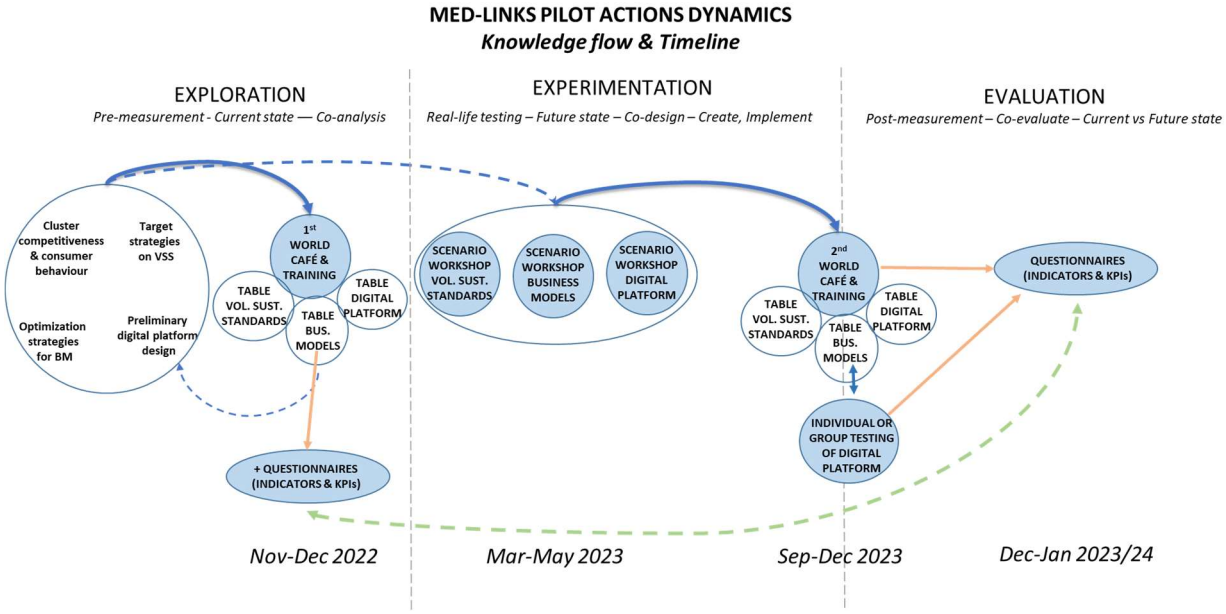

Table 1: Participation in Med-Links Living Lab participatory activities

Living Labs	1st World café participants	Scenario Workshops' participants	2nd World Café participants
Egypt	9	12	10
France	7	12	7
Greece	15	12	15
Italy	13	12	10
Morocco	12	12	10
Total	56	60	52

Findings

Optimized business models for small scale F&V supply chains were identified through integrated participatory activities and show the need of improved coordination between supply chain stakeholders – including vertical integration strategies that can reduce compliance costs, improve control over production quality and better share the value amongst stakeholders. With the aim of maximizing profits, small producers need to create strategic alliances in a variety of fields: finance, transport, distribution or production. The co-developed Business Models promote the creation of farmer associations (encouraged by local policies) to improve market-access, to increase bargaining power and to receive administrative support. To export F&V, an effective

communication strategy is necessary to build trust with consumers over product quality and traceability.

Regarding F&V voluntary sustainability standards, Living Labs have co-developed an ideal VSS featuring a carbon footprint accounting system, a functional promotion strategy, a strict verification and control system, that is coherent with each production area. The co-designed VSS involves regulatory and organizational support to simplify certification procedure, as well as initiatives for a micro fund credit in order to overcome adoption barriers and sudden yield lost. The impact of VSS on SCS depends on the SCS type. In Short Food Supply Chains, farmer-consumer relationship is already based on trust, therefore VSS is considered unnecessary. However, in other SCS, adopting VSS may be mandatory to gain access to international marketing channels or to align with local policies (public markets).

A digital tailored market linkage solution has been co-designed for producers to improve market access and to take well-informed business decisions. Several communication and coordination tools support the exchange of information of platform users. Data obtained through Living Lab participatory activities indicate that producer clusters require technical VSS training to adopt better suited production practices. To answer export-oriented producers concerns, the blockchain technology and a befitting governance have been implemented to ensure data privacy and safety. Export-Oriented farmers mainly use the platform to conduct transactions, whereas local selling producers seek training materials and networking activities.

