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METROPOLITAN TERROIR

Shaping Alternative Agri-food System Scenarios through Strategic Foresight

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Abstract

The following thesis analyses the agri-food sector, from production to consumption, through the integration of two complementary methodologies: systemic design and strategic foresight from the Copenhagen Institute for Futures Studies. In the first phase, the Foresight methodology will be used to identify trends and drivers that highlight the main changes taking place, while systemic design will be used to relate them in order to understand the interconnections between the various factors and obtain an overview of the entire agri-food system. Once the context has been outlined and the most relevant factors of change identified, the work will focus on developing alternative and plausible scenarios concerning the foods of the future and the evolution of the agri-food sector in the coming years. These scenarios are intended as a critical tool to question the evolution of a system that impacts every human being. By materialising these visions through tangible elements, the research seeks to move beyond abstract speculation, prompting deep reflection on the potential trajectories of this essential sector in the coming years.

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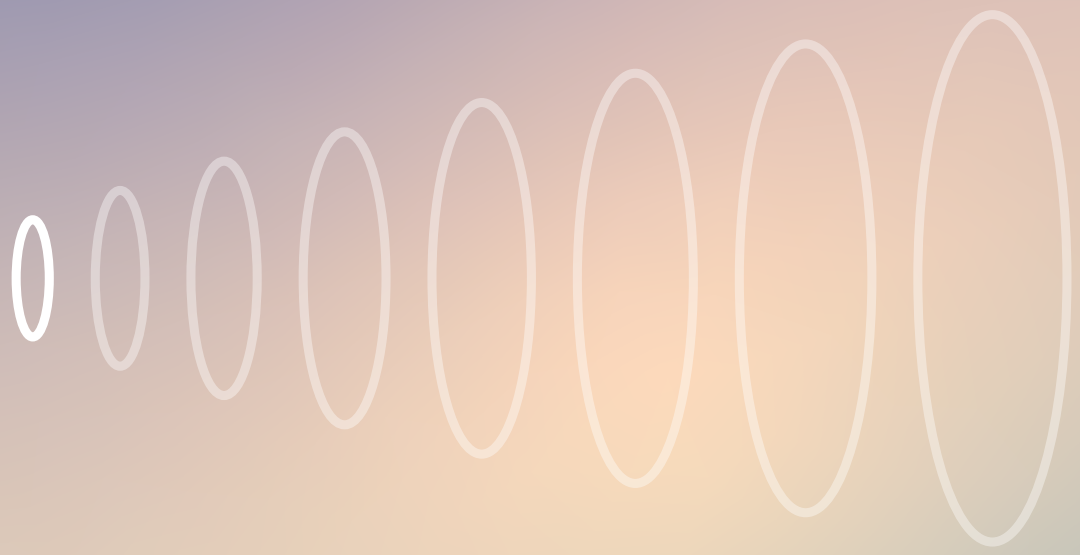
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01

Design Process

Design Process

The Design Process developed in this thesis is based on the integration of two complementary methodologies: **Systemic Design** ***(Fig. 1.1)*** from the Politecnico di Torino and **Strategic Foresight** from the **Copenhagen Institute for Futures Studies (CIFS)** ***(Fig. 1.2)***. The latter is an independent, non-profit think tank established in 1969, specialising in the analysis of trends and future scenarios to support strategic decision-making processes at an international level. Specifically, the **Systemic Thinking** was fundamental in analysing the topic (agri-food sector) in depth and holistically. Rather than a rigid sequence of tools, this approach provided the key to understanding the relationships and mutual influences between the various factors analysed, avoiding a fragmented view of the whole system. At the same time, the CIFS methodology guided the actual foresight activity. Starting from an analysis of the most influential factors characterising the sector today, it was possible to project these dynamics forward to understand how they will shape the agri-food system in the future.

Strategic Foresight
A discipline that involves systematically anticipating and preparing for future challenges and opportunities in ways that expand conventional strategic thinking in the face of change. It typically deals with the medium to long-term future (beyond the current strategic planning horizon) with the overarching goal of enhancing awareness of change and considering alternative futures in ways that generate valuable insights for better strategic anticipation. (CIFS, Toolkit for Applied Strategic Foresight)

Systemic Thinking
Systems thinking is a discipline for seeing wholes. It is a framework for seeing interrelationships rather than things, for seeing patterns of change rather than static snapshots. (Peter Senge, 1990)

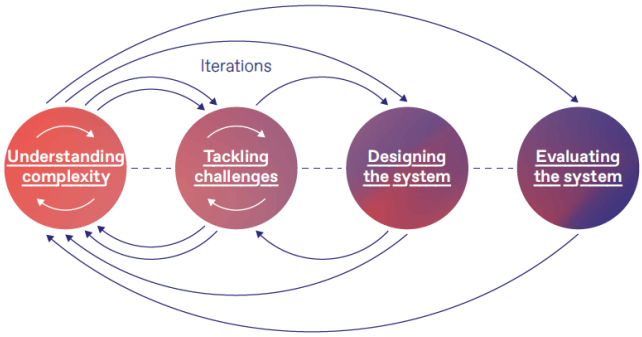


Fig. 1.1 Systemic Design methodology, Politecnico di Torino.

COPENHAGEN INSTITUTE FOR FUTURES STUDIES

Fig. 1.2 Copenhagen Istitute for Future Studies.

1.1 Stages of the Process

Megatrend
Megatrends are long-term transformative forces that profoundly shape the future landscape and tend to stay their course even in turbulent times. They represent the closest element to relative certainty we have, serving as global points of orientation that, while universal in scope, manifest with varying impacts at the local level. (CIFS, Toolkit for Applied Strategic Foresight)

Driver of change
Drivers of change are the fundamental and dynamic forces that cause change by shaping trends and modulating their potential impact. Since these elements exert a direct influence on the system, the boundary between them and trends often blurs as a trend itself can act as a driver for other developments making any rigid distinction between the two practically irrelevant. (CIFS, Toolkit for Applied Strategic Foresight)

Trend
A trend is defined as an observable and measurable directional shift in a situation or in human behavior that, whether supported by data or simply perceived, operates as an interconnected and interdependent force. They often blend into each other, making them difficult to separate. There is no guarantee that a trend observed in the past will continue in the future, and often, counter-trends emerge in response or opposition to the dominant trend. (CIFS, Toolkit for Applied Strategic Foresight)

Weak signal
Weak signals are subtle and often early indicators of emerging trends or disruptions that are not yet widely recognised or understood. Originating from the fringes, they may initially appear insignificant or disconnected from mainstream developments, yet they have the potential to significantly impact the future even though they may completely fade away before manifesting into a driving force. In this sense, weak signals can be thought of as 'pockets of the future' already embedded in the present. (CIFS, Toolkit for Applied Strategic Foresight)

The Project Workflow ***(Fig. 1.3)*** was articulated across **six distinct phases** comprising Research, Analysis, Envisioning, Strategy, Design, and Impact. These were approached not as a linear journey but through an **iterative and flexible flow**, characterised by constant steps back and forth to incorporate each new discovery and refine the results. Each phase was defined by the application of **specific concepts** and **tools** drawn from the two methodologies used, **Systemic Design** and **Strategic Foresight**, seeking to bring them into dialogue with one another. This was particularly vital during the initial research into the agri-food system, allowing for the establishment of connections between various factors to gain a **holistic overview** of the entire sector.

RESEARCH

The Research phase served to **identify the factors driving the current and future development of the agri-food sector**, taking into account both the dynamics within the system and the external forces influencing it. Following the methodology of strategic forecasting, these elements were classified into **megatrends**, **drivers of change**, **trends** and **weak signals**, based on their trajectory and the extent of their impact on the system. This phase combined **in-depth desk research** with a series of **semi-structured interviews** with experts in the agri-food sector, aimed at adding authority and value to the results. Throughout this process, forecasting tools for mapping trends and the context were integrated with a systemic approach to understand the intricate interactions between the various factors, ultimately treating the sector as an **interdependent system** of connections between various elements.

ANALYSIS

The Analysis phase brings together the assumptions and insights gained during the research to examine them analytically, **assessing their actual strategic relevance** for the future of the agri-food system. At this stage of the process, the use of a **matrix** allows us to cross-reference the **potential impact** of each factor with its **level of uncertainty,** thereby assigning values that enable us to **classify and prioritise the elements** according to their importance. The aim is to identify the drivers capable of triggering the most significant dyna-

mics of change within the system, **isolating the key factors** upon which to build possible futures. This analysis is therefore crucial for the subsequent Envisioning phase, as the construction of alternative scenarios will start precisely from the most relevant elements that have emerged from this assessment.

ENVISIONING

The Envisioning phase builds on the **key forces for change** identified during the analysis to **develop alternative future scenarios** through various combinations of these factors. This is a highly **creative phase** in which the knowledge gained is put into practice to imagine divergent but plausible scenarios, constructed on the basis of what has been analysed and understood about the system. The work initially involves the technical construction of the scenarios, followed by a **storytelling** part necessary to **enrich the narrative of the hypothetical worlds**, and concludes with a **classification of these futures** based on their plausibility and the desirability of them actually occurring. At the end of this process, one of the developed scenarios is selected, which will become the fundamental basis for the subsequent strategic and design phases.

STRATEGY

The Strategy phase serves to **establish a strategic path** over time to achieve the final features identified in the reference scenario. This work was carried out using the **backcasting method**, which allows us to work backwards, starting from the **key features** of the reference scenario to **identify the steps and strategies** required to achieve those specific targets. The roadmap was constructed on two parallel but distinct levels: the first concerns the **uncontrollable contextual dynamics** that must occur for the scenario to materialise, which are based on **projections of current real factors** identified in the previous phases; while the second focuses on **more controllable strategies**, hypothesising the **actions a company should undertake** to facilitate the development of that scenario and actively build its distinctive features.

DESIGN

The Design phase constitutes the actual design process, where all the research work and foresight tools applied so far are turned into something tangible. The main objective is to **visualise the future**

scenario, making it more real through the creation of specific **"artifacts of the future"**, i.e. physical or digital elements that serve to support the narrative and understanding of the hypothetical world. In this phase, design thus becomes the fundamental means of translating the complexity of the research into objects or experiences capable of **stimulating deep reflection**, allowing people to perceive clearly and immediately the dynamics of the developed scenario and the possible evolutions of the imagined system.

IMPACT

The final phase of Impact represents the stage at which we seek to map and **envision the effects generated by the new model** within the agri-food system, classifying them according to their **significance** and the **scale** of the change they may trigger. This analysis is not merely a final assessment, but forms part of the **critical reflection** that has accompanied the entire project from the outset, with the aim of understanding how the proposal might actually alter the **sector's balance**. Maintaining the analytical approach that has characterised the entire project, this stage seeks to predict how the **system might evolve**, assessing how the new model introduced into the scenario might transform existing dynamics for the better or for the worse. This is a final mapping exercise necessary to provide an **overview of the intervention**, seeking to highlight not only the **benefits** but also the **new challenges** that this evolution of the system brings with it for the future.

Approach:

SYSTEMIC APPROACH

Methodology:

STRATEGIC FORESIGHT

SYSTEMIC DESIGN

Process:

RESEARCH

Awareness of the Context

Tools:

Scanning

Identification and analysis of:

- 10 **Megatrends**
- 7 **Drivers**
- 11 **Trends**
- 2 **Weak Signals**

Understanding Complexity

Tools:

Systemic Frameworks

Elaboration of 30 **Systemic Frameworks** to map the interconnections and impacts of every scanned factor

Tackling Challenges

Tools:

Systemic Frameworks

Identification from every framework analysed of:

- 32 **Challenges**
- 19 **Opportunities**
- 51+ **Case Studies**

Expert Consultation

Tools:

Semi-Structured Interviews

Expert consultation for qualitative validation:

- 7 **Experts contacted** across diverse fields of expertise to ensure a multidisciplinary perspective.
- 3 **Semi-Structured Interviews** conducted to refine and validate the research assumptions.

ANAL

Dynamics c

Tools:

Impac Uncer Matrix

Classification c analysed facto

- 15 **High Im Drivers**
- 8 **Critical Uncertaint**
- 1 **Seconda**

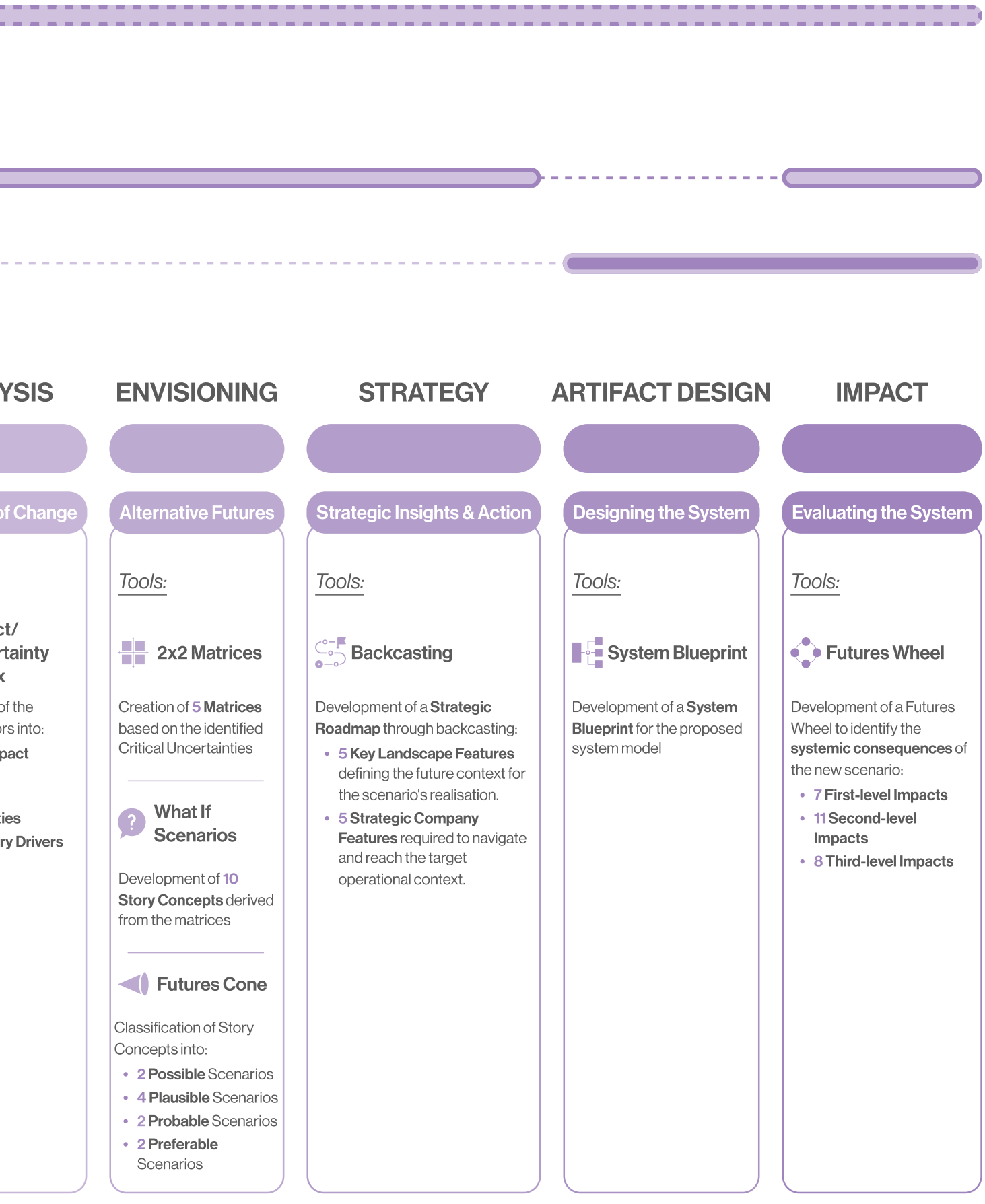
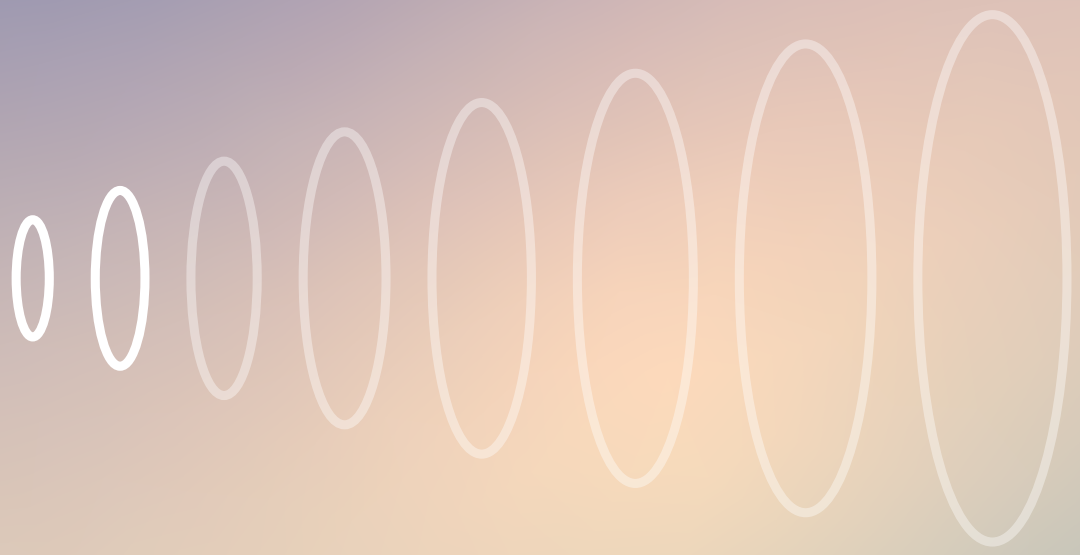


Fig. 1.3 Project Workflow.



02

Agrifood System

Agrifood System

To understand the true scale of agri-food systems, it is sufficient to observe their importance in the global economy. Global agri-food systems constitute a gigantic global enterprise that produces approximately **11 billion tonnes of food each year**. With an estimated gross production value of **3.5 trillion of dollars**, the primary sector provides about **a quarter of total global employment**, with a share of nearly 60% in **low-income countries** (FAO, 2021a). Furthermore, as highlighted in the introduction, the agri-food sector is a complex system, characterised by a supply chain divided into **multiple stages** and process steps.

The agri-food system covers the entire food chain (e.g. cereals, vegetables, fish, fruit and livestock products) from farm to fork, including when it is grown, harvested, processed, packaged, transported, distributed, marketed, purchased, prepared, consumed and disposed of (FAO, 2021b).

These procedures vary considerably **depending on the specific raw material**; consider, for example, the clear difference between the operations required for the production and processing of meat and those for the management of a fruit and vegetable product such as an apple. Despite this variability, it is possible to identify a **logical sequence of value creation**. Generally, each agri-food product goes through **four main sequential stages**, supplemented by an additional cross-cutting stage that occurs in parallel with each stage of the process.

2.1 Agri-food system and Food system

Agri-food systems embrace all interconnected **actors and activities that generate value throughout the entire product life cycle**, from primary production to distribution, consumption and final disposal. The **food system**, understood as the specific subset dedicated to **products for human nutrition**, is located within this framework ***(Fig. 2.1)***. This operational core integrates traditional agricultural resources, such as crops, livestock and fisheries, together with non-agricultural flows such as those derived from synthetic biology. The functioning of the system is based on constant exchanges with

external supply chains. In fact, the sector absorbs fundamental technical inputs, such as fertilisers and machinery, while at the same time supplying intermediate raw materials to non-food industries, as is the case with maize for biofuels or cotton for the textile sector. This flow architecture is constantly shaped by economic, social and natural pressures that influence its dynamics and production patterns.

Agri-food system and Food system conceptual framework

Source: FAO, The state of food and agriculture 2021

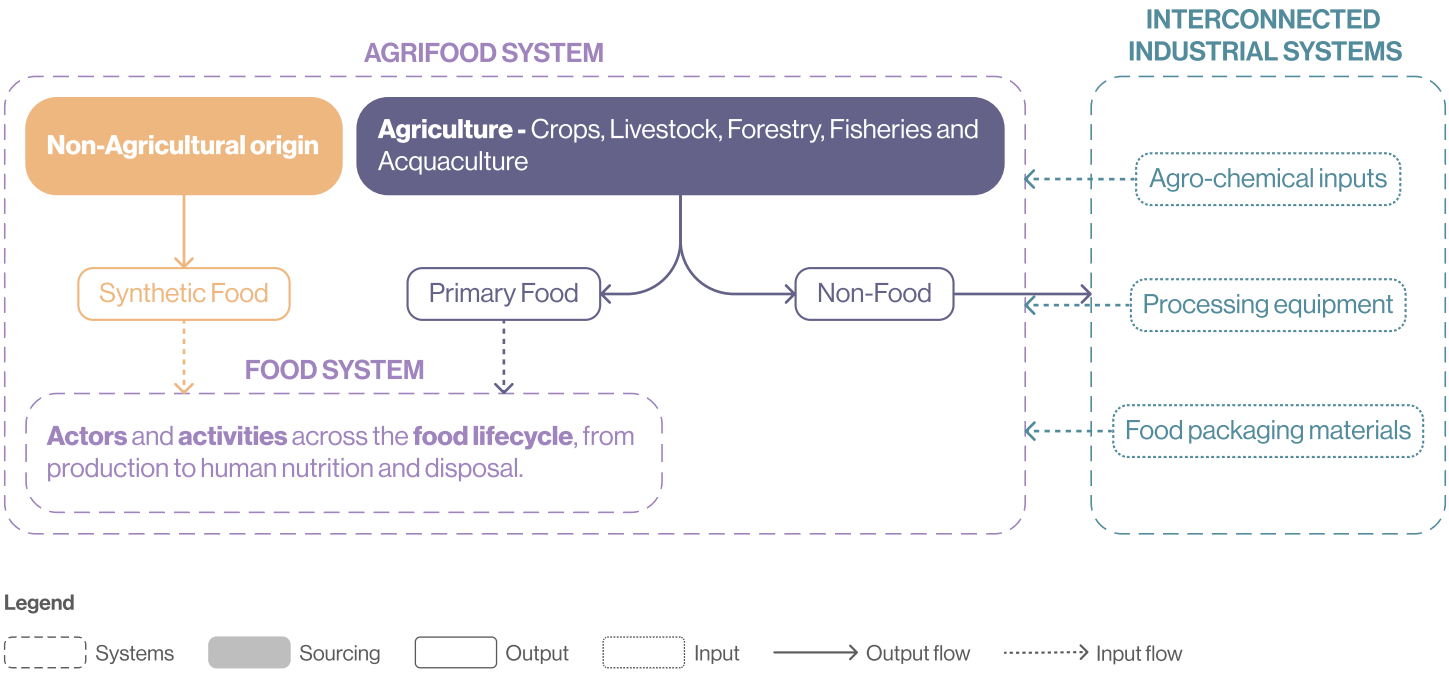


Fig. 2.1 Agrifood system and Food system conceptual framework.

2.2 Stages of the Agri-food value chain

The **four main stages** ***(Fig. 2.2)*** that define the product's journey are:

1. ***PRIMARY PRODUCTION:*** the activity of origin, which includes agriculture and livestock farming, where raw materials are grown or generated.

2. ***FOOD PRODUCTION AND PROCESSING:*** the industrial stage in which raw materials are processed, transformed, preserved and packaged into finished or semi-finished products.

3. ***DISTRIBUTION:*** the logistical stage that deals with the transport, storage and handling of processed products to points of sale or catering establishments.

4. ***CONSUMPTION:*** the final stage, which includes the purchase and use of the product by the end consumer.

The "5th Phase": Food loss and waste management

The value creation sequence is overlaid by the crucial phase of food loss and waste management, a strategic pillar for the sustainability and economic efficiency of the entire system. This stage is **cross-cutting** because it is present and has an impact on each of the four previous stages, as each of them produces waste and losses in its own way:

- *WASTE IN PRIMARY PRODUCTION:* unharvested or unmarketable products (e.g. due to aesthetic defects).

- *WASTE IN PRODUCTION AND PROCESSING:* processing residues (e.g. peelings, vegetable residues, slaughter by-products).

- *LOSSES IN DISTRIBUTION:* deterioration or expiry during transport and storage.

- *LOSSES IN CONSUMPTION:* food waste in households or catering.

Agrifood system flows and phases

Source: FAO, The state of food and agriculture 2021

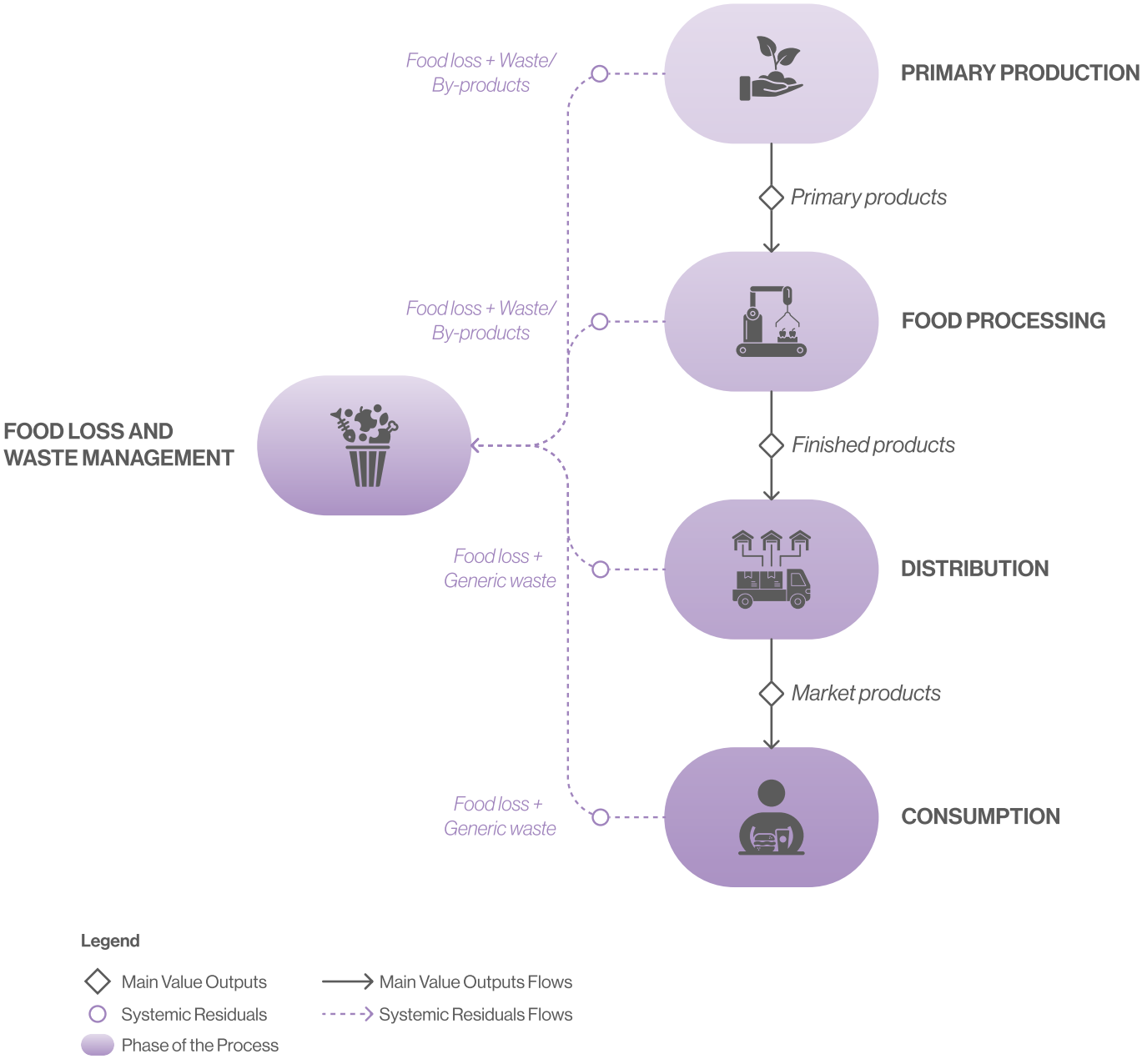


Fig. 2.2: Agrifood system process.

2.3 Agri-food system Analytical Framework

To ensure a clear and effective understanding of the complex agri-food chain and to focus the analysis on the most relevant factors for the future, the sector has been simplified into three main and deeply interdependent macro-phases: **primary production**, **food processing** and **consumption**. This breakdown is motivated by the fact that the factors and changes with the greatest impact are strategically concentrated in these three segments. For the purposes of this study, some traditionally distinct phases have been integrated. The distribution phase has been considered within food processing, as logistical choices are closely linked to and optimised by the processing industry. The analysis of waste and loss management has been concentrated mainly in the food processing and consumption stages, as these are the stages that generate most food loss and food waste. These losses are directly linked to processing technologies and, above all, are shaped by consumption habits and choices, which influence and determine the final amount of waste in the system.

Primary Production

The primary production phase ***(Fig. 2.3)***, which constitutes the initial link in the supply chain, encompasses all activities and practices that take place directly in the field, mainly identified with **agriculture** and **livestock farming**. The analysis conducted on this macro-phase focused on the interaction between technology and traditional production models. In particular, the study focused on the main issues of these models, primarily related to their environmental unsustainability (e.g., intensive use of resources or the progressive soil degradation). Consequently, the research also explored current trends, again from a technological point of view, focusing on new models and production solutions that actively seek to limit or resolve these issues.



Fig 2.3 Primary production.

Food Processing

Secondary production or food processing ***(Fig. 2.4)*** is another segment of the supply chain that is heavily dependent on technologies and production models. In this phase, technological analysis has taken on a predominant role, exploring both the current state of **industrial production** and the new transformative trends that are reshaping the sector. Compared to primary production, the processing phase is more influenced by new habits and new modes of consumption. In this regard, the analysis included not only strictly technological innovations, but also the introduction of certain novel foods, understood both as **process innovations** and as the integration of new raw materials that respond to emerging nutritional and environmental needs.



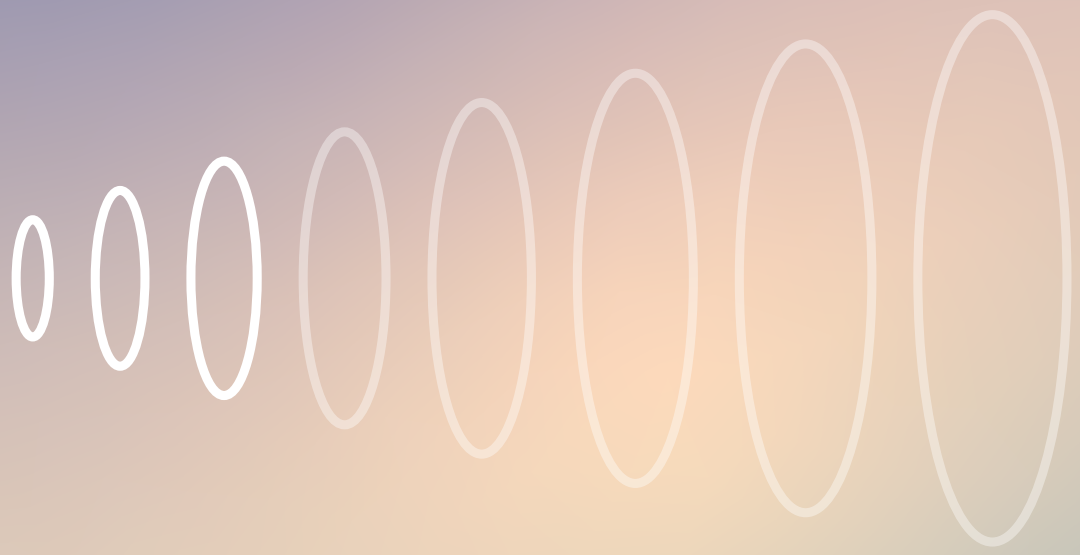
Fig. 2.4 Food processing.

Consumption

The consumption phase ***(Fig. 2.5)*** is intrinsically linked to eating habits and encompasses the more social and cultural aspects of the sector. The analysis in this section focused on the evolution of new **consumption patterns and habits**, highlighting how demand is shifting towards products that reflect new sensibilities. A crucial element is the development of new diets and nutritional choices, strongly influenced by the progressive change in people's lifestyles, which require more practical, healthy or ethically consistent food solutions, with obvious knock-on effects on the processing and primary production phases.



Fig. 2.5 Consumption.



03

Research

Research

The research process was carried out in **three main phases**, aimed at analysing the agri-food sector from every angle. The process began with the **Awareness of the context** phase, focused on identifying the factors that influence the sector, followed by **Understanding complexity** and **Tackling challenges**, aimed at understanding how these elements influence the agri-food system and what challenges and opportunities they generate. The activity was conducted sequentially and iteratively for each element examined, whether it was a megatrend, a driver, a trend or a weak signal. The desk research was supplemented by a phase of **Semi-structured interviews with experts** from various fields, which were essential for enriching and making the results of the online research more reliable.

3.1 Research Flow

AWARENESS OF THE CONTEXT

The Awareness of the context phase was focused on **scanning the agri-food environment** to map current dynamics and **identify factors** capable of influencing the system's long-term development.

SCANNING

Most foresight work begins with a scanning phase necessary to identify and collect all the obvious **forces of change** that characterise the topic being analysed, as well as those emerging factors and patterns that are less visible. For this reason, two **different scanning methods** were used in parallel and interchangeably, which differ from each other precisely in terms of the perspective and approach taken to analyse and explore the topic.

- ***ENVIRONMENTAL SCANNING*** focuses specifically on identifying the most influential and already **evident forces** of change driving the evolution of the sector. The research activity primarily investigates the **Contextual Environment** to understand, through the analysis of existing data and information, those factors and dynamics that have the potential to determine future developments.

- ***HORIZON SCANNING*** is defined as the structured collection of **weak signals** and **emerging developments** that arise at the

Contextual environment
In this thesis, the contextual environment describes those macro-level factors that shape long-term developments and are not under the direct control of entities operating within the analysed sector.

Operating environment
In this thesis, the operating environment includes those factors and developments occurring directly within the agro-industrial sector. However, the contextual environment affects the operating environment, and many of the drivers that will shape development in the longer term will emerge from outside this specific sector.

margins of mainstream thinking, focusing analysis in particular on the dynamics of the **Operating Environment**. It involves identifying those discontinuities which, although they may appear unstructured or insignificant today compared to the dominant trends, have the potential to generate significant impacts in the future. The aim is therefore to broaden the perspective beyond what is already visible on the radar, accepting the intrinsic uncertainty of these elements that could evolve into new strategic drivers.

UNDERSTANDING COMPLEXITY

If the previous phase served to gather the "dots", this second phase, called Understanding Complexity, was fundamental in connecting them. It is in this step that the application of Systemic Thinking is evident, which served to identify the connections between the elements that make up and influence the system, questioning the implications of each change at an increasingly deeper level in a process that inherently stimulates **critical thinking**. In this phase, the work focused on relating the data, trends and drivers that emerged from the scanning, abandoning the analysis of isolated phenomena to embrace an overview. Essentially, this involved mapping interdependencies and mutual influences, applying a cascade investigation logic (similar to the functioning of a **Future Wheel**) to visualise the direct and indirect consequences. The analysis made it possible to answer crucial questions about "what influences what?", tracing the impacts that these factors generate on the different stages of the agri-food supply chain and thus revealing the real complexity of the dynamics at play. The outputs of this process are structured analytical frameworks that highlight the primary connections of each factor, revealing the true complexity of the dynamics shaping the agrifood system's evolution.

TACKLING CHALLENGES

After identifying the connections and complexities, it was necessary to sift through all this material to understand where the critical issues actually lie and where new avenues are opening up. The aim of this phase was not to find immediate solutions, but to identify the tensions running through the agri-food sector, distinguishing between problems that are now evident and the latent potential that often remains unexplored. In essence, this was a synthesis aimed at defining the real **challenges** at stake and the potential **opportunities**. To

substantiate this selection, case study-based research was conducted on each individual challenge and opportunity that emerged. This in-depth analysis served not only to confirm the validity of the hypotheses, but also to observe how the system is actually moving today to address critical issues or exploit these new **areas of intervention**.

EXPERT VALIDATION

This phase was crucial in lending **authority** and substance to the research. Through **semi-structured interviews**, the study moved beyond the theoretical dimension to engage directly with the operational and academic realities of the sector. The primary objective was to **validate the hypotheses** emerging from the desk research, using dialogue with **multidisciplinary experts** as a critical filter to confirm or refute the signals identified during the scanning phase. This step enabled the construction of a solid bridge between the documented evidence and the experience of those working within the system on a daily basis, ensuring that the overall picture did not remain an isolated speculation, but **acquired the rigour necessary** to define the real challenges and the current state of the sector.

SCANNING

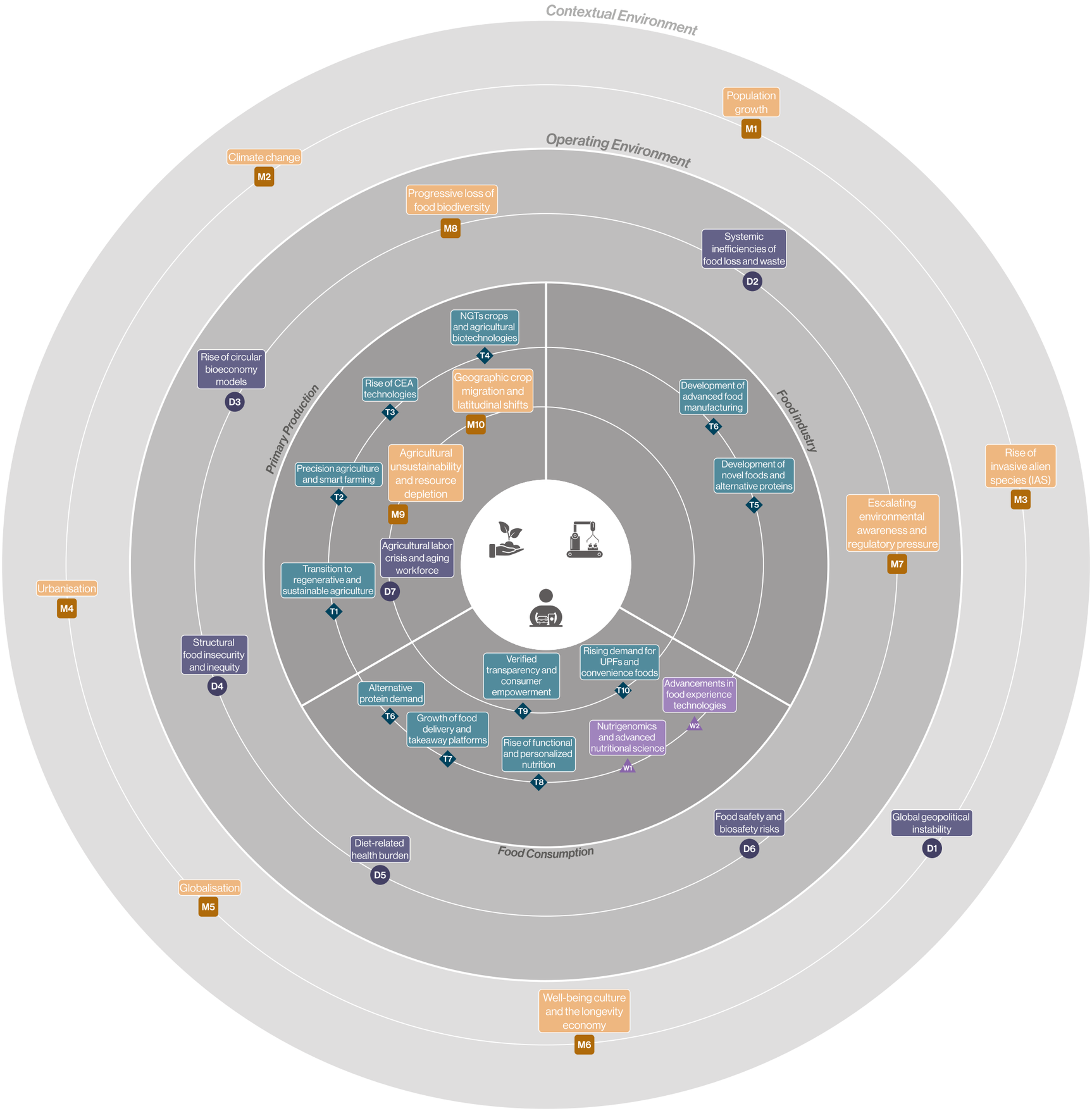


Fig. 3.1 Scanning map.

3.2 Contextual Environment Scan

The Contextual Environment scan identified a series of factors external to the agri-food sector, corresponding to **major global factors** that have a cross-cutting influence on all areas, including the system under study. These factors are usually **long-term forces** that will have a progressive and profound impact, defining the future trajectory of the sector in both the short and long term. These are now well-known and obvious dynamics, which cannot be ignored as essential variables in the systemic context.

The **main factors analysed** are:

1. *Population growth*
2. *Climate change*
3. *Rise of invasive alien species (IAS)*
4. *Urbanisation*
5. *Globalisation*
6. *Well-being culture and the longevity economy*
7. *Global geopolitical instability*

This section highlights the factors belonging to the **Contextual Environment** ***(Fig. 3.1)***, which are analysed and contextualised within the agroindustrial sector. Each factor is examined in a methodical way: first by visualising the relevant data that confirm the trend, followed by the Understanding Complexity phase to identify its relationships, impacts and interdependencies within the agrifood system. Finally, the Tackling Challenges phase serves to identify the challenges and opportunities generated by each factor; for each of these, actual case studies have been reported which, acting as concrete solutions or suggestions, confirm the emergence of these conditions in the sector.