While the solutions co-developed in living labs interactions for business models configurations, voluntary sustainability standards and digital technology, could be in general considered more as adaptation strategies rather than operational innovations within food supply chain systems, at the context specific level of the particular case studies those were defined and structured as innovative solutions. In fact, local stakeholders have identified such solutions specifically for fruit and vegetables supply chain systems that are not yet structured and are characterized by poor competitive opportunities in potential markets.

Practical Implications

In conclusion, the co-development of a set of three innovations leads to potential improvements regarding the coordination between farmers themselves and with their economic and social partners. Innovations also provides producers with effective strategies to enhance the outcomes of certification processes, and to communicate more effectively about product quality and growing practices. Support needs have been identified and are provided through a digital platform offering training materials, information sharing and financing tools.

Theoretical Implications

The knowledge flow dynamics within the Living Labs activity do not contribute only to the operational co-creation of innovations (Business models, VSS, Digital tool) but also to co-develop social learning (Knickel et al. 2023). From a theoretical perfective, the research efforts applied to the innovation co-development allowed to integrate the social learning dimensions (i.e., learning process, learning outcomes, learning impacts. Beers et al., 2016) within the three steps of the living labs dynamics (i.e., exploration, experimentation, evaluation. Evans et al., 2017). The exploration phase of the Living Lab approach has contributed to identify the current state and the desired future state with regards to the three innovations analysed, but it also let stakeholders set the base learning process and define their knowledge, roles (relations) and actions as potential solutions (learning process). In the experimentation phase of the living labs, the three innovations were tested and validated, so that learning outcomes were obtained as knowledge exchange was applied to identify potential solutions and the related roles and relations of the stakeholders involved (learning outcomes). The evaluation phase measures the impact of the innovation envisaged on the stakeholders' activity, as well as the impact of learning on the innovation capacity (learning impacts).

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Experimental design for an integrated management system of dairy farming: preliminary results (LR 5/2006 – Programmazione del Sistema Integrato dei Servizi si Sviluppo Agricolo – SISSAR, Attività di ricerca e sviluppo)

Emanuele Bianco[a], Emilio Simonetti[a], Stefano Bovolenta[b], Valentina Cecchini[b], Nadia Innocente[b], Elisa Lanza[b], Carolina Pugliese[c], Chiara Aquilani[c], Andrea Confessore[c], Simona Rainis[a].*

[a]Agenzia regionale per lo sviluppo rurale Ersa, Via del Montesanto 17, 34170 Gorizia (Italy); emanuele.bianco@ersa.fvg.it; emilio.simonetti@ersa.fvg.it; simona.rainis@ersa.fvg.it.

[b]Università degli Studi di Udine, Dipartimento di Scienze Agroalimentari, Ambientali e Animali, via delle Scienze 206, 33100 Udine (Italy); stefano.bovolenta@uniud.it; valentina.cecchini@uniud.it; nadia.innocente@uniud.it; elisa.lanza@uniud.it.

[c]Università degli Studi di Firenze, Dipartimento Scienze e Tecnologie Agrarie, Alimentari, Ambientali e Forestali, Piazzale delle Cascine 18, 50144 Firenze (Italy); carolina.pugliese@unifi.it; chiara.aquilani@unifi.it; andrea.confessore@unifi.it.

*Corresponding author: simona.rainis@ersa.fvg.it.

Abstract:
Intensification and standardization of farming systems have contributed to the progressive banalization of dairy products and to the loss of ability to generate ecosystem services. But new market trend shows an increasingly interest towards the typicity and identity of products. This justifies a change in the overall competitive strategy for the dairy sector, enhancing the choices maded upstream, as those linked to production area, fodder component of animals' diet, type of species/breeds raised and cheese making techniques. Recently, several tools of "precision animal husbandry" have been developed. Preliminary results of a triennial experimental design for an integrated management system of dairy farming are hereby presented. The project is articulated as follows:

- application of “Virtual Fencing” (GPS technologies collars) and “Precision Livestock Farming”;
- analysis of the management systems of mini-dairies farms;
- study of the dairy productive path of these farms.