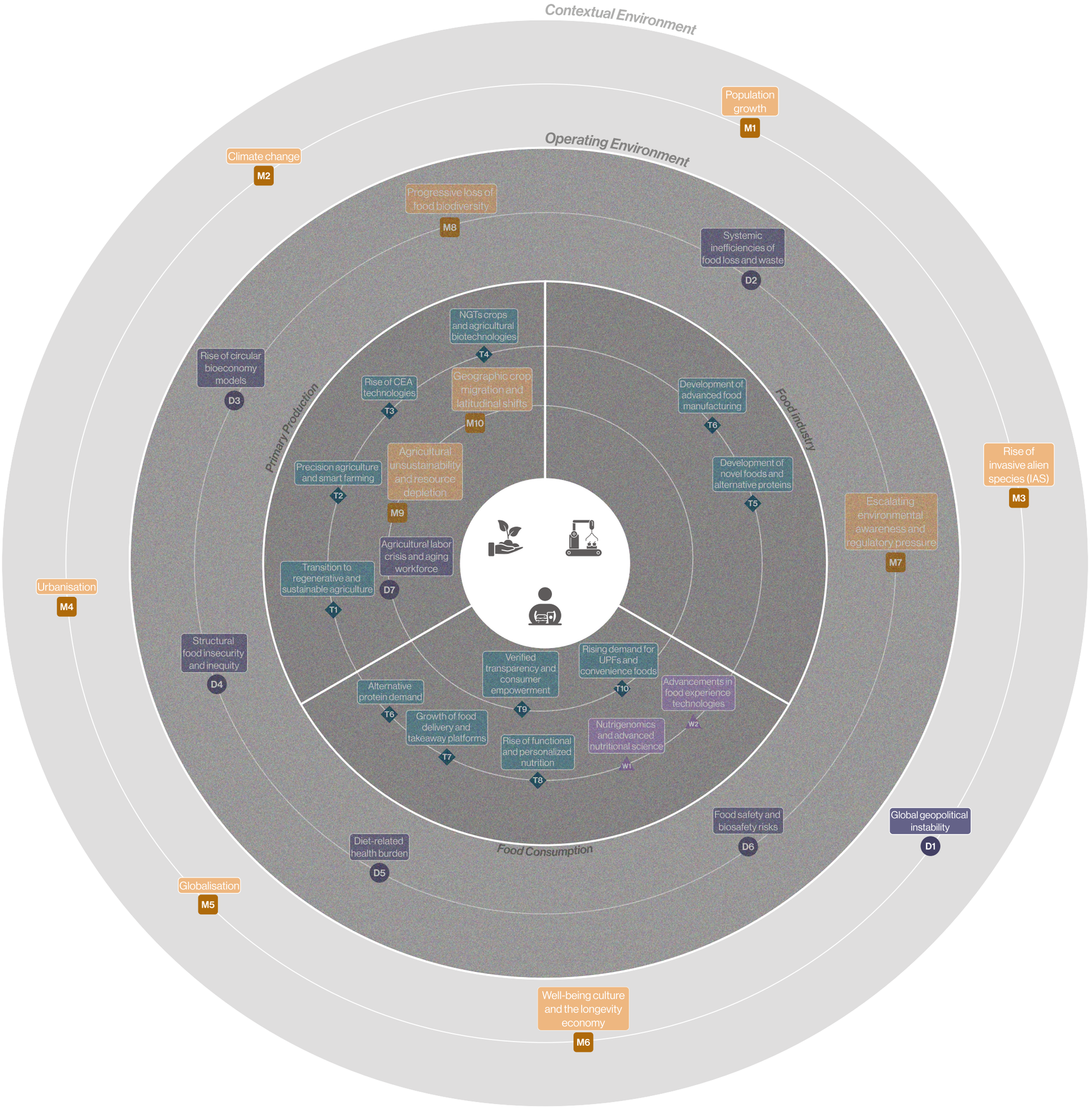


Fig. 3.1 Scanning map.

M1 - Population Growth

Population growth is a key socio-demographic factor for the agri-food sector, as the increase in global population generates a direct increase in food demand. This scenario requires an intensification of agricultural production, which will need to **increase by around 50% by 2050 compared with 2012** (FAO, 2025), putting increasing pressure on natural resources. As shown in ***(Fig. 3.2)***, the world population has been growing continuously since 1994 and, according to projections, will continue to rise until it **peaks at 10.4 billion around the mid-2080s**, before stabilising until the beginning of the next century (UN DESA, 2024).

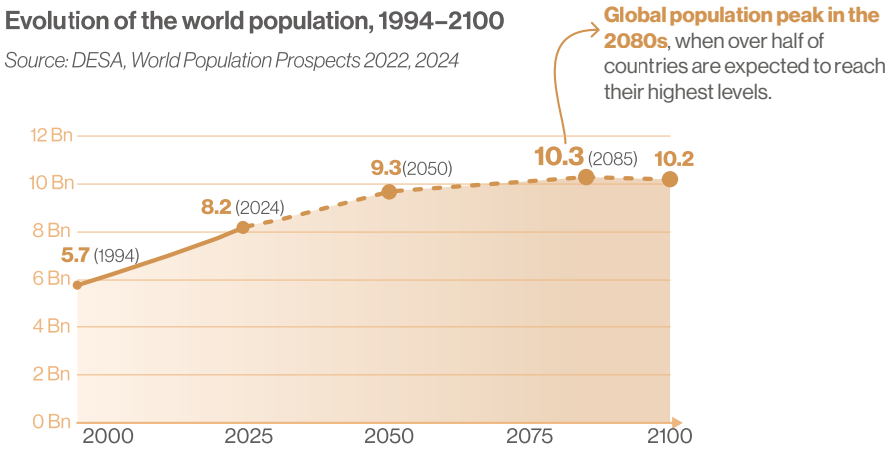


Fig. 3.2 Evolution of the world population, 1994-2100.

Geography of population growth

Looking at the geography of this phenomenon in ***(Fig.3.3)***, it is clear that growth is not uniform. While the major part of **European countries have already peaked**, expansion will continue beyond 2054 in 126 other countries, which are now home to more than half of the world's population. This diverse group includes demographic giants such as **India**, **Indonesia** and **Nigeria**, but also nations such as the **United States**, **Canada** and **Australia**, where growth is mainly driven by immigration. It is precisely the trajectory of these countries that will determine, due to their specific weight, the extent and timing of the global peak (UN DESA, 2024). Consequently, food demand will not increase uniformly either, shifting pressure on resources towards specific geographical areas.

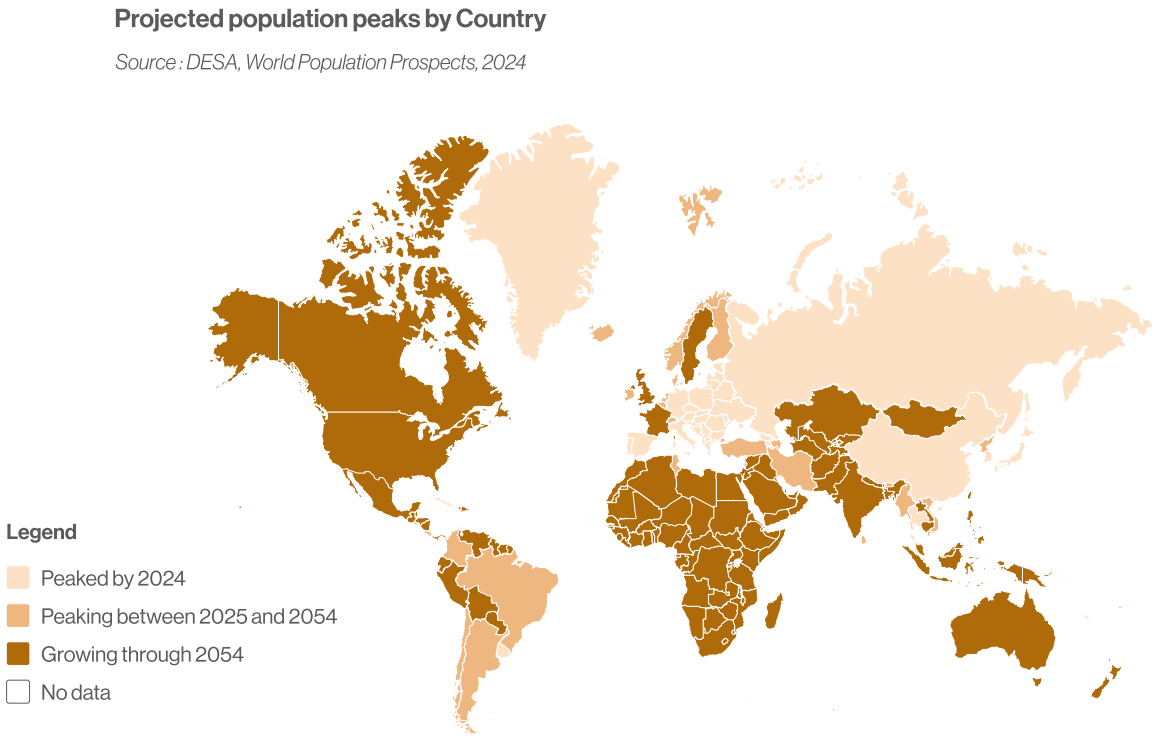


Fig 3.3 Projected population peaks by Country.

Impacts on the Agrifood System

Population growth translates within the agri-food sector mainly into an **increase in demand for food** and, consequently, in production, which, as mentioned above, needs to increase by **70% by 2050**. This scenario as can be seen in the Framework ***(Fig. 3.4)*** will inevitably lead to an **intensification in the use of resources** necessary for production, such as **water** and **soil**, which are already overused at present and may not be sufficient to meet future production needs. This pressure risks increasing the problem of **food insecurity** and further **widening the gap** in access to food between high-income and low-income countries, amplifying the global phenomenon of **food inequity**.

Identification Challenges and Opportunities of the framework

An analysis of the system framework reveals two main challenges in responding to the problem of increasing food demand. The first concerns the ***optimisation of available resources (C1)***, seeking to make the most of them and reducing waste and excess as much as possible. Addressing this challenge could involve different strategic trajectories focused on optimizing available resources by doing more with what is available and reducing waste. One potential pathway lies in the application of circular bioeconomy practices to maximise the value of each raw material, while another attempts to exploit advances in mechanisation and digital tools specifically within the agricultural phase, an area that is currently being applied in two distinct production models:

- ***PRECISION AND SMART FARMING*** operate through the constant monitoring of every crop parameter, allowing for extremely targeted management of data and agricultural inputs. This control capability translates into resource optimisation, as it allows plants to be provided with only what is strictly necessary, eliminating waste of water and fertilisers while increasing the overall efficiency of the system.

- ***CONTROLLED ENVIRONMENT AGRICULTURE (CEA)*** technologies, such as vertical farming or hydroponic and aquaponic systems, allow for maximum optimisation of water and nutrients, while also reducing soil use and freeing production from the land.

A second very important challenge is the need to ***identify new alternative food sources (C2)*** that can increase the diversification and intensification of traditional crops. In this scenario the integration of products obtained from novel foods can in fact ease the pressure on traditional resources, ensuring greater resilience through the diversification of global production.

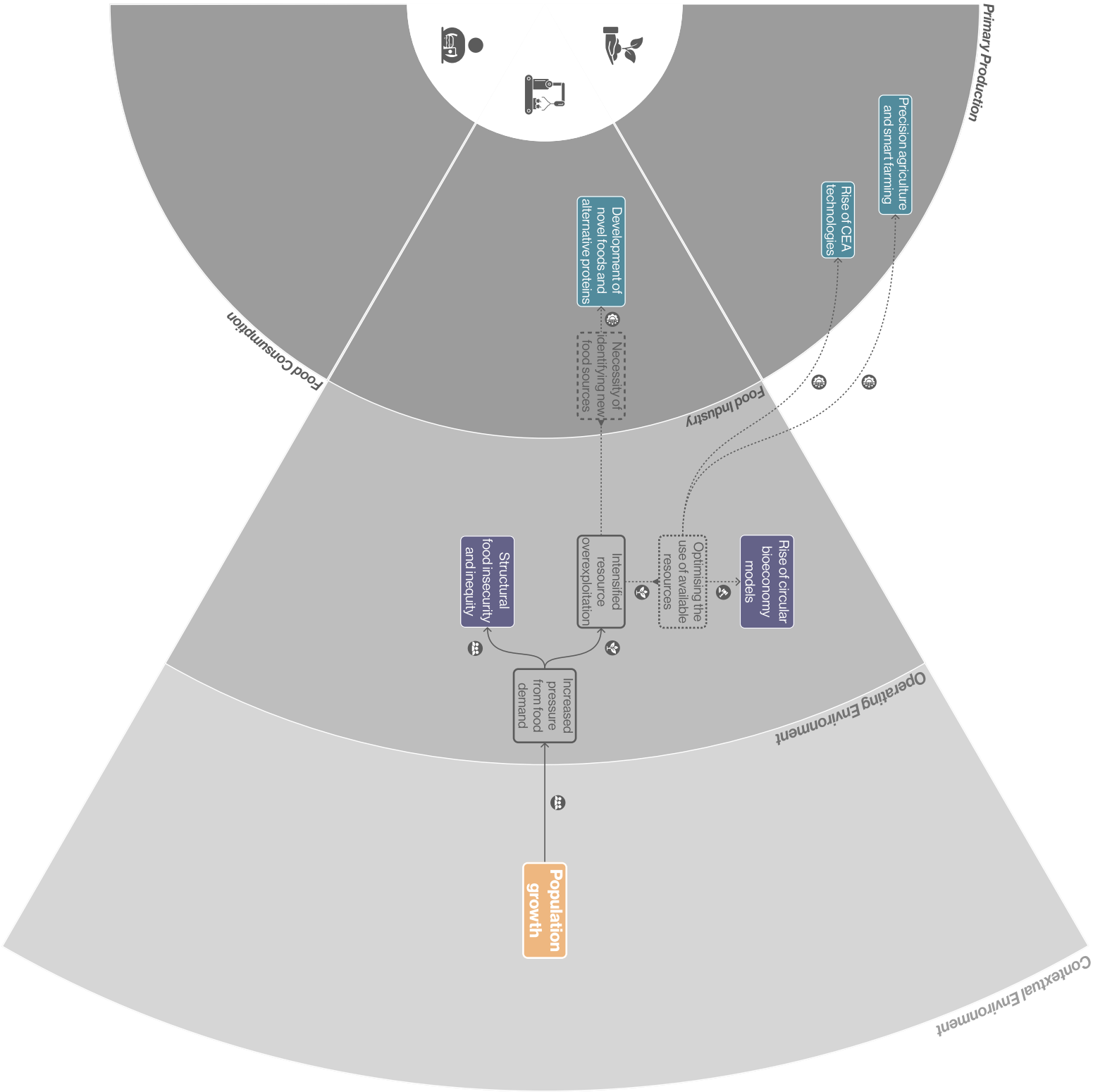


Fig. 3.4 Population growth, Systemic Framework.

C1 - Optimising the use of available resources.

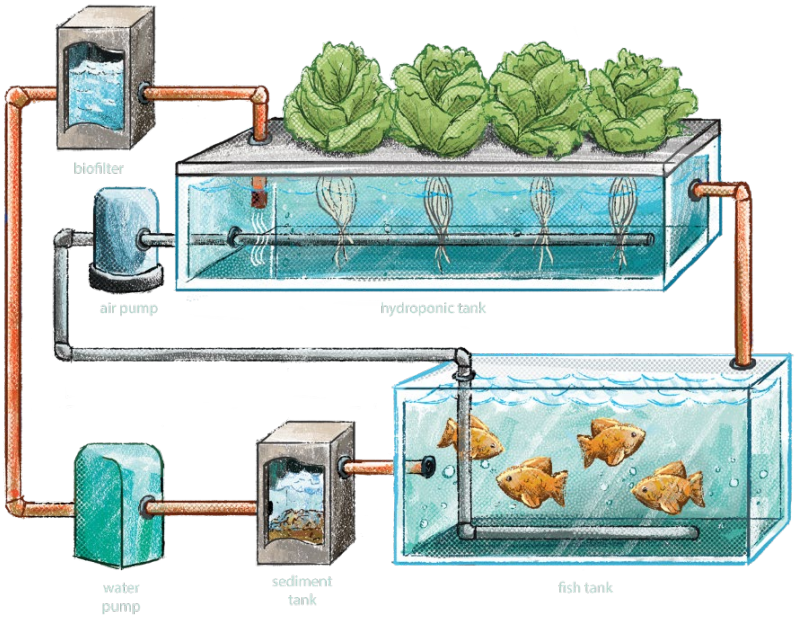
GrowUp Box

London, UK

GrowUp Box is an **urban micro-farm** developed inside a container that uses an **aquaponics system** to grow plants and raise fish in a sustainable way. The water in the tanks containing tilapia, a hardy species that can live without stress even in unheated water, is filtered by the plants and reused, **minimising resource** and **energy consumption**. The project shows how it is possible to produce food in cities in an efficient, circular and environmentally friendly way.

Keywords:
#Urban microfarms
#Aquaponic system
#Resource efficiency

Response to the identified challenge:
GrowUp Box responds to the need to optimise resources by minimising the necessary inputs and maximising internal production yields. While many controlled environment agriculture models struggle to be scalable due to extremely high energy costs, this aquaponics module offers a concrete solution for **small-scale production**. By integrating the nutrient cycles between fish and plants, the system transforms waste into a resource, enabling **circular production** that drastically reduces water and energy consumption compared to traditional methods.


biofilter
air pump
hydroponic tank
water pump
sediment tank
fish tank



C2 - Necessity of identifying new food sources.

Kelpeat

Cuneo, Italy

Kelpeat is an innovative company that transforms **macroalgae** into **healthy and sustainable food solutions**. Using marine biomass from European farms, the company offers a regenerative production model that eliminates the need for agricultural land and fresh water. The aim is to **integrate ocean resources** into the **daily food system**, reducing pressure on terrestrial ecosystems while promoting a resilient and low-environmental-impact supply chain.

Keywords:
#Blue Economy
#Macroalgae valorisation
#Functional foods

Response to the identified challenge:
Kelpeat enhances previously unused aquatic food sources with high nutritional properties through the development of **functional snacks**. The integration of macroalgae such as **Kelp** and **Dulse** in different percentages provides essential nutrients such as Omega-3 and vitamin B12, transforming these underutilised biomasses into a strategic resource for the **diversification** of the food system.

ORIENTAL SURF

Con alga kelp, curcuma e finocchietto
with kelp seaweed, turmeric, fennel

100% VEGAN



Fonte di minerali rari, **Omega-3** e **vitamina B12**

Source of rare minerals, **Omega-3** and **vitamina B12**

KELPEAT

OCEAN HEALTHY BITES

M2 - Climate Change

Climate change is probably the issue of the century, progressively influencing the course of all human activity. **Donella Meadows** and the **Club of Rome** were among the first to draw attention to this issue with their book **"The Limits to Growth" (1972)**. As with all climate change caused by human activities on Earth, we are witnessing a rise in global temperatures which, as can be seen in ***(Fig. 3.5)***, is estimated to have **increased by 1.55°C compared to the pre-industrial period** as a global average. This increase is by no means uniform: it has been faster and more pronounced in the **northern hemisphere**, especially near the Arctic regions and glaciers, which are warming at almost twice the rate of areas further away from the ice. At the same time, the southern hemisphere has also recorded significant heat records, showing an acceleration in warming in several areas. All this has a decisive influence on the agro-industrial sector, affecting agricultural and livestock production in particular. According to a recent study, it is estimated that by 2100, up to **30% of global food crop** production could experience climate conditions that currently do not host major crop production anywhere across the globe (Kummu et al., 2021).

Annual temperature anomalies relative to the pre-industrial period, 2000-2025

Source: Our World in Data (2024), CO2 and Greenhouse Gas Emissions

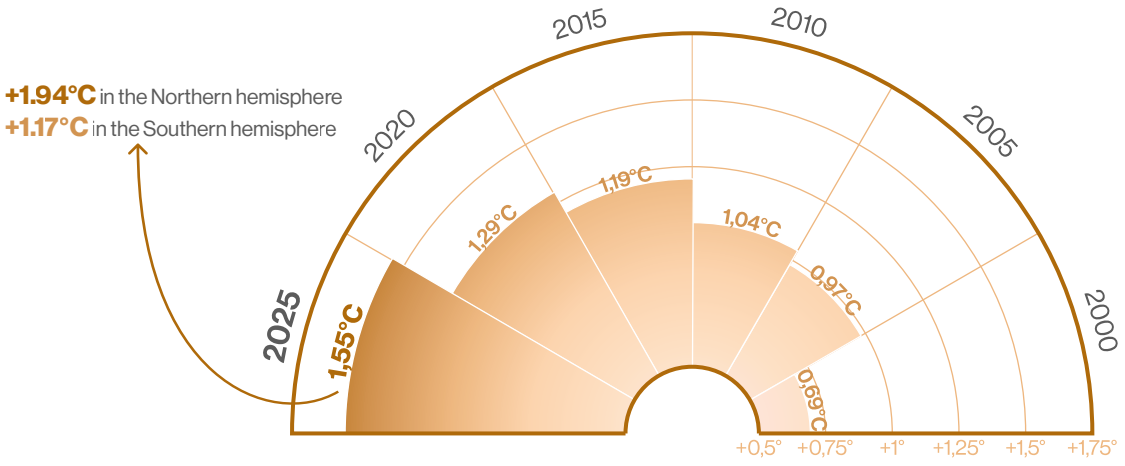


Fig. 3.5 Annual temperature anomalies relative to the pre-industrial period, 2000-2025.