Encouraging data confirm the possibility to introduce virtual fences also in the alpine reality. A first and updated picture of the situation of the dairy farms in Friuli Venezia

Giulia was draft in order to formulate detail instructions and best practices guidelines for supporting regional dairy companies with a short supply chain.
Keywords: Virtual Fencing; Precision Animal Husbandry; Herd Management; Alpine Dairy Farm; Dairy Productive Path; Sustainable Agriculture.

Purpose

The intensification and standardization of farming systems, as well as the industrialization of transformation phase, have contributed to the progressive banalization of dairy products (poor "intrinsic" quality) and to the loss of ability to generate ecosystem services for the entire society (poor “extrinsic” quality) (Bovolenta et al., 2019). Therefore, it seems appropriate to enhance the choices maded upstream of the dairy production chain, such as those linked to the production area, the component fodder of animals' diet, the choice of species/breeds raised and the cheese making techniques (Berton et al., 2021; Ramanzin et al., 2021). In recent years, the developed tools of "precision animal husbandry", adopted in the stable, to optimize the use of resources and enhance the productive and reproductive performance of animals, have been also proposed for pasture environment. They allow to identify and locate animals, evaluate the characteristics of foods, study eating behavior, check animal health status and body condition, evaluate milk quality, etc. (Berckmans et al., 2017; Golinski et al., 2023; Lee et al., 2018). At the same time, a market that increasingly pays attention to the typicality and identity of products (such as origin, welfare and health of farmed animals, environmental issues, etc.) justifies a change in the overall competitive strategy for the dairy sector. It is important, then, to improve information regarding the virtuous choices of producers, because customers research these “extrinsic features” of quality, in parallel with the value generated by the objective attributes such as nutritional, organoleptic or dietary characteristics (Rainis, 2021). With this logical scheme and objectives, an experimental design for an integrated management system of dairy farming was proposed. The aim is to elaborate best practices for supporting regional dairy companies characterised by short supply chain. These farms, in fact, need to be accompanied for introducing new business approaches, compatible with environmental sustainability, circularity in the use of resources, animal welfare and production valorisation, in order to face new scenarios with efficient tools (Michalk et al., 2019; Rainis, 2022).

Design and data collection

In the framework of the SISSAR program (Integrated System of Agricultural and Rural Development Services), funded by the Autonomous Regione of Friuli-Venezia Giulia, the Regional agency for the rural development - Ersa, together with University of Udine and Firenze is working on a 3 years project, articulated as follows:

(1) application of “Virtual Fencing” (GPS technologies collars) and “Precision Livestock Farming” to livestock farms;
(2) analysis of the management systems of regional mini-dairies and alpine farms;

(3) study of transformation and production systems along the mini dairies and alpine farms.

The “Precision Livestock Farming” is based on innovative and automated activity management strategies. This allows, in addition to an improvement in operating conditions for the breeder, also to collect, process and analyse productive and reproductive data, with the aim to integrate them with other information. In this way, it is possible to guide managerial and technical decisions, based on spatial and temporal variability, in order to improve resource efficiency, productivity, quality, profitability and sustainability of agricultural production. Furthermore, these technological devices are employed for monitoring animals’ health status, body condition and reproductive cycles (Michalk et al., 2019; Stevens et al., 2021). The application of the virtual fences that falls within this type of new approach enables to remotely trace boundaries, without the need to install expensive physical fences. Virtual Fencing works through collars worn by animals and they are equipped with a GPS system to communicate with a Smartphone application by GSM connection. The mobile application allows the farmer to determine the location and perimeter of the virtual fences, as well as to monitor the livestock. Specifically, the animals are kept in the designated area through dissuasive audio signals of increasing intensity; successively, if the animals does not turn and head towards the inside of the enclosure, the collar release up three electric pulses (Confessore et al., 2022). The first action of the project has the aim to test, for the first time with dairy cows in the alpine arc, the employment of the virtual fencing, in two different moments and locations, in order to evaluate the applicability in the alpine context (Fig. 1). In the first farm, animals were trained between late May and early June, during the preparing feed transition phase for the transhumance and then, in October, to observe the ability to retain and memorize the learned information. In the second farm, the cows were managed throughout the virtual fencing during all the grazing period in the mountain pastures. Samples of hair for the quantification of cortisol, a stress related index, were kept from the cows tested in action 1. This sampling can provide useful information regarding reaction of animals managed with virtual fencing technology.