Frequency of extreme weather events

Climate change caused by human activities is the main cause of the **increase in extreme weather events**, as highlighted by the European Environment Agency (EEA, 2021). According to a NASA study published in The Guardian, climate change is the main cause of the increase in the intensity of floods and droughts, phenomena that seem to be progressing even more rapidly than global temperatures. Confirming this acceleration, Grace satellite measurements show that such events have become more frequent and severe, reaching twice the average recorded between 2003 and 2020 in 2024 (Harrabin, 2025). This scenario of instability translates into a direct threat to global food security. In fact, according to the report published by the FAO in "The Impact of Disasters on Agriculture and Food Security 2025", disasters have caused agricultural losses of approximately **USD 3.26 trillion over 33 years** (1991–2023), a figure representing 23% of total global economic damage, mainly affecting cereals (4.6 billion tonnes), but also fruit, vegetables and livestock. This damage occurs mainly in **low- and middle-income countries**, which suffer the greatest losses due to less resilient infrastructure, for example Africa loses 7.4% of its agricultural GDP. In terms of the most significant types of disasters, **floods** are in first place, responsible for over **USD 1.5 trillion**, followed by **storms** and **droughts**, which represent equally significant problems ***(Fig. 3.6)***. However, the impacts of these events go beyond immediate production, as they affect infrastructure, markets and ecosystem services with consequences that can persist for years. It is therefore a priority to develop assessment tools that also capture indirect impacts, non-economic values and biodiversity loss, identifying solutions that can make agri-food systems structurally more resilient (FAO, 2025).

Agricultural economic loss by hazard types, 1991–2023

Source: The Impact of Disasters on Agriculture and Food Security, 2025

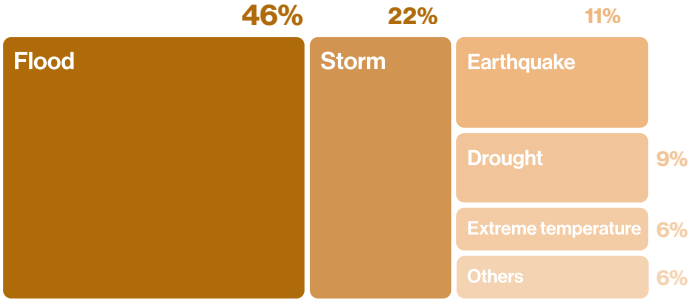


Fig. 3.6 Agricultural economic loss by hazard types, 1991-2023.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.7)*** Climate change is among the most concerning threats to the agro-industrial system, mainly due to **increased frequency and intensity of extreme weather events**. In 2024, events such as floods and droughts reached twice the average recorded between 2003 and 2020, causing systematic devastation of ecosystems and progressive **degradation of resource** availability. This phenomenon hits low-income countries hard, where scarce resources significantly exacerbate food insecurity and food inequity. The impacts are particularly evident in primary production, where extreme events lead to **crop losses** and **agricultural biodiversity loss**, which has suffered an estimated economic loss of USD 3.26 trillion over the last 33 years. In addition, global warming is a major driver of species displacement; as these organisms enter new habitats, they can disrupt ecological balances, leading to the loss of local biodiversity and essential ecosystem services. At the same time, we are witnessing the **migration of crops northwards**, such as avocados flourishing in Sicily and vines moving to Northern Europe. It is estimated that, as a result of this phenomenon, by 2100 up to 30% of global food crop production could be in climatic conditions that are totally foreign to current production areas. A glimmer of hope comes from the growing awareness of the problem, which is prompting many countries to adopt mitigation policies such as the **European Green Deal**, launched by the von der Leyen Commission in 2019, aiming for climate neutrality by 2050 (European Commission, n.d.).

Identifying Challenges and Opportunities within the Framework

The analysis highlights how the ***need to optimise resources (C1)*** is not only a challenge of rising food demand, but also a necessary defense against their accelerated depletion due to global warming. This leads us to seek solutions that maximise production efficiency, ensuring an approach that is sustainable over time. At the same time, the challenge of ***making agriculture more resilient to climate change (C3)*** is emerging, a goal that currently pursued in two ways. On the one hand, there are regenerative practices, which focus on soil health and carbon sequestration through techniques such as crop rotation and cover crops; on the other hand, biotechnological innovations like **NGTs** offer crucial strategic pathways, allowing for genomic interventions to develop crops resistant to pathogens or drought.

New genomic techniques (NGTs)
NGTs (New Genomic Techniques),represent the evolution of agricultural biotechnology based on the CRISPR/Cas9 system, developed by Nobel Prize winners Charpentier and Doudna. Unlike traditional GMOs, which introduce foreign DNA from other species (transgenesis), NGTs intervene on the genome with genes from the same species. This "editing" approach allows targeted mutations to be obtained to increase crop resilience without inserting genetic material external to the original biological system. (Garancini, 2023)

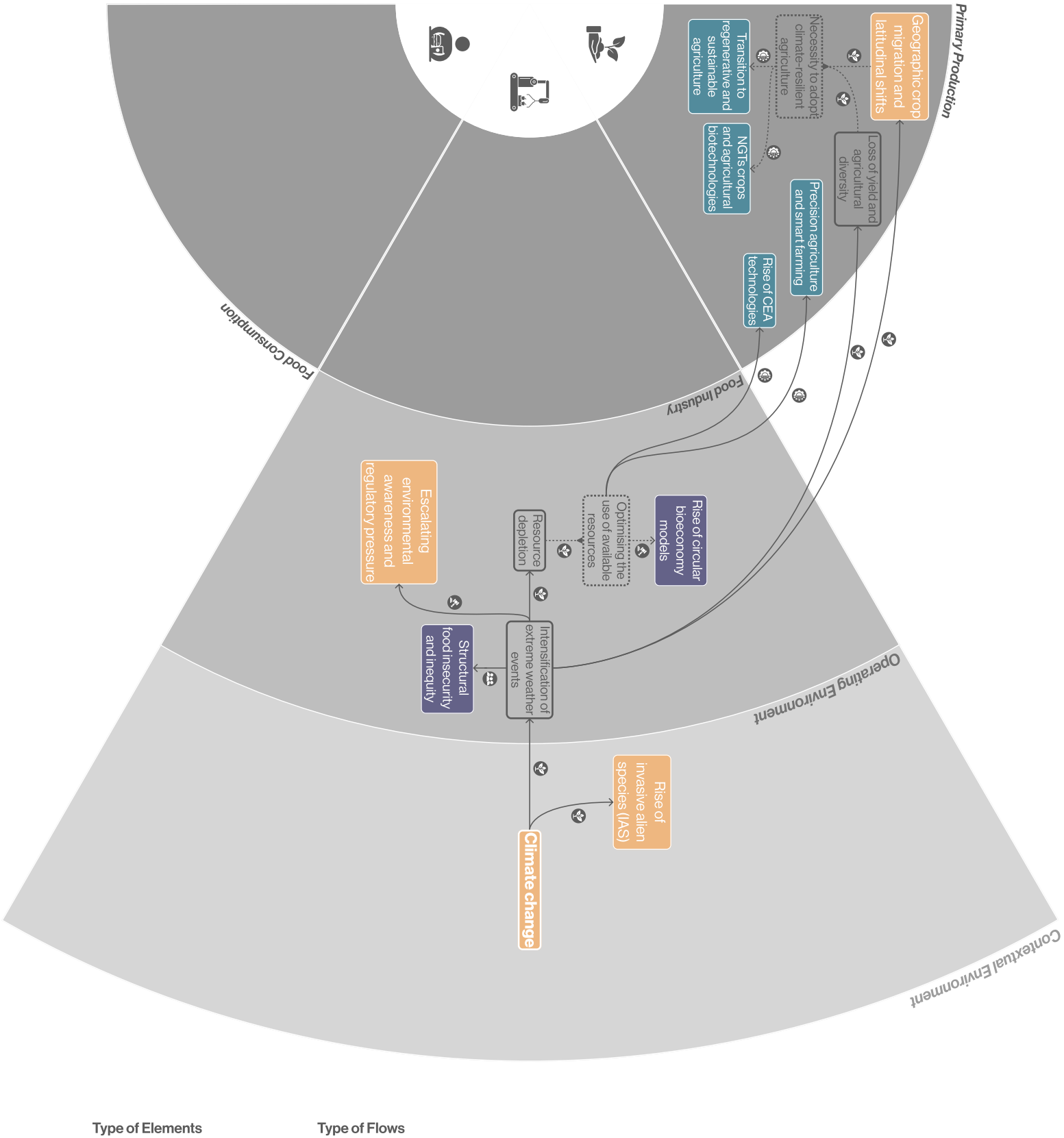


Fig. 3.7 Climate Change, Systemic Framework.

C3 - Necessity to adopt climate-resilient agriculture.

TEA4IT

Italy

TEA4IT is an initiative coordinated by **CREA** (Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria) that uses new **Assisted Evolution Technologies (NGTs)** to innovate the main Italian agri-food supply chains. The project was created thanks to the "Drought" and "Agriculture" decrees, which paved the way for field trials to respond to environmental challenges, and uses **genome editing** and cisgenesis to develop more **resistant plants** capable of defending themselves against pests and drought without altering their original genetic identity. This is a fundamental step towards agriculture that protects the environment and the typical characteristics of Made in Italy products, drastically reducing the use of pesticides and fertilizers.

Keywords:
#Assisted evolution technologies
#Climate resilient agriculture
#Genome editing

Response to the identified challenge:
The TEA4IT project tackles the challenge of climate resilience by providing precision genetic tools to cope with environmental instability. While traditional crossbreeding techniques take decades, NGTs make it possible to **obtain resistant varieties quickly**, responding promptly to the speed of global warming. This technical solution stabilizes Italian food production, **allowing crops to thrive in conditions of thermal and water stress** without compromising the health of ecosystems.

TEA4IT



M3 - Rise of Invasive Alien species (IAS)

Invasive species pose a serious and growing threat to biodiversity and sustainable development. Their spread has accelerated significantly since the 1970s, driven by the expansion of global trade and transport networks, which act as primary vectors for biological invasions. Currently, approximately **40,000 alien species** have been documented globally ***(Fig. 3.8)***, introduced by human activities into territories outside their natural range. This **trend is projected to increase by 36% by 2050** (Seebens et al., 2021). However, it is essential to make a distinction: as reported in the 2023 IPBES report, approximately **>3500 of these are considered to be truly invasive** (**IAS**), as they are capable of causing concrete damage to ecosystems and human activities. This phenomenon is further amplified by global warming, which alters the balance of local ecosystems by creating favourable conditions for the establishment and spread of species that would not previously have found a hospitable climate. The rates of introduction of these species into previously unaffected regions have increased steadily in recent years, reaching a rate of approximately 200 new species documented each year (Bacher et al., 2025). The economic impact is enormous: between 1970 and 2017, **biological invasions caused global losses of over 1.288 trillion dollars**, with a 400% increase every decade, and this is expected to continue to grow dramatically in the coming years (Diagne et al., 2021).

IAS
Invasive alien species are animals, plants or other organisms that are introduced by humans, either intentionally or accidentally, into places outside of their natural range, negatively impacting native biodiversity, ecosystem services or human economy and well-being. (IUCN, n.d.)

Global incidence and typological classification of Invasive Alien Species (IAS) within total alien populations.

Source: IPBES (2023), Invasive Alien Species Assessment

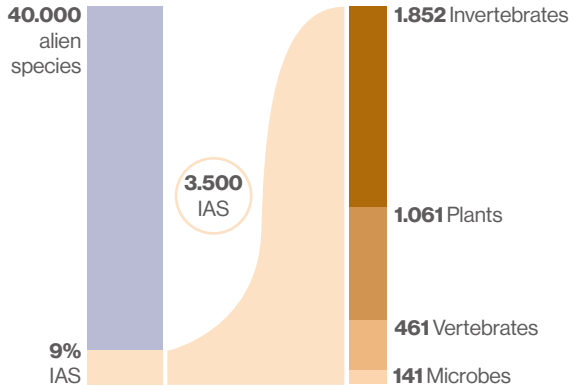


Fig. 3.8 Global incidence and typological classification of Invasive Alien Species (IAS) within total alien populations.

Impacts on the Agrifood System

As mentioned above, the progressive increase in the distribution of alien species, and in particular IAS, is amplified by climate change, which is altering ecosystem conditions, allowing these species to adapt and develop, as well as by globalisation, which is another factor that has historically caused these species to spread to other habitats. The main impacts of IAS on the agri-food system are linked to the problems they can create in new ecosystems, destroying local biodiversity and reducing native species, in some cases amplifying food security problems in sensitive areas. In addition, they can generate contamination and biosecurity risks through the transmission of pathogens and the proliferation of **zoonotic diseases, which today account for 60% of emerging infectious events worldwide** (Jones et al., 2008). In agriculture, a prime example of this dynamic is **Xylella fastidiosa** ***(Fig. 3.9)***, a bacterium that infects olive trees through an insect vector, the spittlebug, devastating entire crops without the need for direct consumption by the animal. From the point of view of primary production, IAS cause a drastic loss of yields, as in the cases of the **Spodoptera frugiperda** ***(Fig. 3.10)*** larva in Africa and Asia, or by attacking local species, as in the case of the **blue crab** (Callinectes sapidus) ***(Fig. 3.11)*** in Italy, which has caused serious damage to local fish fauna, especially in the lagoon areas of the Po river delta. Finally, still in primary production, the presence of these alien species often pushes farmers to increase their use of pesticides in an attempt to contain damage and protect yields. This triggers a vicious circle in which the increase in chemical load exacerbates pollution and environmental unsustainability, further weakening local biodiversity, which should instead act as a natural barrier against infestations.

Zoonotic disease
Human disease occurring following the natural and reciprocal transmission of a pathogen or parasite between animals and humans. (Roy et al., 2023)



Fig. 3.9 Xylella fastidiosa.



Fig. 3.10 Spodoptera frugiperda.



Fig 3.11 Callinectes sapidus.

Identifying Challenges and Opportunities within the Framework

From the analysis of the specific framework on the distribution of invasive alien species (IAS) ***(Fig. 3.12)***, it emerges that agricultural production faces the challenge of ***developing structural resilience production to biological invasions (C4)*** which, due to climate change, will tend to intensify in the near future. In this context, biotechnology, and NGTs in particular, offer concrete tools for creating plant varieties with intrinsic defences not only against climatic anomalies, as shown in the previous analysis, but also against pathogens and infections carried by alien species that compromise agricultural yields in various parts of the world. At the same time, there is an opportunity to ***enhance the value of edible invasive species by integrating them into diets (O1).*** In addition to generating potential business opportunities linked to possible organoleptic profiles of interest, this enhancement also promotes increased food biodiversity, a fundamental pillar of a healthy and balanced diet. One of the main barriers to the spread of these new type foods will be consumer acceptance, which is why it will be essential to launch awareness and education campaigns to guide people towards integrating these products into their diets.

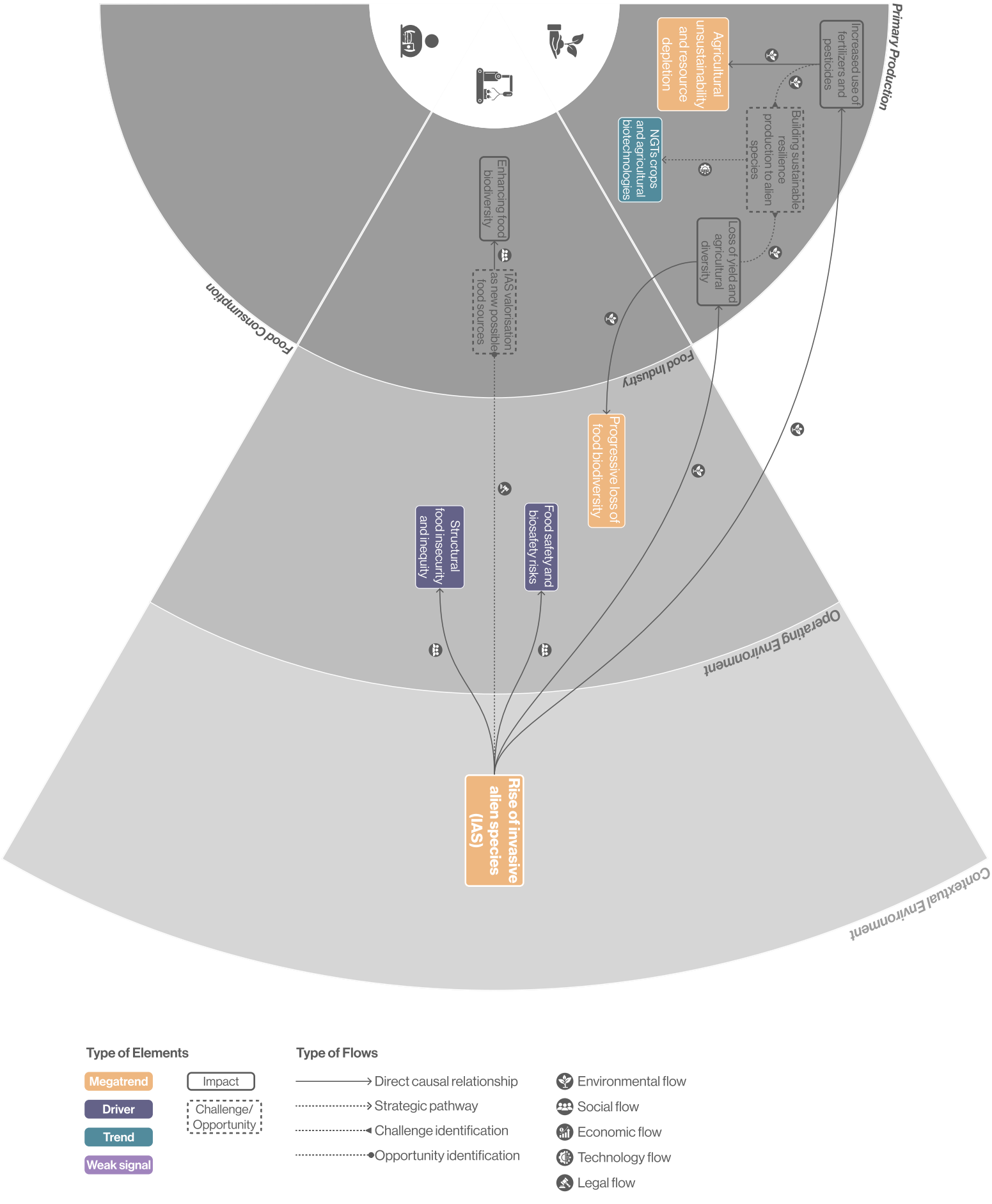


Fig. 3.12 Rise of Invasive Alien Species (IAS), Systemic Framework.

C4 - Building sustainable resilience production to alien species.

QCAV-4

Australia

QCAV-4 is one of the world's first genetically modified organisms (**GMOs**) to be authorised for consumption and sale, developed by Queensland University of Technology. The project was created to save the **Cavendish** variety from **TR4 fungus** (Fusarium wilt tropical race 4), an incurable pathogen first isolated in **Australia** in 2015. As the fungus spreads rapidly in the soil, aided by flooding, researchers have made the plant immune by inserting a gene from a resistant wild banana, thus creating a definitive **biological barrier** against a disease that threatens global production.

GMO
GMO (short for "genetically modified organism") is a plant, animal or microbe in which one or more changes have been made to the genome, typically using high-tech genetic engineering, in an attempt to alter the characteristics of an organism. Genes can be introduced, enhanced or deleted within a species, across species or even across kingdoms. GMOs may be used for a variety of purposes, such as making human insulin, producing fermented beverages and developing pesticide resistance in crop plants.
(NIH, 2026)

Keywords:
#GMO
#TR4 fungus
#Crop resilience

Response to the identified challenge:
The innovation of QCAV-4 is an example of the **virtuous use of biotechnology** to make food production in Australia more resilient to **biological invasions**. In particular, thanks to this application, it has been possible to save the Australian banana industry in tropical northern Queensland, which produces over 95% of the bananas consumed throughout the country. In this way, instead of having to abandon plantations to seek virgin soil, thus also avoiding new deforestation practices, the production system becomes resilient to the presence of the pathogen, ensuring **stability in the supply chain** without having to physically eradicate the invasive species from the land.



01 - IAS valorisation as new possible food sources.

Blueat

Rimini, Italy

Mariscadoras is a start-up and benefit corporation that, through the Blueat project, promotes the **consumption of invasive alien species (IAS)** that are permanently established in the Mediterranean. The initiative directly impacts small-scale traditional fishing, encouraging the removal of organisms that are harmful to the marine balance, such as the **blue crab**. By transforming an ecological threat into a **valuable gastronomic resource**, Blueat generates new economic opportunities for coastal communities while promoting the regeneration of local ecosystems.

Keywords:
#IAS valorisation
#Blue economy
#Consumer education

Response to the identified opportunity:
The Blueat project by transforming the blue crab into a food resource, relieving pressure on overfished native species and activating a virtuous circle in which an **ecological threat is appropriately valued as a food resource**. To overcome the barrier of novelty, the company actively supports customers with advice, recipes and food pairings. This approach not only encourages purchase and consumption, but also makes the **integration of alien species into the daily diet** a conscious and functional action for the protection of marine ecosystems.