Contextually, agronomic evaluations have been conducted to determine the surfaces’ size and botanical composition and to estimate biomass production of the pasture. The surveys carried out are being processed in order to calibrate a simplified model for estimating pasture biomass that integrates the information on the vegetation characteristics collected, using remote sensing resources (Sentinel 2), with the forage use behavior of the available fodder resource by the monitored animals. This highly innovative system will allow rational pasture management to be adapted to the geography of the territory and to the business needs of the farms, as well as to the type and seasonal variations in productivity of the nutritional resource. The calibration of the breeding technique to actual fodder production is functional to the sustainable management of the company, also from the point of view of environmental protection and the improvement of animal welfare (Greenwood et al., 2021; Lawrence et al., 2019). The tests will be repeated starting from May 2024.

The other two activities are oriented to collect data and information, to develop a useful data collection protocol and a method capable of determining the overall sustainability of livestock breeding systems. The information will be the basis for develop guidelines, useful to accompany the farmers towards the challenges that arise from the ecological transition (Guyomard et al., 2021; Distel et al., 2020).
Seven farms, both bovine and goat, representative of the various productive scenarios of Friuli Venezia Giulia, were identify. Benefits, costs and consequences, regarding the adoption of innovative management and monitoring tools and methods, were taken into consideration (Fig. 2 and 3). The target of this activity will be achieved in the 3 year period, is to assess environmental sustainability of the production activity with a "Life Cycle Assessment" approach, considering also the co-products and the value of the ecosystem services provided by livestock breeding systems. The targed will be achieved even through the use of AgriCS AZ model, a web calculation platform of environmental impact indicators useful to guide the farmers' choices regarding the organization of breeding system, developed by Ersa inside the RDP 2014-20 (Rural Development Program). An advantage of the AgriCS platform is the possibility of development and implementation, for this reason the results that it returns have an experimental connotation and are being validated.
In parallel, for the third action, the analysis of the state of the art of livestock farms that produce and transform milk from a short supply chain perspective at regional level were performed. Subsequently, the transformation and maturing methods in the companies of action 2 had been specifically studied, both in the mountain huts and in downstream context, with a specific survey of the main technical parameters relating to boiler processing and storage and refinement (Fig. 4 and 5).
In order to valorise the dairy productions, from the sensory and nutritional point of view, the determination of the aromatic and fatty acids composition and analytical sensory panels were carried out on the cheese under investigation, obtained during the productive processes.

Fig. 1: bovine with virtual fencing collar.

Fig. 2: lowland stable.

Fig. 3: goat breeding.

Fig. 4: product samples for sensory analyses and technological evaluations.

Fig. 5: dairy production warehouse.

Findings

The first of the three years of activities foreseen by the project focused on the application of the virtual fencing for the management of grazing animals. The first results obtained confirmed the possibility to introduce virtual fences also in the alpine context. The tested animals demonstrated a quick adaptation to this new technology; furthermore, they also showed a good level of retention of the training period. The virtual fences allowed to manage the rotation of grazing parcels in a rational and coordinated manner. In this way, the herd was moved remotely, depending on the forage availability of the meadows and the nutritional needs of the animals. The agronomic and botanical surveys allowed to map the floristic composition and food availability of the considered lands.

Thanks to the action 2 and 3, a first and updated picture of the situation of the dairy farms is available. The information was collected throughout visits of the technicians in site and *via* specific questionnaires focussed on issues concerning farm organisation, supply of feedings and row materials, relationship with other ecosystem components, welfare of reared animals and social aspects concerning zootechnical activity. Information collected will allow an evaluation of the choices made and the current management modality of the farms. More than 350 record for every farm has been collected. A data processing method able to take into account the global sustainability of the zootechnical production unit is being developed. As regards the aspects of dairy production, in the specific, the main parameters had been recorded, both along the boiler phase, both during the conservation and maturation of the product in the storage rooms.