Blueat™

LA PESCHERIA
SOSTENIBILE

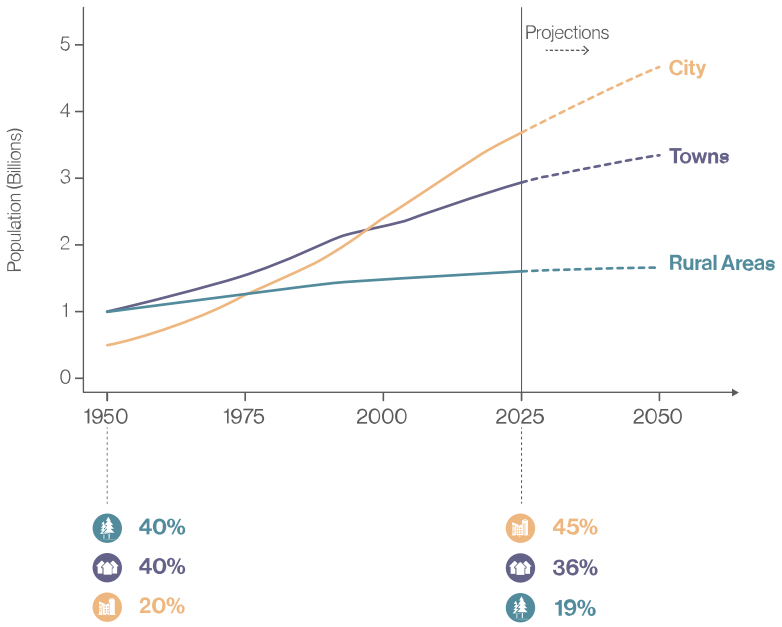


M4 - Urbanisation

Today, a large part of the world's population lives in urban areas, reaching approximately **3.7 billion people (45%) in 2025** (UN DESA, 2025). This scenario represents a radical change from the past. In fact, looking at ***(Fig. 3.13)***, we can see that in 1950 only one-fifth of the 2.5 billion global inhabitants lived in cities, while the majority still resided in small towns or rural areas (UN DESA, 2025). Currently, the highest levels of urbanisation are found in various areas of **East and South-East Asia**, with countries such as Taiwan (78%) and the Republic of Korea (76%), as well as in **North Africa and West Asia**, where the United Arab Emirates (75%) and Jordan (73%) stand out (UN DESA, 2025). **Sub-Saharan Africa** also shows very high urban concentrations in countries such as Equatorial Guinea (83%) and Djibouti (80%), although the region has significant internal variations with countries such as Zimbabwe still predominantly rural (UN DESA, 2025). Urbanisation is an important demographic factor that must be considered in the analysis, as it has the potential to fundamentally change the way people live, work and form communities worldwide (UN DESA, 2025).

World population living in cities, towns and rural areas, estimates, 1950–2025, and projections, 2025–2050.

Source: World Urbanization Prospects 2025 (United Nations, 2025).



City: These are areas with a high density (at least 1,500 inhabitants per km²) and a large population (at least 50,000 inhabitants).

Towns: These are urban clusters outside of cities with a moderate density (at least 300 inhabitants per km²) and a population of at least 5,000 inhabitants.

Rural Areas: These consist of grid cells with a density below 300 inhabitants/ km², or denser cells not part of a city, town or semi-dense area.

Fig. 3.13 World population living in cities, towns and rural areas (1950-2050).

The rise of megacities

The expansion of the urban population is directly reflected in the increase in the number of cities globally, in fact between 1975 and 2025, the total number of urban centres in the world more than doubled, marking a profound change. This process includes the phenomenon of the increase in the number of megacities (centres with over 10 million inhabitants), which has accelerated remarkably, from 8 in 1975 to **33 in 2025, of which 19 are located in Asia** ***(Fig. 3.14)***. Currently, **Jakarta** is the most populous city in the world with almost 42 million inhabitants, followed by Dhaka with almost 37 million and Tokyo with 33 million. Geographically, nine of the ten most populous cities on the planet are Asian, with Cairo as the only exception, in ninth place (UN DESA, 2025). Projections for **2050** indicate that the number of **megacities will rise to 37**, while **Dhaka** is expected to become the most populous city in the world by the middle of the century (UN DESA, 2025). However, despite the expansion of large megacities, most of the urban population lives in small and medium-sized towns. In fact, 96% of the approximately 12,000 cities existing in 2025 will have fewer than one million inhabitants, and 81% will have fewer than 250,000 residents (UN DESA, 2025). By 2050, it is estimated that the total number of cities in the world will exceed 15,000, with a constant prevalence of centres with a population of less than 250,000 inhabitants. In terms of urban growth, approximately one-third of cities that recorded expansion rates of more than 4% per annum between 2015 and 2025 are located in **sub-Saharan Africa**, followed by **Central and South Asia** (UN DESA, 2025).

Evolution of the global megacity count (1975-2050)

Source: World Urbanization Prospects 2025 (United Nations, 2025).

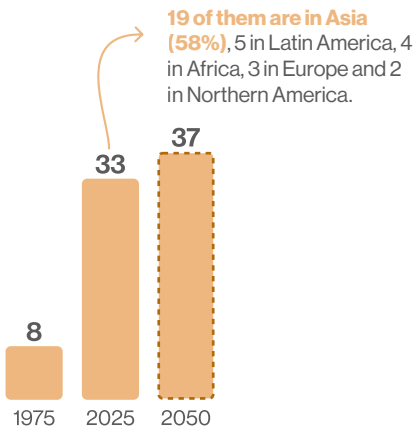


Fig. 3.14 Number of global megacities (1975-2050).

Impacts on the Agrifood System

The analysis of the urbanisation framework ***(Fig. 3.15)*** has shown that this megatrend acts as a powerful driver of change, influencing the agri-food sector both in primary production and in consumption patterns. With regard to agricultural production, the **progressive decline of rural communities** and the consequent depopulation of the countryside inevitably lead to the **loss of local food identity**, as the know-how and authenticity of production typical of small rural farms disappears. At the same time, the **urban environment profoundly alters consumers' lifestyles**, accelerating their daily rhythms and increasing the so-called **convenience demand**. This acceleration in consumer lifestyles translates not only into an expansion of the food delivery market, but also into a greater dependence on ready-made foods, which often coincide with **ultra-processed foods (UPFs)**, and a general **homogenisation of diets**, in contrast to the diversification which is a cornerstone of healthy eating. However, as De Bruin and Holleman point out, the impact of this phenomenon is not uniform and depends heavily on the context. In fact, in countries where urbanisation is not accompanied by adequate economic growth, it becomes an **accelerator of inequality and poverty**, making access to healthy nutrition extremely difficult and structurally aggravating food insecurity problems (De Bruin and Holleman, 2023).

Ultra-processed foods (UPFs)
According to the NOVA classification, ultra-processed foods represent the fourth category of the system and are defined as industrial formulations produced through a series of complex technological processes. These products are based on the fractionation of whole foods into isolated substances such as sugars, oils and proteins, which are then reassembled using techniques such as extrusion or pre-frying. The frequent addition of additives, including flavourings, colourings and emulsifiers, is intended to give the product hyper-palatable sensory properties and high convenience of use. Due to the low cost of ingredients and long shelf life, these foods tend to replace fresh, regular meals, profoundly altering the nutritional balance of contemporary diets. (Monteiro et al., 2019)

Identifying Challenges and Opportunities within the Framework

Urbanisation poses challenging issues for the agro-industrial sector, requiring, first and foremost, ***reconnecting citizens with farming practices (C6)***. Since awareness of agricultural cycles has been largely lost in urban contexts, educational programmes are essential to restore the link with the land and food production methods. At the same time, the progressive concentration of the population and workforce in cities creates a need to ***locate primary production close to large urban centres (C5)***. In this perspective, the development of controlled environment agriculture (CEA) and vertical farming models represents a strategic option for integrating food production directly into the urban fabric, reducing the distances in the supply chain. Finally, to ***counteract the homogenisation of diets typical of urban life (C7)***, awareness-raising efforts are needed to guide consumers towards more varied and informed food choices, using food education as a tool to break the standardisation of urban diets.

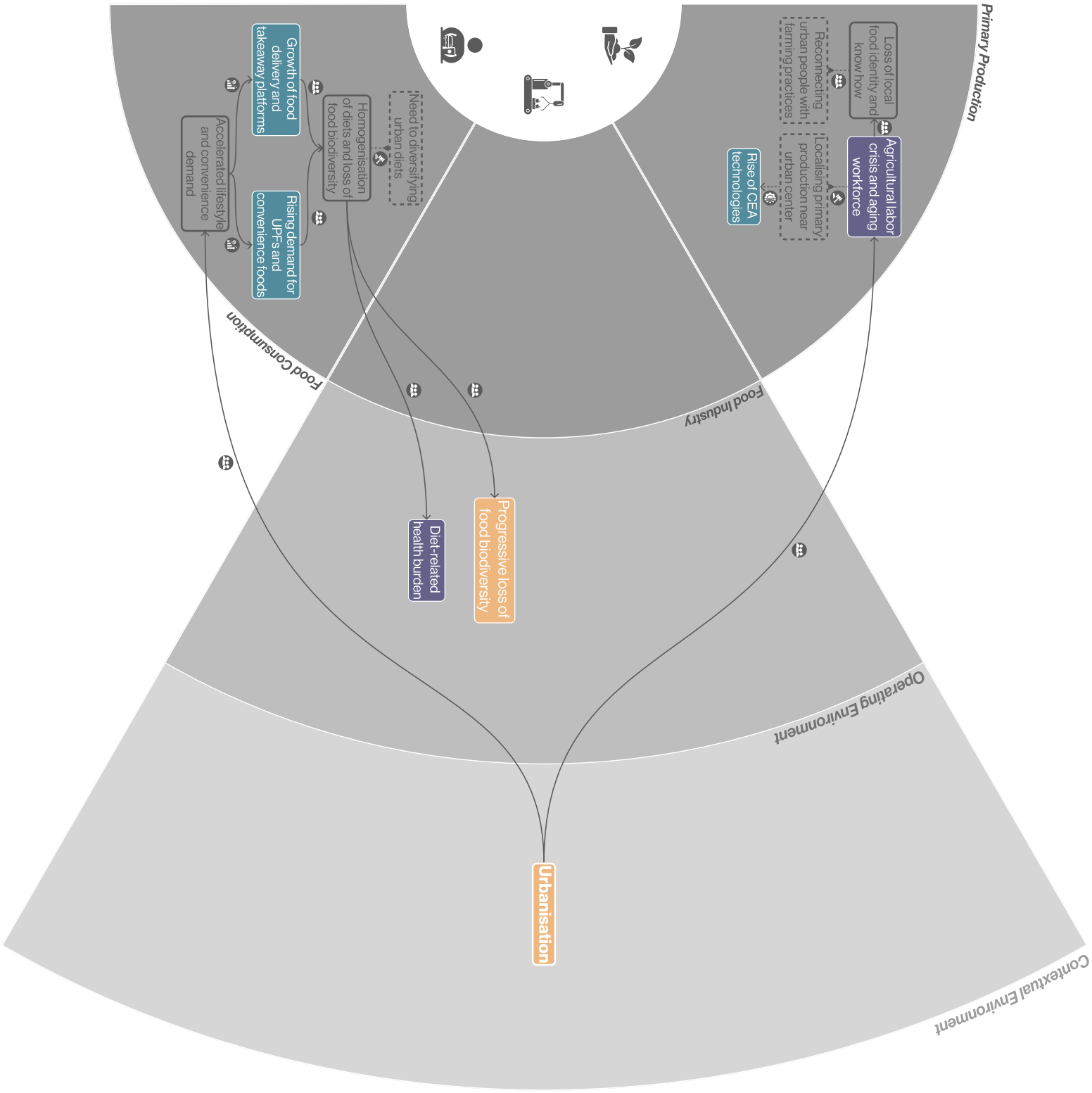


Fig. 3.15 Urbanisation, Systemic Framework.

C5 - Localising primary production near urban center.

“Una serra per Mirafiori”

Torino, Italy

“Una serra per Mirafiori” (A greenhouse for Mirafiori) project is an innovative model of sustainable urban food logistics that responds to the need to **reconnect cities with agricultural production**. It consists of creating the first **urban aeroponic greenhouse** in a disused area, a technology that r**educes water consumption by 98%**. This greenhouse produces “zero waste” micro-vegetables which, thanks to a local distribution system using cargo bikes, are delivered to the **cooperative’s social catering service** with a view to creating a very short supply chain and effectively **zero food miles**. The project thus combines zero-emission logistical efficiency with technological innovation and social inclusion.

Keywords:
#Aeroponics
#Community inclusion
#Zero-mile delivery

Response to the identified challenge:
The project responds to this challenge by integrating controlled environment agriculture (CEA) systems directly into the urban fabric, **eliminating the distance between production and consumption**. The use of aeroponics allows urban voids to be converted into efficient production centres, demonstrating that it is possible to locate primary production even in densely populated areas. Furthermore, this project also has a dual social purpose: the greenhouse supplies a canteen in the Miafiori neighbourhood with zero-kilometre produce and also serves as an **educational workshop for young people** with difficulties, transforming agricultural activity into a tool for **community inclusion and regeneration**.



C6 - Reconnecting urban people with farming practices.

Brooklyn Grange

New York, USA

Brooklyn Grange is an urban agriculture project in New York, with **large farms located on the city's rooftops**. In addition to producing organic vegetables on a large scale, the company designs and builds green roofs in metropolitan areas, **promoting more resilient city models**. It is an **active community centre that organises events**, workshops and educational experiences, transforming industrial spaces into productive agricultural areas that **bring citizens closer to nature**.

Keywords:
#Urban agriculture
#Rooftop farm
#Community food awareness

Response to the identified challenge:
The answer to this challenge lies in the social value attributed to urban farming practices, seen as a fundamental tool for **reconnecting people with nature**. By bringing food cultivation directly to the rooftops of buildings, the project transforms urban spaces into places of encounter and **active participation for the community.** Through the organisation of workshops and educational activities in its gardens, Brooklyn Grange allows New Yorkers to rediscover a direct connection with nature and the value of food.



C7 - Need to diversifying urban diets.

Food In Our Schools Matters

Bridgetown, Barbados

The Food In Our Schools Matters campaign tackles the **childhood obesity crisis** in the Caribbean, caused by **poor-quality food in school canteens**. The strategic innovation is not educational, but legislative, as the campaign aims to implement strong **nutritional policies** that regulate the sale and marketing of **unhealthy foods in schools** by law. The aim is to transform the environment by creating a regulatory framework that makes healthy food options structurally prioritised and accessible for children.

Keywords:
#UPFs restriction
#Combat childhood obesity
#Food education

Response to the identified challenge:

The project responds to the challenge from the bottom up by seeking to leverage the legislative system that regulates school canteens. The main objective is to **protect children from the influence of ultra-processed food marketing** by seeking to impose a healthier and more nutritious food offering in canteens. This intervention aims to break the monotony of ultra-processed products by **introducing real diversification into the daily diet in schools**. Ensuring access to a variety of nutrients not only promotes healthier growth, but also educates the younger generation to consume more consciously, making the urban food system more resilient and less dependent on standardised consumption patterns.

WHAT WE TEACH OUR CHILDREN ABOUT FOOD MATTERS.

NOTHING AT SCHOOL SHOULD EVER ENCOURAGE UNHEALTHY CHOICES.

M5 - Globalisation

An analysis of globalisation highlights the evolution of a world economic system that has moved from a state of relative isolation to one of **total structural interdependence at a global level**. Historically, this process has developed in two main waves: the first began in the 19th century and was driven by the **industrial revolution**, while the second, from 1945 to the present day, has been accelerated by **technological innovation** and **market liberalisation**. As can be seen in ***(Fig. 3.16)***, the scale of this transformation is truly impressive. In fact, the **average volume of global imports and exports in 2024 was more than two thousand times higher than in 1800**, marking a +200,000% growth adjusted for inflation. However, this hyper-connectivity of today's global economy, characterised by deep international trade links between states, has made the system inherently more **vulnerable to shocks** (WTO, 2021). The major crises of recent decades, such as the financial collapse of 2008 and the **COVID-19 pandemic in 2019**, have demonstrated how global interdependence in production makes the system vulnerable to sudden disruptions. In the current landscape, marked by an increase in environmental hazards and growing **geopolitical tensions between countries** ***(Tab. 3.1)***, which can be considered the main **wild cards** in the system, there is an urgent need to design more resilient global trading systems. The challenge no longer lies solely in the efficiency of the value chain, but in the system's ability to absorb external shocks and ensure market stability in the face of unforeseen events.

Wild card
Events or developments with low (perceived) probability, but with high impact when they occur. Such events have the potential to significantly alter the future landscape in unpredictable ways by disrupting existing trends and projections, making them critical considerations for strategic foresight. Although wild cards cannot fully be anticipated or planned for, wild card analysis helps organisations to better adapt to surprises arising in turbulent organisational environments by identifying these events and assessing their potential implications. (CIFS, Toolkit for Applied Strategic Foresight)

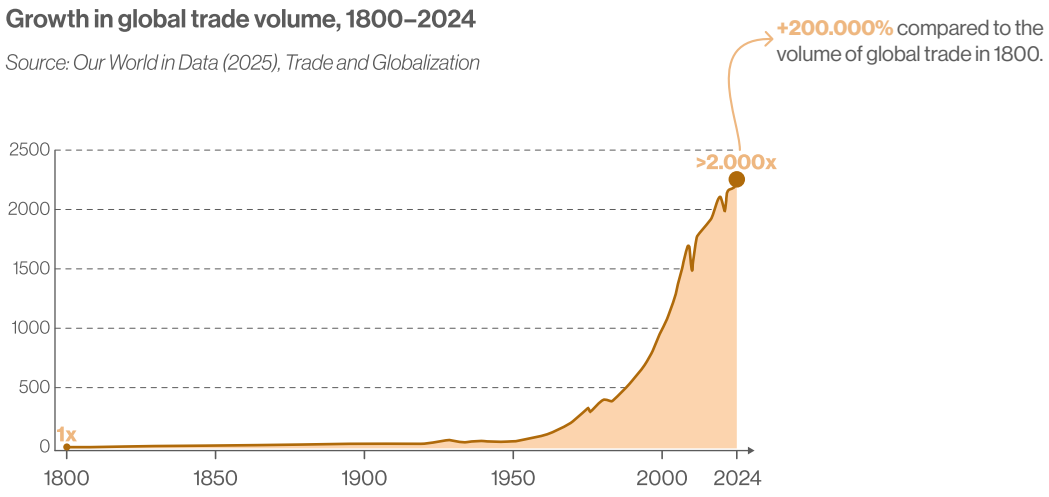


Fig. 3.16 Global trade volume (1800-2024).

Taxanomy of the main types of hazards.

Source: World Trade Report 2021 (WTO)

Hazard types		Examples
Natural risks	Geophysical hazard	Earthquakes, dry mass movements, volcanic activity
	Meteorological hazard	Extreme temperatures, storms, fog
	Hydrological hazard	Floods, landslides, wave actions (e.g. tsunamis)
	Climatological hazard	Drought, wildfire, glacial lake outburst
	Biological hazard	Bacterial/viral epidemics/pandemics (e.g. the COVID-19 pandemic), insect infestation, animal diseases
	Extra-terrestrial hazard	Asteroid impact, solar flares
Technological and operational risks	Industrial accident	Chemical or oil spills, building collapse, radiation, explosion, poisoning, fire
	Transport accident	Crashes, sinking
	Cyber disruption	Cyber-attacks, information system failures, data breaches
Socio-economic risks	Violence and conflict	War, terrorism, civil unrest, riots, pirates
	Political hazard	Adverse trade and economic policies, social tensions, institutional instability, rule of law degradation
	Macroeconomic and financial hazard	Commodity price shocks, exchange rate shocks, hyperinflation, market crash, liquidity crises, synchronized insolvencies

Tab. 3.1 Taxonomy of the main hazard types.

Impacts on the Agrifood System

Globalisation, understood as the intensification of trade flows on a planetary scale, highlights how agri-food systems have become increasingly **structurally interdependent at a global level**. Although this openness has guaranteed access to resources and food products even to nations with low self-sufficiency, it has simultaneously introduced a systemic vulnerability resulting from **deep dependence on international supply chains**. This scenario makes the system extremely sensitive and volatile in the face of external shocks, whether they be climatic disasters capable of disrupting the supply of certain foods or geopolitical tensions manifested through the imposition of tariffs and trade barriers. Throughout history,

globalisation has had a significant impact on agricultural production, with **progressive crop standardisation** leading to an ever-increasing rise in intensive monocultures of large commodities such as soy, palm oil and sugar cane (FAO, 2019). These trends, mostly driven by the private sector, but often with governmental support or facilitated by a lack of adequate regulation, have major implications for the world's ecosystems and biodiversity (FAO, 2019). The **reduction in biological diversity** in the fields directly affects the **vulnerability of territories to environmental changes** and systemic crises. At the same time, globalisation is one of the main drivers of changing consumption patterns, promoting a marked homogenisation of diets worldwide (Hanus, 2018). This trend towards nutritional standardisation makes **diets less diverse and less healthy**, fuelling, in combination with urbanisation processes, a **growing demand for convenience solutions and ultra-processed foods (UPFs)**.

Identifying Challenges and Opportunities within the Framework

From the analysis of the globalisation framework ***(Fig. 3.17)***, two fundamental challenges and one opportunity stood out. The first challenge concerns the general agro-industrial system which, having been made highly vulnerable by the interdependence of global markets, must be made ***more resilient to any geopolitical, climatic or other similar shocks (C8)*** that could block production and supply chains. In primary production, an opportunity to mitigate the crop standardisation brought about by globalisation and ***increase the food biodiversity of diets (C7)*** lies in the use and ***revaluation of local and underutilised species (O2)***. These varieties called **NUS** are essential not only for restoring agrobiodiversity, but also for ensuring nutritional security and the diversification of food systems thanks to their intrinsic climate resilience (Kalmpourtzidoual et al., 2025). Finally, in terms of consumption, globalisation has been one of the factors that has most influenced the standardisation of diets, making them less diverse and less healthy (Hanus, 2018). This trend poses the additional challenge of increasing consumer food diversification, perhaps by leveraging policies and incentives and increasing food literacy globally.

NUS (Neglected and underutilised species)
NUS are species that have been left at the margins of research and development. The word 'neglected' underlines the low level of research investments made on these species when compared with mainstream commodities and "underutilized" alludes to their untapped livelihood potentials. NUS include wild, semi- or fully domesticated plants from various food groups (cereals, vegetables, legumes, roots and tubers, fruits, spices) with diverse growth forms (field crops, trees, shrubs, vines, and others). (IFAD, 2021)

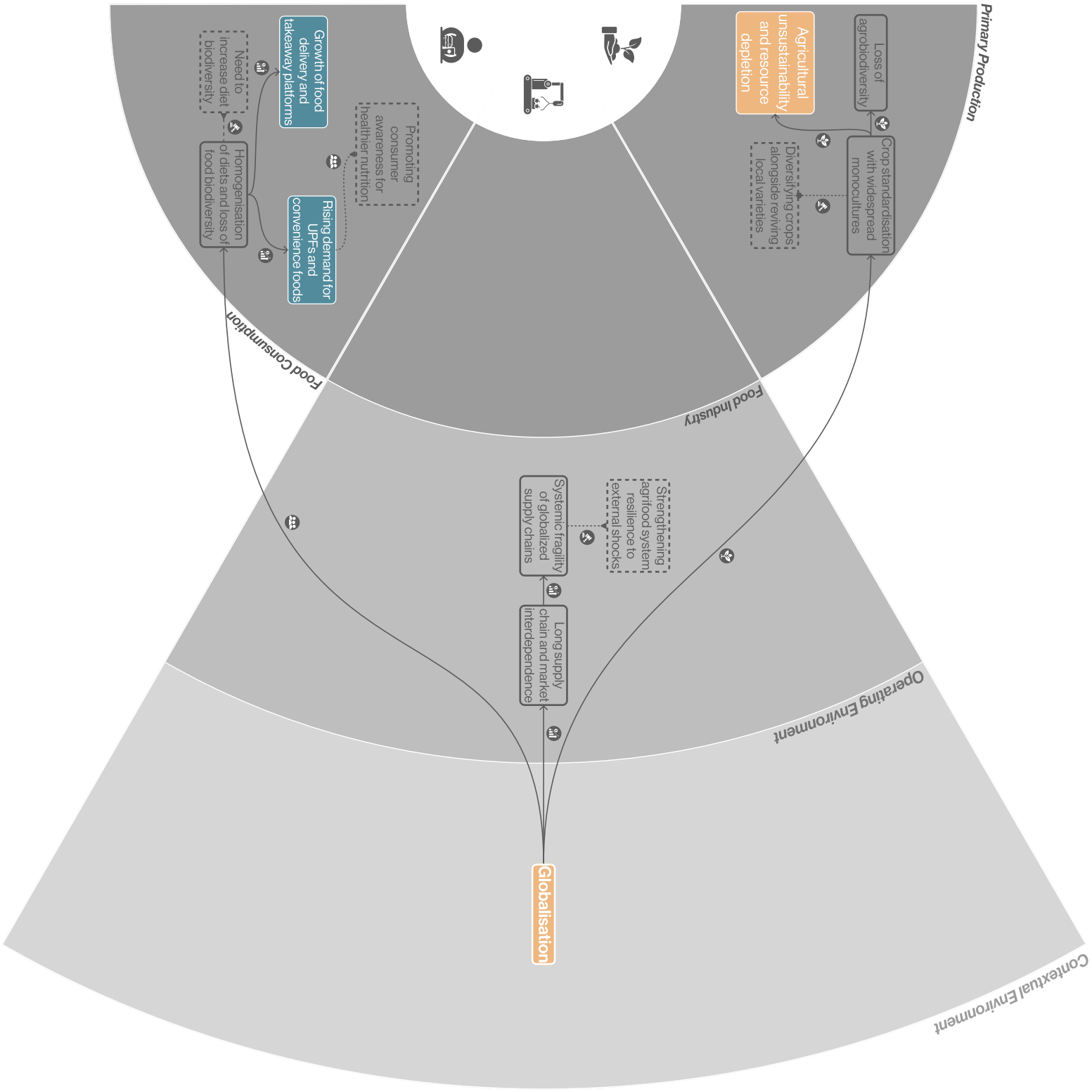


Fig. 3.17 Globalisation, Systemic Framework.

C8 - Strengthening agrifood system resilience to external shocks.

The Blue Growth farm

Genova, Italy

The Blue Growth Farm is a European project developing a **modular offshore platform** for the integrated production of fish and renewable energy. The system **optimises the use of resources such as water, soil and energy**, exploiting the marine environment and renewable sources such as wind and waves to power the entire plant. The aim is to create an efficient and sustainable **blue economy model**, reducing environmental impact and promoting more resilient food production.

Keywords:
#Offshore acquaculture
#Blue economy
#Renewable energy

Response to the identified challenge:
This project is based on the idea of creating a production model that is completely **independent from external factors**. In this context, resilience coincides with independence, since a system capable of producing its own resources autonomously is **less vulnerable to external changes**. Although it is difficult to imagine that this type of production would be sufficient to feed a large number of people, it represents an **effective response to certain crises** that may occur on a global scale.

theBlueGrowthfarm



02 - Diversifying crops alongside reviving local varieties.

BioValue

Salonicco, Greece

The BIOVALUE project, funded by **Horizon 2020 (EU)**, tackles the problem of **poor food diversity** with a holistic approach involving the entire agri-food chain, from producers to consumers. The initiative focuses on the recovery and valorisation of **neglected and underutilised species (NUS)** characterised by high genetic diversity, which are integrated into new products and recipes for the market.

Keywords:
#Neglected and underutilized species (NUS)
#Agri-food biodiversity
#Controlled and certified value chain

Response to the identified opportunity:
The project integrates the conservation of local varieties into a concrete market strategy. Biovalue does not limit itself to the scientific protection of underutilized species, but transforms them into active resources for food production, creating products that meet the tastes and needs of consumers. In this way, crop diversification ceases to be just a theoretical goal and becomes an economically advantageous activity for farmers. This approach ensures that the **restoration of biodiversity** is supported by real demand, **guaranteeing the survival of local varieties** through their stable and **profitable integration into the agri-food chain**.

BioValue

BioValue

BioValue Project App

GET IT ON Google Play

Download on the App Store



M6 - Well-being culture and the Longevity Economy

The concept of **wellness** has evolved from a passive condition to an **active and conscious pursuit**, defined as a set of intentions, choices and actions geared towards an optimal state of health and vitality. Therefore, wellness no longer concerns only the physical sphere, but takes on a **holistic and multidimensional dimension** in which various social, mental and environmental factors must act in harmony (GWI, 2023). This cultural transformation has fuelled economic growth in this sector ***(Fig. 3.18)***. In fact, according to data from the Global Wellness Institute (GWI), the global **Wellness Economy** reached a value of **USD 5.6 trillion in 2022**, with a projection of USD 8.5 trillion by 2027. However, this expansion highlights a profound **geographical disparity**, with approximately 90% of the global market concentrated in three macro areas: North America, Europe and Asia-Pacific. The gap is particularly stark when looking at per capita spending: while in North America and Europe the amount reaches USD 5.108 and USD 1,595 respectively, in Sub-Saharan Africa spending drops to just USD 68 (GWI, 2023). In these areas, the main focus remains on subsistence and basic food security, making proactive health a secondary goal to survival.

Wellness Economy
The wellness economy is defined by the Global Wellness Institute (GWI) as the set of industries that enable consumers to integrate wellness-oriented activities and lifestyles into their daily lives. This multidimensional ecosystem is divided into eleven diverse sectors, ranging from nutrition to preventive medicine. The GWI mapped and measured this market for the first time in 2014, estimating a global value of USD 3.4 trillion for 2013. (GWI, 2023)

Global Wellness Economy market size and growth projections, 2017-2027

Source: Global Wellness Economy Monitor 2023 (Global Wellness Istitute)

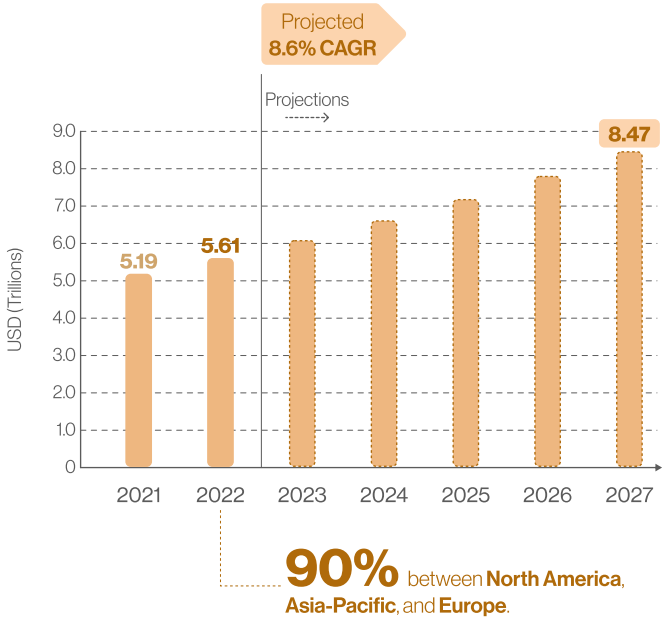


Fig. 3.18 The Ascendance of the Global Wellness Economy.

In the Longevity Economy Era

Longevity Economy
The Longevity Economy is the sum of all economic activity generated by the needs and contributions of people aged 50 and over. This concept, introduced and explored by the AARP, is not limited to direct spending on goods and services by seniors, but includes the entire economic impact, tax contributions and the value of work, both paid and voluntary, produced by this demographic group. (AARP, n.d.)

This growing focus on health and wellbeing has fuelled the phenomenon of the **Longevity Economy**, a growing global phenomenon driven not by increased fertility and births, but by a **progressive reduction in mortality** (Fengler et al. 2024). This phenomenon is clearly reflected in the change in the global demographic structure. In 2022, the number of **individuals over 50 exceeded that of young people under 15**, and this difference is set to increase significantly in the coming years ***(Fig. 3.19)***. This divergence highlights a **profound social transformation**, characterised by a **progressive ageing of the population**, which will become the driving force behind new economic and social balances.

Projected consumer class trends by age group (2022–2040)

Source: World Data Lab 2024

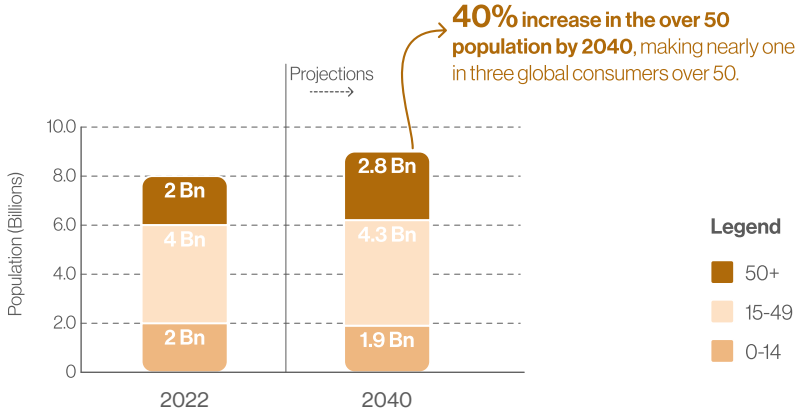


Fig. 3.19 The evolving scale of the senior consumer base.

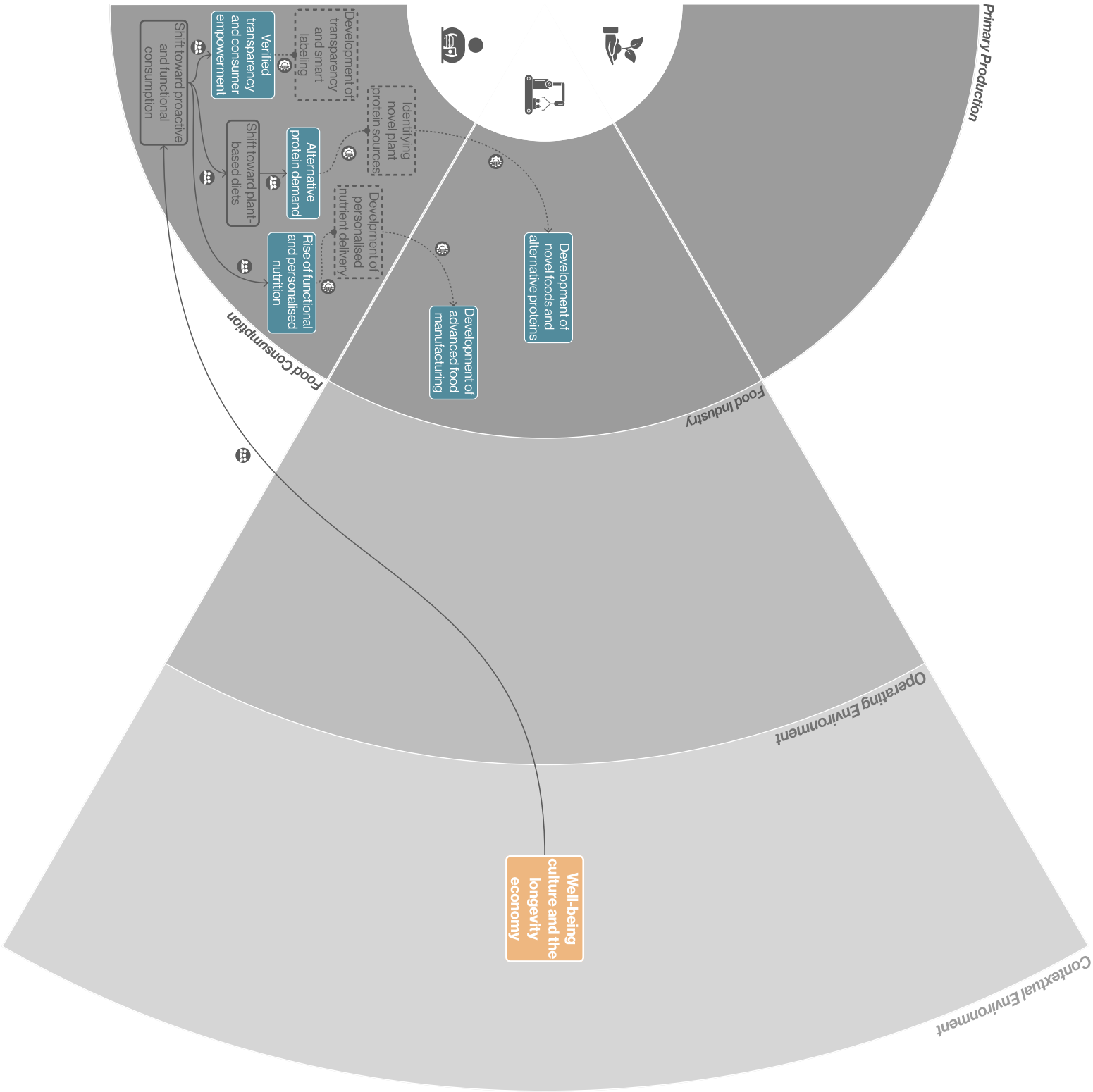
Impacts on the Agrifood System

The increased focus on healthy lifestyles, especially in North America, Europe and Asia-Pacific, has inevitably led to a change in eating habits, with nutrition being a key factor in proactive health. In 2022, the **global healthy food market** was worth **USD 1.079,3 billions**, ranking as the second **largest sector of the wellness economy** with a share of around 20% (GWI, 2023). The main impact on consumption lies in greater awareness: consumers are now more attentive

to the composition of their meals and actively seek out **brands and products that are more transparent and certified as healthy** (GWI, 2023). This is accompanied by a gradual **reduction in the consumption of animal proteins**, particularly meat, which is perceived as a food to be limited according to modern food pyramids. This **shift towards plant-based diets** has generated a growing need for supplementation and a **strong demand for alternative proteins** of non-animal origin. Finally, the sector is influenced by the growth of precision nutrition, which allows consumers to manage their health individually. Thanks to the use of technologies such as wearables, genetic testing and AI-powered meal scanning apps, nutrition is becoming a tailor-made experience. This has given rise to the concept of **"Me-ganism"**, where consumers take total control of their health through food choices guided by real-time data to make them more effective and meaningful (EIT Food, 2026).

Identifying Challenges and Opportunities within the Framework

From the analysis of the framework ***(Fig. 3.20)***, the evolution of the health market and changing consumption patterns outline three strategic opportunities for the sector. The first lies in the demand for transparency and traceability, which can be met through the ***development of smart labelling (O3)***. Adopting technologies such as blockchain overcomes the limitations of traditional labels, creating secure certification systems that guarantee consumers the veracity of the health properties declared throughout the supply chain. Secondly, the transition to plant-based diets and the search for meat alternatives are encouraging the ***exploration of new protein sources (O4)***. This opportunity is being realised through the study of novel foods, in particular algae and mycoproteins derived from fungi. These sources make it possible to formulate products that provide a complete amino acid profile, proactively responding to the growing demand for non-animal proteins with a reduced environmental impact. Finally, the emergence of precision nutrition enables the ***development of systems for personalised nutrient delivery (O5)***. Through advanced food manufacturing, which includes the use of nanotechnology and 3D printing, the industry can design foods with a composition and structure optimised for the specific biological needs of the individual user. These technologies allow for precise control of nutrient release and intake, transforming the food product into a tailor-made solution for health and longevity management.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.20 Well-being culture and Longevity Economy, Systemic Framework.

03 - Development of transparency and smart labeling.

Connecting Food

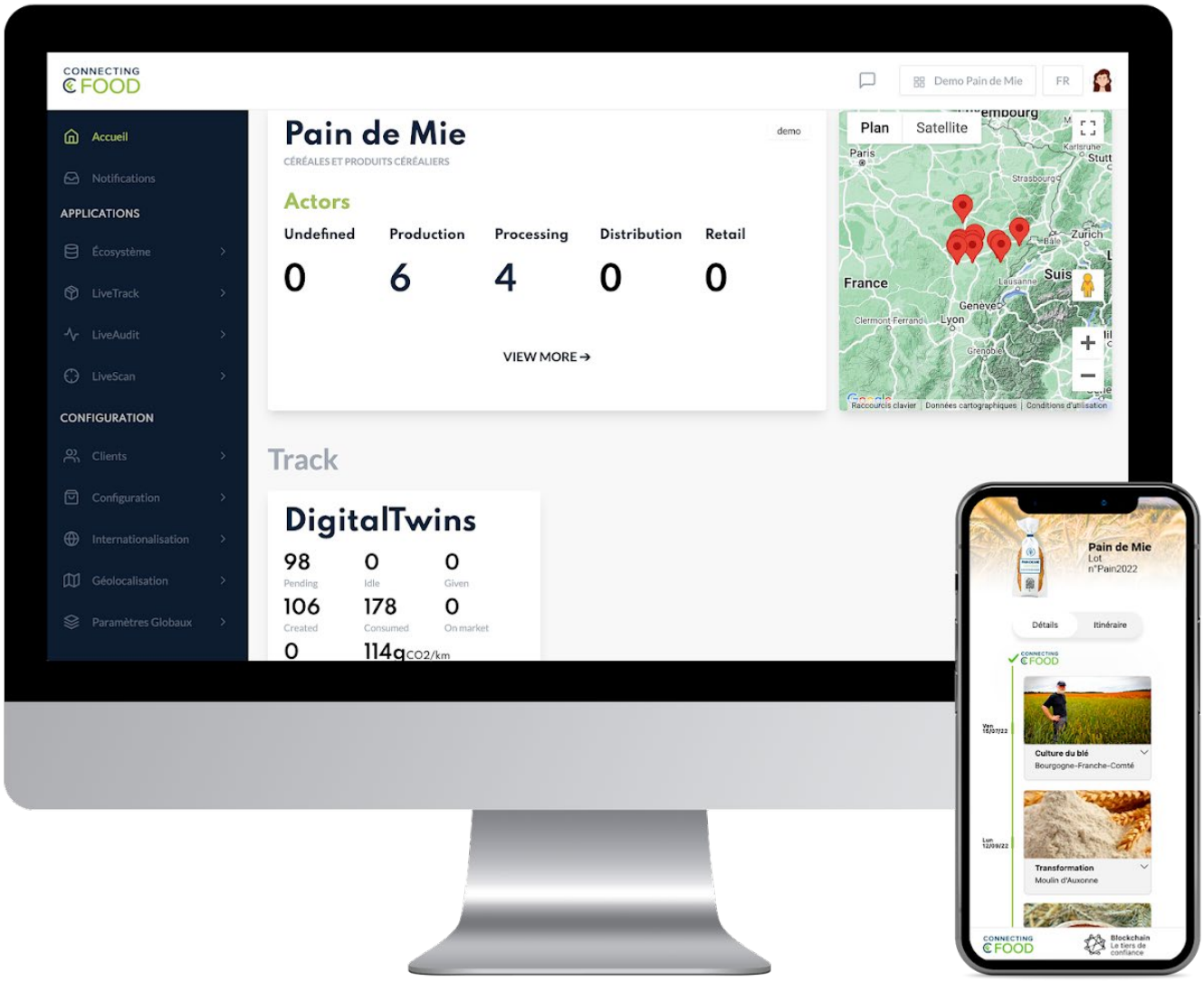
Paris, France

Connecting Food is a **digital platform** that uses **blockchain technology** to track products throughout the entire **supply chain**, ensuring total transparency throughout. Its main innovation is **"Live Audit"**, a digital auditing system that verifies in real time whether each production batch actually complies with the declared quality, ethical and health criteria. Through a **smart QR code on the packaging**, consumers can instantly access a digital certification confirming the integrity and healthiness of the product.