The sensorial evaluation of the products, whose processing had been followed in the experimental phase, also made possible to characterize these cheeses from an organoleptic point of view, relating the pasture-based dairy systems to milk and its derivatives product quality (Stanton et al., 2018; Joubran et al., 2021). A team of expert tasters is being formed who will be able to provide support in enhancing the typical nature of regional mountain pasture products.

Practical and Theoretical Implications

The opportunity of using Virtual Fencing collars in the Alpine context, as the project is confirming, certainly has very interesting operational implications. First of all, these new technologies promise to be very useful for reducing the workload in geographically and orographically challenging areas. Taking into account the use of these precision agriculture tools, they facilitate sustainability in pasture management, calibrating carefully the livestock load and ensuring an environmentally friendly exploitation of resources, thanks to the integration of GPS data and the information provided by satellites (Horn and Isselstein, 2022).

The monitoring phase in the companies is also scheduled for the following grazing season, to have further feedback on the critical points identified in the farms and in their productive activities. As the project continues, the evidence that emerges will be returned in the form of easy-to-consult indications for setting the necessary corrective actions to the companies involved, becoming at the same time good practices for the

local livestock context. These guidelines will be disseminated during specific training sessions planned for operators in the sector.
Based on the present findings and the studies, it will be possible to set up a type of product promotion, which focuses on the recognisability of the peculiarities of the productions linked to the territory and the consequent virtuous ecosystem impacts implicated. With this perspective, it will also be possible to increase the operators' income (Rainis et al., 2022).
Furthermore, the aim of the study is also to give important indication to the planning and programming Bodies for the territorial governance and management assistance related to the dairy sector.

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Cultivation of four cultivars of *Panicum miliaceum* L. of different origins, for agronomic evaluation, adaptation to Mediterranean climatic conditions and determination of production.

N. Trotta[1], P.P. Adinolfi[1], M. Mele[1], D. Zito[1], M. Giannatiempo[1], L. Barra[1], E. L. Frusciante[1], E. De Falco[2]*

*nikita.trotta@crea.gov.it

[1] Council for Agricultural Research and Economics – Research Centre "Plant Protection and Certification", S.S. 18, n.242, - 84091 Battipaglia (SA), Italy

[2] University of Salerno - Department of Pharmacy, Via Giovanni Paolo II n.132, Fisciano (SA), Italy

Abstract:

The aim of this work was the agronomic evaluation of the following four millet *(Panicum miliaceum* L.) crops obtained using the cultivars "Horizon" and "Rumenka", millet from the "Sativa Company", an ecotype selected at Ivan Bruno farm (Sala Consilina, SA). From now on read "cultivar". The experimental trial was carried out in Battipaglia (Italy) during 2023 on a clay loam soil. The cultural precession was faba bean. No fertilizer was administered during the production cycle. The cultivars showed a very short life cycle included between 46 and 68 days and did not require phytosanitary treatments, with a low water demanding. Horizon was the most productive for the grain yield (1.7 t/ha), while Sativa was the least productive (0.9 t/ha). Weren't found statistically significant differences among the varieties for the "specific weight of the caryopses" (average value 66.5 kg/hl; SD 2.90 kg/hl; CV 4.4%). Sativa millet was the most productive for the fresh and dry biomass of the aerial portion: 23.8 t/ha and 11.9 t/ha respectively. The least productive was Horizon with fresh biomass of 7.5 t/ha and dry biomass of 4.2 t/ha. Regarding the qualitative composition of the caryopses, Sativa millet and I. Bruno were found poor in sodium but rich in fibres, vice versa cultivars "Rumenka" and "Horizon" were more caloric, richer of fibres and poorer in sodium. Differences in sugars, total fats and proteins between the considered cultivars were not found.