Keywords:
#Smart labeling
#Food blockchain
#Live audit

Response to the identified opportunity:
The project proposed by Connecting Food seizes this opportunity by **transforming the label from a static element into a dynamic tool for certifying product transparency**. Through blockchain technology, Connecting Food creates a smart labelling system where transparency extends not only to origin but also to objective compliance with **health standards**. This technology helps **tackle the issue of greenwashing** by providing citizens with immutable, verified data on nutritional quality and production processes. The label thus becomes a bridge of trust that promotes healthy products, enabling consumers to make informed choices based on reliable digital evidence rather than merely marketing promises.

CONNECTING FOOD



04 - Identifying novel plant protein sources.

Pro Future

Barcelona, Spain

Pro-Future is a European initiative funded by **Horizon 2020** and coordinated by **IRTA** (Institute for Research and Technology in Agri-Food) in Spain. The project aims to **scale up the production of microalgae** as a **sustainable protein source** for human consumption. Under the institute's guidance, research focuses on species such as **Spirulina** and **Chlorella**, optimising cultivation processes to make them economically competitive, with the aim of **integrating these nutrients into commonly used foods** such as pasta and bread, reducing the environmental footprint of the global food system.

Keywords:
#Microalgae protein
#Novel food
#Sustainable nutrition

Response to the identified opportunity:
The Pro Future project responds to this challenge by identifying **microalgae as a highly efficient protein source** that requires neither fertile soil nor fresh water for its production. Under the scientific direction of IRTA, innovation focuses on **transforming microscopic organisms into versatile ingredients for the daily diet**. This approach allows for the diversification of urban protein sources, easing pressure on traditional livestock supply chains.

PRO FUTURE



05 - Develpment of personalized nutrient delivery.

Nourished

Birmingham, UK

Rem3dy Health, based in Birmingham, has developed Nourished, a project that represents the meeting point between **3D printing** and **nutraceuticals**. The company produces personalised supplements in the form of **gummy "stacks"**, consisting of **seven layers of nutrients selected based on biometric data** and other information such as the user's wellness goals. This technology overcomes the limitations of traditional supplements by **combining different active ingredients** in a single fresh product **optimised for individual absorption**.

Keywords:
#3D printing
#Nutraceuticals
#Precision health

Response to the identified opportunity:
The project responds to this opportunity by offering a solution that overcomes the limitations of mass production, where supplements are usually the same for everyone. Thanks to the dosage control provided by 3D printing, nutrient administration becomes a **precision process with dosages calibrated to the actual biochemical needs of the individual**. The most interesting aspect is the ability to transform digital data into a **personalised physical product**, ensuring that each user receives exactly the substances they need at that moment.

Take our quiz

Discover your stack



D1 - Global geopolitical instability

Due to growing tensions and global geopolitical conflicts, people's main concerns reflect the depth of fears related to major cross-border conflicts, such as **Russia's invasion of Ukraine** and the **conflicts in the Middle East**, including the risks of instability in the Taiwan area (World Economic Forum, 2025). In this sense, the risk of geopolitical disasters represents a possible wild card capable of upsetting the current global balance. As clearly emerges from the World Economic Forum 2025 study, **geopolitical risks are now the main concern for about one in three people** ***(Fig. 3.21)***. Specifically, the two main perceived geopolitical risks are:

- ***Armed conflict between states***, identified as the most immediate material threat for the current year.
- ***Geo-economic confrontation***, which includes the use of tariffs and sanctions as instruments of political pressure.

The Perceived Risks Landscape

Source: World Economic Forum Global Risks Perception Survey 2024-2025

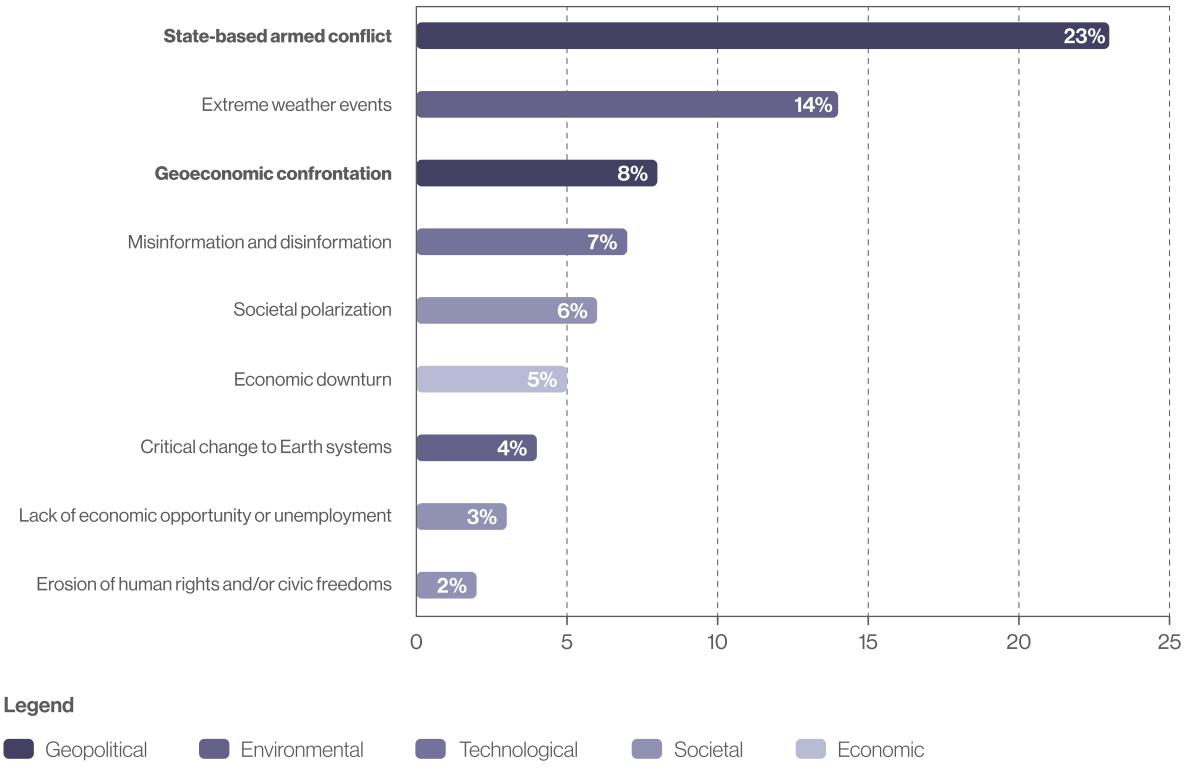


Fig. 3.21 Major risk perceptions.

Weaponisation of Trade

Weaponisation of trade
The use, or threat of use, of trade tools to exploit economic vulnerabilities and asymmetries in order to force a change in the behavior of a country, in any domain of bilateral and/or political relations. (Jaeger et al., 2020)

The global trade system is undergoing a period of intense tension due to what former British Prime Minister Gordon Brown describes as a veritable **weaponisation of trade**. According to Brown, the **Trump administration has "weaponised" the interdependence of global financial and trade markets** ***(Fig. 3.22)***, turning global economic ties into a tool of pressure that risks collapsing the entire economic order (Jolly, 2025). This aggressive **protectionist action** manifests itself through the imposition of **extremely high tariffs**, which have reached 145% for products imported from China and 10% for the rest of the world (Jolly, 2025). By exploiting the mutual dependence of markets as a weapon, this strategy calls into question **international stability** and forces a reconsideration of global supply strategies.



Fig. 3.22 The Trump administration's trade tariffs.

Impacts on the Agrifood System

Due to supply chain interdependence, **global agro-industrial systems are now extremely fragile to shocks** that suddenly block distribution. In this scenario, geopolitical conflicts are one of the main problems, highlighting the **lack of resilience of these systems** and causing sudden logistical disruptions (Mkumbukiy, 2025). As shown in ***(Fig. 3.23)***, these tensions primarily manifest as **high market volatility** and **soaring commodity prices** (Mkumbukiy, 2025). This increase inevitably inflates production costs, penalising above all

those countries most dependent on external suppliers. **Italy** is a classic example of this vulnerability, due to its **heavy dependence on Russian natural gas** in particular. The outbreak of armed conflict between Russia and Ukraine in 2022 led to a drastic increase in energy costs, resulting in **Italian companies losing competitiveness** compared to their competitors in other countries (Il Post, 2025). This dynamic is leading to a progressive **concentration of the market**, with only large companies having the strength to scale such high production costs, while small and medium-sized enterprises risk being crushed by economic pressure. On the consumption front, geopolitical conflicts drive inflation and price hikes, **eroding purchasing power** and forcing consumers to **sacrifice quality and health** for cost savings. This encourages the **consumption of ultra-processed foods (UPFs)** and convenience foods, which are chosen because they are more affordable. In several geographical areas, conflicts dramatically **exacerbate food insecurity**, as reported in the SOFI 2025 report, which highlights how 100% of the population of the Gaza Strip has faced high levels of acute food insecurity precisely because of conflicts, a condition that also affects more than half of the inhabitants of Sudan and South Sudan (FAO, 2025). In these contexts, geopolitical tensions not only increase prices but also physically prevent access to food, transforming crisis areas into nutritional emergency zones. Finally, armed conflicts lead to serious **environmental repercussions**, with the devastation of ecosystems and the loss of biodiversity making the entire system even less resilient to future shocks (Mkumbukiy, 2025).

Identifying Challenges and Opportunities within the Framework

With geopolitical volatility set to remain high in the coming years, organisations' investment in geopolitical risk forecasting and management becomes a prerequisite. Scenario planning exercises are valuable tools to help companies prepare for a range of different outcomes, with organisations needing to assess not only whether their suppliers and supply routes are vulnerable to conflict, but also what the reputational risks are in collaborating or doing business with partners who are in some way involved in a conflict (World Economic Forum, 2025). This ability to adapt and ***strengthen resilience to external shocks (C8)*** is no longer a strategic choice, but a necessity for business continuity in a global market where interdependence is a primary risk factor, especially in the agrifood sector.

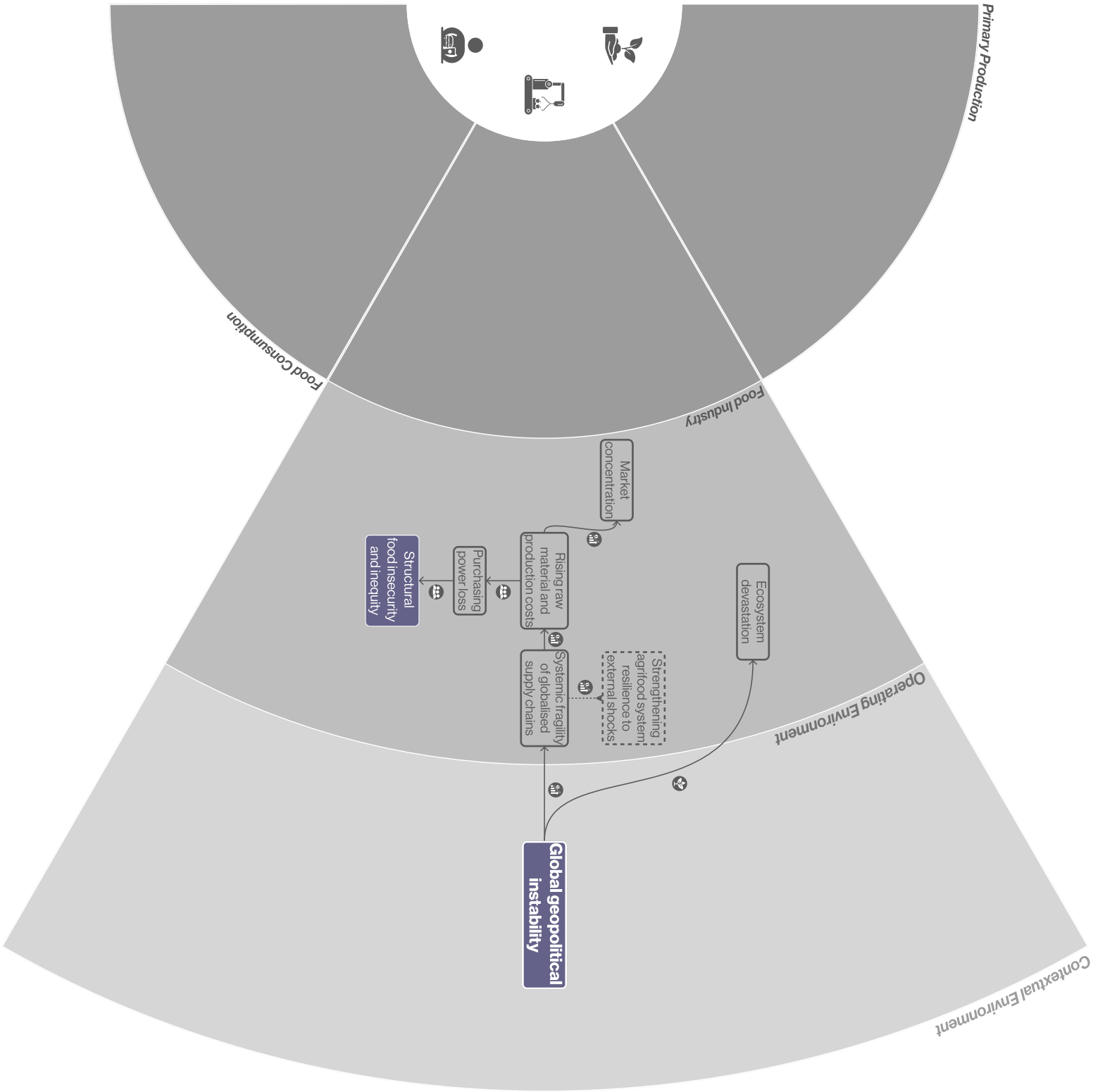


Fig. 3.23 Global geopolitical instability, Systemic Framework.

C8 - Strengthening agrifood system resilience to external shocks.

Future Food Istitute

Bologna, Italy

The Future Food Institute is an **international ecosystem** working to **make food systems more sustainable and innovative**. Founded in Bologna, its approach integrates different skills to transform the entire agri-food chain, promoting collaboration between universities, institutions and businesses. The main objective is to **generate a positive impact** that starts with agricultural production and ends with final consumption.

Keywords:
#Strategic foresight
#System resilience
#International ecosystem

Response to the identified challenge:
The project responds to this challenge by **supporting companies** in **developing strategies that look beyond traditional market dynamics**. Through the analysis of future scenarios, the institute helps stakeholders in the system to **consider complex and often unlikely risk factors**, such as geopolitical tensions or sudden climate emergencies. This type of strategic support enables companies to go beyond simply reacting to crises as they occur and instead **build proactive resilience**. Preparing for unpredictable external events and taking a longer-term view thus becomes a fundamental tool for ensuring the stability of the global agri-food system.

FUTURE
FOOD
INSTITUTE



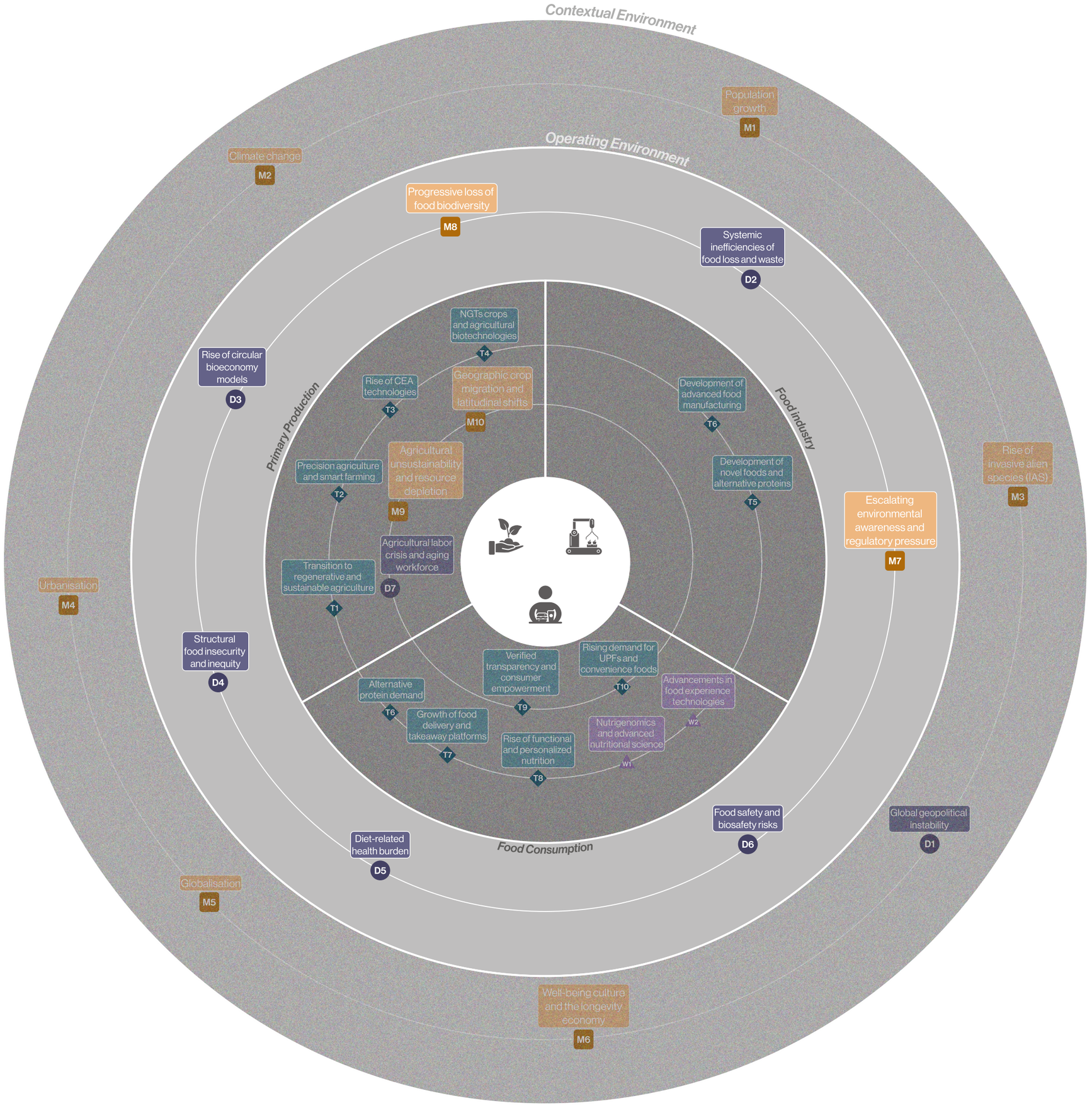
3.3 Operating Environment Scan

The analysis of the operating environment identified the factors that characterise the entire agro-industrial system from within. These are not dynamics limited to a single specific phase, but extremely relevant **systemic forces that have a significant impact on the entire agri-food system**. In this case too, the factors analysed are long-term forces, as they are mainly structural **drivers** and **megatrends** specific to the sector that already influence the current sector and will define its future development.

The **main factors analysed** are:

1. *Escalating environmental awareness and regulatory pressure*
2. *Progressive loss of food biodiversity*
3. *Systemic inefficiencies of food loss and waste*
4. *Rise of circular bioeconomy models*
5. *Structural food insecurity and inequity*
6. *Diet-related health burden*
7. *Food safety and biosafety risks*

This section highlights the factors belonging to the **Operating Environment** ***(Fig. 3.1)***, which are the elements that characterise the entire agro-industrial system from within. Each factor is examined methodically: first by visualising the relevant data that confirm the trend, followed by the Understanding Complexity phase to identify relationships, impacts and interdependencies within the agrifood system. Finally, the Tackling Challenges phase serves to identify the challenges and opportunities generated by each factor; for each of these, actual case studies have been reported which, acting as concrete solutions or suggestions, confirm the emergence of these conditions in the sector.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal

Fig. 3.1 Scanning map.

M7 - Escalating environmental awareness and regulatory pressure

The analysis of the megatrend Escalating environmental awareness and regulatory pressure highlights how, in particular, the **growing severity and awareness of the climate crisis** is pushing the agro-industrial system towards a radical transformation in the coming years. At the international level, the United Nations Sustainable Development Goals (SDGs) represent the main top-down regulatory framework, with SDG 12 in particular imposing strict standards to promote responsible consumption and production patterns to make agri-food systems more resilient. In Europe, this growing awareness is also reflected in consumer sensitivity, with Eurobarometer data confirming that **91% of citizens** consider the **sustainable management of natural resources** to be a top priority for the future of the sector (European Commission, 2024). However, it is essential to recognise that this environmental awareness is not evenly distributed, as the ability to prioritise sustainability remains closely linked to economic wealth. The **Environmental Kuznets Curve (EKC) theory**, theorized by Grossman and Krueger in 1991, describes an inverted U-shaped trajectory whereby environmental impact increases in the early stages of development and only begins to decline once a certain threshold of prosperity has been exceeded (Wang et al., 2024). This means that while advanced economies can afford to invest in innovation and strict standards, developing nations are often forced to sacrifice ecological quality to ensure basic economic growth. Currently, even in the most prosperous contexts, this path to transition is facing a sharp slowdown due to unpredictable external shocks. Recent geopolitical instability and global conflicts have forced a change of course in **national agendas**, shifting the focus towards **protectionism and short-term security of supply**. As **Maria Pia Genesin** also pointed out in her interview, the urgency of managing rising raw material costs and supply chain disruptions has made the **2030 Agenda goals more fragile**, prompting many policymakers to prioritise immediate operational resilience over long-term environmental commitments (Mkumbukiy et al., 2025).