Keywords: millet, agronomic, nutritional characterization

Purpose

One of the most economically important plants in prehistory was broomcorn millet (*Panicum miliaceum* L. of the Poaceae family), a cereal of the same grass subfamily as maize, sorghum and foxtail millet. Since 2011, millet is growing as an economic plant mainly cultivated in Eastern and Central Asia, Africa, America and Eastern Europe (Russia and Ukraine) and North America [1]. FAOSTAT's data 2021 shows that Asia and Africa still maintain first and second position with a Gross Production Value of 4,285,120 and

3,045,637 thousand US$ respectively. While the Gross Production Value of America increased from 52,980 in 2011 to 137,312 in 2021, at the same time in Europe decreased from 2011 to 2021 of 103,708 thousand US$ (https://www.fao.org/faostat/en/).
Although it is used especially for animal feeding, it also plays an important role in human nutrition also because it does not contain gluten [2]. It is mostly consumed as porridge or placed in meat stews, or roasted grains are eaten with milk.
The aim of this work was to evaluate the agronomic characteristics and yield of four millet crops of different origins, in an area of Southern Italy, where the millet is rarely cultivated. In this paper was studied adaptability of millet to the pedoclimatic conditions and its production ability. Finally, the qualitative nutritional characteristics evaluation will permit us to choose the cultivar more suitable for human nutrition.
The experimental trial was carried out in Battipaglia, in South Italy, 40°57'16"/44°98'60", 72.0 m elevation on a clay loam soil with pH 7.4 and the following content of main nutrients: soil organic matter (3.40 g/kg), total nitrogen (0.40 g/kg), phosphorus (125mg/kg), potassium (0.58 meq/100g), sodium (0.21 meq/100g). The climate classification is Csa (Hot-summer Mediterranean climate) according to Köppen and Geiger (annual mean air temperature 16.1°C, annual sum of precipitation 1,128 mm). The driest month is July with 19 mm of precipitation. August is the hottest month of the year with an average temperature of 25.2 °C.

Design

The seeds of *Panicum miliaceum* L. used for the experimental trial were the cultivars "Horizon" and "Rumenka", millet reproduced from the "Sativa Company", and ecotype selected at Ivan Bruno farm (Sala Consilina, SA). The seeds were recovered by the University of Salerno.
The samples were sown on July 7, 2023, in plots with length of 7.00 m and width of 1.2 m. For each plot six continuous rows 20.0 cm apart were sown. Field bean green manure was cultivated on the entire plot before sowing the millet. The experimental field included three replicates of each sample randomly arranged throughout it [3]. It was surrounded by border plots with other varieties of millet, covered with anti-hail sheets to protect the crop from bird attacks. Furthermore, the paths between the plots were mulched with straw (Fig. 1).

Figure 1. Agronomic experimental trial of *Panicum miliaceum* L. Photos by M. Giannatiempo

Irrigation interventions were done only during the first month of growth. Manual weeding was carried out in the plots in the early stages of growth. No phytosanitary and nutritional treatments were carried out. The harvesting was carried out in manual matter at different times depending on the achievement of vitreous maturation of the caryopses.
During the entire growth period the average minimum temperature was 20.9°C, while the average maximum temperature was 31.2°C, no rainfall was recorded.

Methodology

From each plot were picked up ten panicles in double replication. The traits: panicle length (cm), in according to Test Guidelines UPOV Ad13 [4], panicle weight (g), weight of seeds of 10 panicles per plot (g) and weight of 1000 seeds were detected.
The following agronomic data were detected: seed yield (t/ha), weight of 1.000 seeds (g), seed specific weight (kg/hl) [5], caryopses moisture (%), fresh and dry biomass of aerial portion (t/ha).
To evaluate the nutritional composition samples of the seeds were delivered to private Analysis Laboratory and were analyzed for the following characteristics: energy value (Kcal/100g), proteins (g/100g), total fats (g/100g) and satured fat (%), carbohydrates (g/100g), fibres (g/100g), sugars (g/100g) and sodium (g/100g).

Approach

Descriptive statistics (including mean, median, minimum value, maximum value and standard deviation) were determined using R, a free software environment for statistical computing and graphics by “The R Foundation “. We used the package “agricolae” [6]. Standard deviation and Coefficient of variation % were estimated as the indicators of variability. Execution of analysis of variance (ANOVA) was performed for all quantitative

traits detected and the significant differences among groups were determined by post-hoc test (LSD test with alpha=0.01) [7].

Findings

Cycle duration:

The number of days from sowing to harvesting was different between the cultivars as reported below: very early (46 days) for “Sativa”, medium (52 days) for “I. Bruno”, late (61 days) for “Rumenka” and very late (68 days) for “Horizon”.

Panicle quality:

Table 1 shows the average values +/- standard deviation of the panicle quality results characteristics for each cultivar and their statistically significant differences.

Table 1. Average value of panicles characteristics and their statistical differences

Cultivar	Panicle length (cm) LSD=4.08 cm	Panicle weight (g) LSD=19.21 g	seed weight per panicle (g) LSD=14.76 g	1000 seeds weight (g) LSD= 1.07 g
Sativa	40.33±2.41 a	40.74±9.16 c	12.22±5.21 c	3.91±0.25 c
I. Bruno Farm	38.40±2.70 a	38.83±3.19 c	25.53±2.68 bc	7.30±0.37 a
Rumenka	31.02±1.41 b	96.25±10.95 a	42.33±9.01 a	5.97±0.52 b
Horizon	27.20±2.48 b	64.17±16.33 b	30.35±15.01 ab	6.27±0.94 ab

The different letters (a-b-c) in the column represent the statistically significant differences among culltivars p<0.01.

Agronomic quality:

Table 2 shows the average values +/- standard deviation of the seed quality results characteristics for each cultivar and their statistically significant differences.

Table 2. Average values of the agronomic traits and their statistically significant differences

Cultivars	Total fresh biomass (t ha-1) LSD = 2.72	seeds weight (t ha-1) LSD = 0.50	grain moisture (%) LSD = 0.13	1000 seeds weight (g) LSD = 1.81
Sativa	23.82 ± 0.70 a	0.9 ± 0.1 b	8.73 ± 0.12 bc	3.91 ± 0.25 b
I. Bruno Farm	10.44 ± 0.15 b	1.3 ± 0.1 ab	8.67 ± 0.06 c	7.20 ± 0.14 a
Rumenka	11.87 ± 1.87 b	1.1 ± 0.1 b	9.07 ± 0.06 a	5.83 ± 0.41 a
Horizon	11.27 ± 0.20 b	1.7 ± 0.1 a	8.87 ± 0.06 b	6.45 ± 1.17 a

The different letters (a-b-c) in the column represent the statistically significant differences among cultivars p<0.01.

Similar results for the fresh biomass were found for the production of dried biomass. Opposite results were recorded for seeds production per hectare. The weight of 1000

seeds was higher for I. Bruno Farm, although without significant differences compared to the cultivars Rumenka and Horizon.
Finally, no significantly different differences were recorded for the “specific weight of the caryopses” (average value 66.48 kg/hl; standard deviation 2.90 kg/hl; cv=4.36%).

Nutritional value:
Table 3 shows the nutritional values for 100g of seeds.
Sativa and I. Bruno cultivars were found poor in sodium but rich in fibres, vice versa Rumenka and Horizon were more caloric. Differences in satured fats and proteins between the considered cultivars were not found.

Table 3. Nutritional Elements for 100 grams of the seeds

Cultivars	En. value (kcal)	Proteins (g)	Fats		Carbohydrates (g)	Fibres (g)	Sugars (g)	Sodium (g)
			Total (g)	Satured (g)				
Sativa	321	6.94	3.37	0.37	62.80	17.65	0.90	0.002
I. Bruno Farm	339	8.19	3.40	0.38	70.20	11.01	0.90	0.002
Rumenka	346	7.25	3.67	0.36	73.70	6.72	0.90	0.005
Horizon	341	8.19	3.41	0.34	72.00	8.57	0.90	0.004

Font: Neotes Laboratory

Practical Implications

The results confirmed that millet has a very short cycle (2-3 months) and does not require phytosanitary and nutritional treatments. The qualitative analysis evidenced highlighted a balanced composition for human nutrition strengthened by the lack of gluten.
Moreover, the shortness of the cycle and the total biomass production for some cultivars could include this species as a green manure in agroecological cropping systems. The results allow us to positively evaluate the inclusion of millet in the cultivation systems of the Mediterranean area for the production of feed for livestock, for human consumption and agronomic practices [8].

Theoretical Implications

It is necessary to deepen the study of millet, because it possesses valid agronomic-nutritional traits and it has a good ability to adapt to the cultivation systems of the Mediterranean area. Millet can play an important role in global food security in the changing climate because water shortage is a significant threat to agriculture for the future [9].
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