The Green Deal and the European regulatory framework

Europe is committed to structurally transforming its economic

model to respond to the climate crisis. Central to this is the **European Green Deal**, launched in 2019, aiming for **climate neutrality by 2050** and a 55% emission reduction by 2030 (European Commission, 2019). This plan sets out a strategy for modernizing industries, ensuring a transition that is economically sound and socially fair.
In this context, the **Common Agricultural Policy (CAP)** is the key instrument for translating Green Deal objectives into the agricultural sector. This policy pursues three main environmental objectives: combating climate change, protecting natural resources, and improving biodiversity (European Commission, n.d.). With the 2023-2027 programming period, the CAP drives the transition through economic support linked to ecological results. The system allocates **40% of the total budget to climate action**, while ecological schemes reserve 25% of direct payments for those who adopt advanced voluntary practices, such as organic farming or soil carbon sequestration (European Commission, n.d.). Completing this regulatory framework is the **Farm to Fork strategy** ***(Fig. 3.24)*** which acts as the operational arm to make the entire food system more equitable, healthy, and environmentally friendly. Its aim is to ensure that every stage of the value chain has a neutral or positive environmental impact, improving security of supply through a constant search for innovation (European Commission, 2024b). Taken together, these measures confirm that European regulatory pressure is transforming environmental sustainability into a structural and indispensable condition for operating in the contemporary agro-industrial sector.

The Pillars of the farm to fork strategy

Source: Farm to Fork Strategy, European Commission (n.d.b)

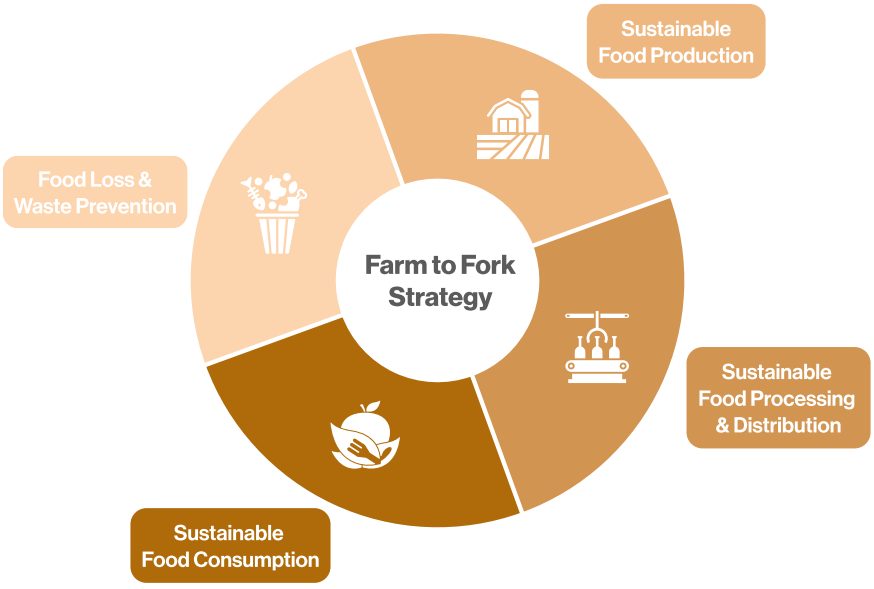


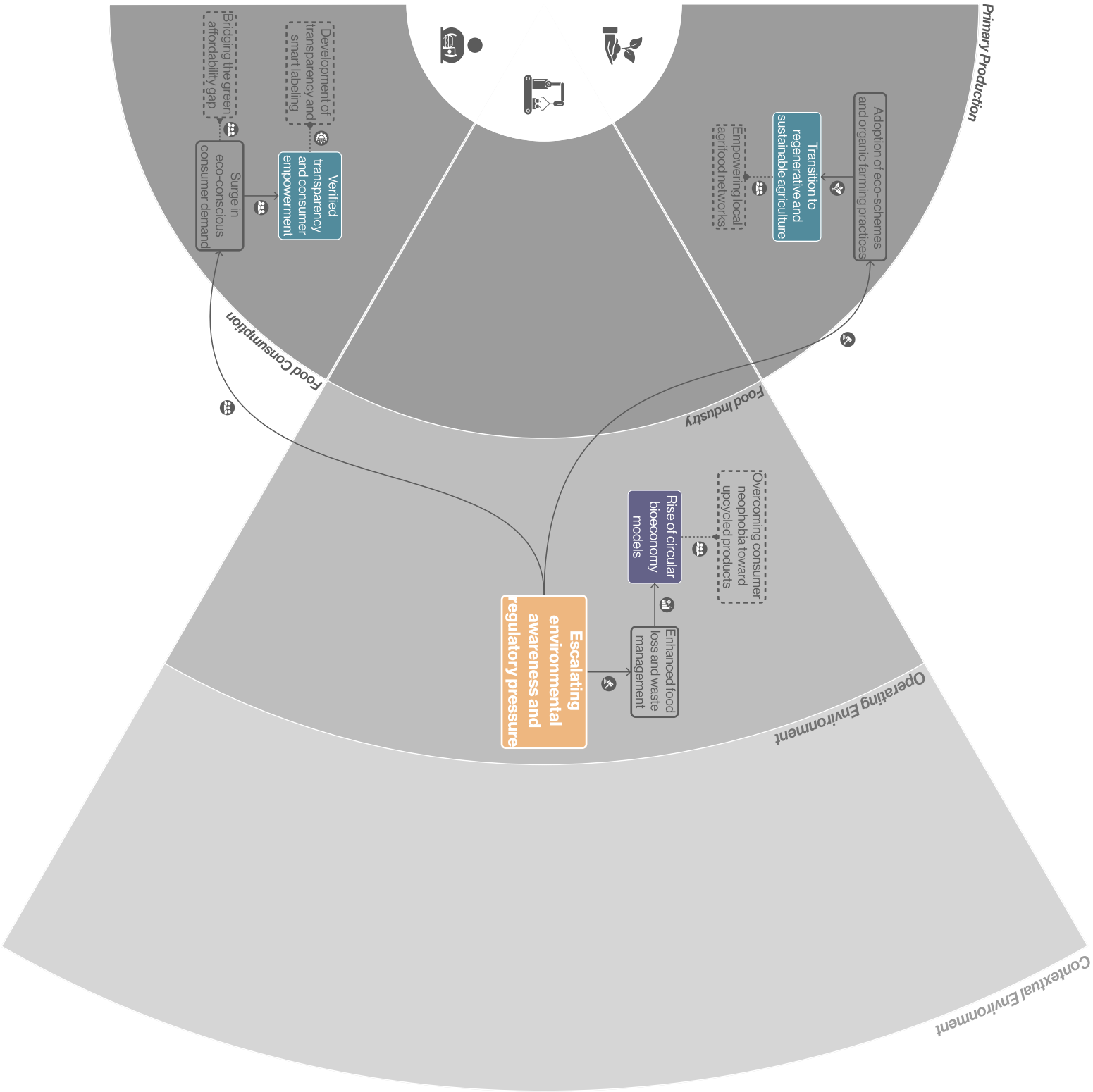
Fig. 3.24 European Farm to Fork strategy.

Impacts on the Agrifood System

Analysis of the framework relating to escalating environmental awareness and regulatory pressure ***(Fig. 3.25)*** highlights a now global factor, closely linked to human activities and global warming. The agri-food sector is one of the protagonists of this transformation, guided by the international objectives of **Agenda 2030,** in particular **SDG 12**, which aims to ensure responsible production and consumption patterns. This approach requires rigorous attention to resource optimisation and a drastic reduction in food loss and waste, pillars of the European Farm to Fork Green Deal strategy that is fuelling the **emergence of upcycling and circular bioeconomy models** for the valorisation of waste. At the same time, SDG 12 is influencing the evolution of consumption, manifesting itself in increasingly eco-conscious **demand and a call for transparency from consumers**, supported by the fact that **91% of European citizens** view sustainable resource management as an absolute priority for the sector's future. (European Commission, 2024). This awareness is also reflected in the primary production sector through agricultural policies that enhance eco-schemes and farming practices, responding to the demand for certified products and pushing the sector towards the adoption of **sustainable and regenerative production models**.

Identifying Challenges and Opportunities within the Framework

This structural evolution, driven by regulatory requirements and climate urgency, outlines operational trajectories that redefine various dynamics and roles within the system. On an industrial level, the ***expansion of upcycling requires deep awareness to overcome consumer neophobia (C9)***, transforming waste into a noble and widely accepted ingredient. This push towards ecological models becomes an opportunity to ***enhance local networks (O6)***, protecting small rural producers who choose quality and high standards over large volumes. However, the transition must address the challenge of the ***economic competitiveness of new "green" products (C10)***. In fact, efforts must be made to reduce the price gap between ecological products and the mainstream market, so that sustainability does not remain an elite choice. In this context, the ***integration of blockchain and smart labels (O7)*** responds to the demand for radical transparency, democratising the sector and enabling informed choices based on full traceability of impact.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.25 Escalating environmental awareness and regulatory pressure, Systemic Framework.

C9 - Overcoming consumer neophobia toward upcycled products.

Polito Food Design Lab

Turin, Italy

The Politecnico di Torino Food Design Lab is a **pop-up laboratory** that collaborates with external organizations and companies to **develop food design** and **food awareness projects**. The lab's activities focus on the management and prevention of **food loss and food waste**, promoting a design culture that integrates sustainability and social innovation. Through this flexible structure, the Lab transforms academic research into concrete actions in the field, **proposing new ways of interacting with food resources throughout the entire supply chain**.

Keywords:
#FoodDesign
#Upcycling
#ConsumerEngagement

Response to the identified challenge:
The project responds to this challenge by offering **educational workshops** and awareness-raising activities involving **different age groups in various social contexts**. To overcome mistrust of upcycled products, the Food Design Lab adopts a **participatory approach** where citizens interact directly with food waste. Under the guidance of mediators, participants experiment with recipes and dishes that make use of industrial by-products, such as apple pomace. This practical experience **transforms the perception of waste** from refuse to valuable ingredient, actively combating food neophobia. By demonstrating the gastronomic and nutritional potential of what is usually discarded, the workshop **helps consumers become familiar with the concept of upcycling**, making the adoption of regenerated products an informed and unbiased choice.



Appl[e]ause

Prove impasti

Politecnico di Torino
1859
Dipartimento di Architettura e Design

FDL
Polito Food Design Lab

panacea
social farm

06 - Empowering local agrifood networks.

Cortilia

Milan, Italy

Cortilia is a foodtech company founded in Milan that operates as an **online farmers' market** through a dedicated **digital platform**. The service allows **urban consumers to purchase fresh, artisanal products directly from local farmers**, breeders, and producers, receiving them conveniently at home through an app. The model is based on a short supply chain, eliminating unnecessary intermediaries and ensuring a **direct link between producers and consumers**, with a strong focus on seasonality and the quality of raw materials.

Keywords:
#Local networks
#Short supply chain
#Urban health

Response to the identified challenge:
The project responds to this opportunity by **focusing on promoting rural work and activities**, which are too often ignored by large-scale distribution channels. The key point is the ability to **empower local producers** by offering them an important showcase in the city and compensation that **recognizes the real value of their work**. At the same time, Cortilia works to **improve diets in urban contexts** by making genuine, minimally processed foods accessible that are usually difficult to find for city dwellers. This creates a system in which rural areas and urban centers support each other, promoting a solid and transparent local agri-food network.

Cortilia

la campagna a casa tua



C10 - Bridging the green affordability gap.

Babaco Market

Milan, Italy

Babaco Market is a subscription service that **recovers fruit and vegetables** that **do not meet aesthetic standards or surplus products** that would otherwise be discarded by large retailers. The company works directly with local farmers to collect products that are excellent in taste and nutritional properties but considered non-compliant for purely aesthetic reasons. These products are packaged in boxes and delivered directly to the consumer's home, reducing the number of steps in the supply chain and promoting regional production that would otherwise be lost.

Keywords:
#Food waste
#Consumer awareness
#Green affordability

Response to the identified challenge:

By **recovering surplus or imperfect but nutritionally excellent products**, the company is able to generate profit by adding value to what would otherwise be discarded, while o**ffering healthy, local food at lower prices than conventional channels**. In this context, consumer awareness plays a key role because it allows people to understand that **aesthetic imperfections are completely unrelated to the nutritional value of the product**. Ethical choices are therefore no longer a luxury for the few, but become an accessible daily practice that reconciles economic savings with support for quality agriculture, making the ecological transition more inclusive for everyone.

babaco market



M8 - Progressive loss of food biodiversity

The global agri-food system is undergoing a dangerous simplification that threatens the stability of the planet. Although humanity has historically cultivated over 6,000 plant species for food, today's production reality is drastically different. In fact, **less than 200 species contribute substantially to food production**, and just nine (sugar cane, maize, rice, wheat, potatoes, soybeans, oil-palm fruit, sugar beet and cassava) account for **66% of the world's total agricultural production** ***(Fig. 3.26)*** (FAO, 2019). This genetic erosion is not limited to agricultural production, but also affects livestock production, which is based on around 40 animal species, only a handful of which provide the vast majority of meat, milk and eggs (FAO, 2019). Even in aquatic ecosystems, despite the harvesting of over 1,800 plant and animal species, 33% of global fish stocks are now considered overexploited (FAO, 2019). This drastic decline in food sources is the direct result of an industrial model that has prioritised **efficiency and high yields**, sacrificing diversification in favour of immediate profits and simplified management, making the agri-food sector an inherently unsustainable system. Furthermore, this phenomenon is further exacerbatedby societies and their consumption patterns, especially in urban contexts, where the growing dependence on ultra-processed and less fresh foods **has distanced consumers from natural cycles**, reducing the intake of essential bio-nutrients and **impoverishing biodiversity directly on our plates** (FAO, 2019).

Distribution of global agricultural production by crop type

Source: The State of the World's Biodiversity for Food and Agriculture, FAO, 2019

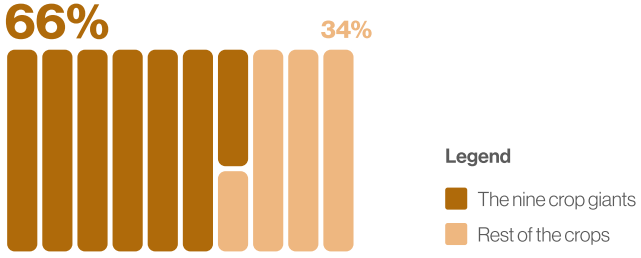


Fig. 3.26 Concentration of agricultural food biodiversity.

The emergence of the Resilience Gap

Specialised Industrial Agriculture
The Specialised Industrial Agriculture acts as a socio-economic paradigm that aims to maximise efficiency through large-scale production and a rigid division of labour, replicating the logic of manufacturing processes. In this system, producers focus on individual stages or a few specific items in order to optimise overall yield. In direct contrast to this model, the Diversified Agroecological Farming emerged, aimed at maintaining a plurality of sources and ensuring ecosystem resilience (IPES-Food, 2016).

The expansion of **Specialised Industrial Agriculture**, now the predominant model in industrialised countries, has reconfigured global food systems around an **obsessive pursuit of efficiency and monoculture**. This approach is based on selecting a few specific species and maximising their yield to meet the rigid requirements of logistics and large-scale food processing. However, this focus has paradoxically made the entire global production system **more fragile and less resilient to shocks**. Designing supply chains with an exclusive focus on optimising output has led to the systematic sacrifice of diversification, which in nature is the primary defence against unpredictability. A diversified system is inherently more likely to absorb shocks, as the variety of its components ensures a flexibility that industrial specialisation has progressively eliminated. This has created a profound critical gap between the productive performance and structural stability of the system. The pursuit of uniformity has led to dangerous genetic **standardisation of crops**, generating widespread vulnerability to epidemics and biotic and abiotic stresses ***(Fig. 3.27)*** (IPES-Food, 2016). The historical evidence of this fragility is evident in the **Great Irish Famine of 1845**, where absolute dependence on a single variety of potato caused total socio-economic collapse in response to the attack of a single pathogen. Similar episodes demonstrate that when biological variability is lost, the system loses the tools it needs to respond to external threats. By breaking down this complexity, industrial agriculture has created dangerous bottle necks where efficiency is no longer an advantage but becomes a global risk.

A timeline of disease outbreaks in highly specialised systems
Source: From Uniformity to Diversity, IPES FOOD, 2016

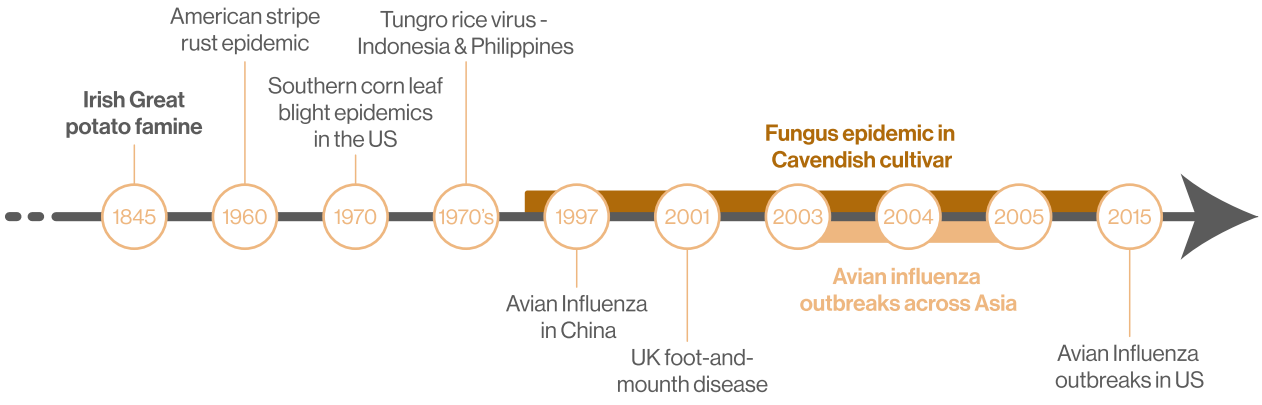


Fig. 3.27 Timeline of disease outbreaks in highly specialised systems.

Impacts on the Agrifood System

The problem of food biodiversity loss lies in the progressive **genetic uniformity** of seeds and animal breeds, which generates widespread **vulnerability to epidemics** and biotic and abiotic stress. This drastically reduces the resilience of agri-food systems, making them more sensitive to shocks than in a diversified model (IPES-Food, 2016). As shown in the framework ***(Fig. 3.28)***, the lack of variability compromises crop stability, as the **spread of pathogens** can trigger food insecurity crises and seriously threaten global biosecurity. Biological homogeneity acts as an incubator for **food safety risks** and zoonotic diseases, such as **Avian influenza**, which finds an ideal environment in standardised animal populations to spread and mutate rapidly. A second line of impact concerns consumption, where the loss of biodiversity favours the production of standardised raw materials, inevitably leading to an increasingly **marked homogenisation of diets**. This process deprives people of essential micronutrients, and since dietary diversification is a fundamental pillar of health, nutritional simplification increases the risk of developing chronic problems and diet-related health burden. Finally, crop uniformity outlines an agricultural system incapable of self-regulation, which must consequently intensify the use of pesticides and fertilisers to prevent the development of diseases and critical issues in the harvest. This fuels a **vicious circle** that makes the traditional agricultural production model increasingly unsustainable from an environmental point of view. The relentless pursuit of efficiency has transformed specialisation into a structural risk that leaves the system without the necessary defences to cope with the unpredictability of the future.

Avian influenza
Avian influenza is a highly contagious viral disease that primarily affects poultry and wild waterfowl. It can be classified into highly pathogenic (HPAI) or low pathogenic (LPAI) strains, depending on the molecular characteristics of the virus in question and its ability to cause illness and death in chickens. Its rapid spread within poultry farms makes strict biosecurity protocols essential, not least because LPAI strains can mutate into more destructive HPAI forms. In addition to the economic impact, the virus poses a zoonotic risk as it can be transmitted to humans or other animals through direct contact or via contaminated environments. (EFSA, 2026)

Identifying Challenges and Opportunities within the Framework

Genetic homogenisation, which generates fragility in agri-food systems, highlights the challenge of ***strengthening these systems to improve their resilience (C8)*** and avoid global crises. With regard to consumption, the issue of food diversification is crucial, and ***consumers must be educated (C11)***, seeking to raise their awareness of the risks of homogenised consumption, perhaps by leveraging food influencers and social networks. Finally, from a primary production perspective, an opportunity to reduce this unsustainable genetic homogenisation lies in the ***revitalisation of underutilised species (O2)*** capable of bringing biodiversity and valuable nutrients to diets.

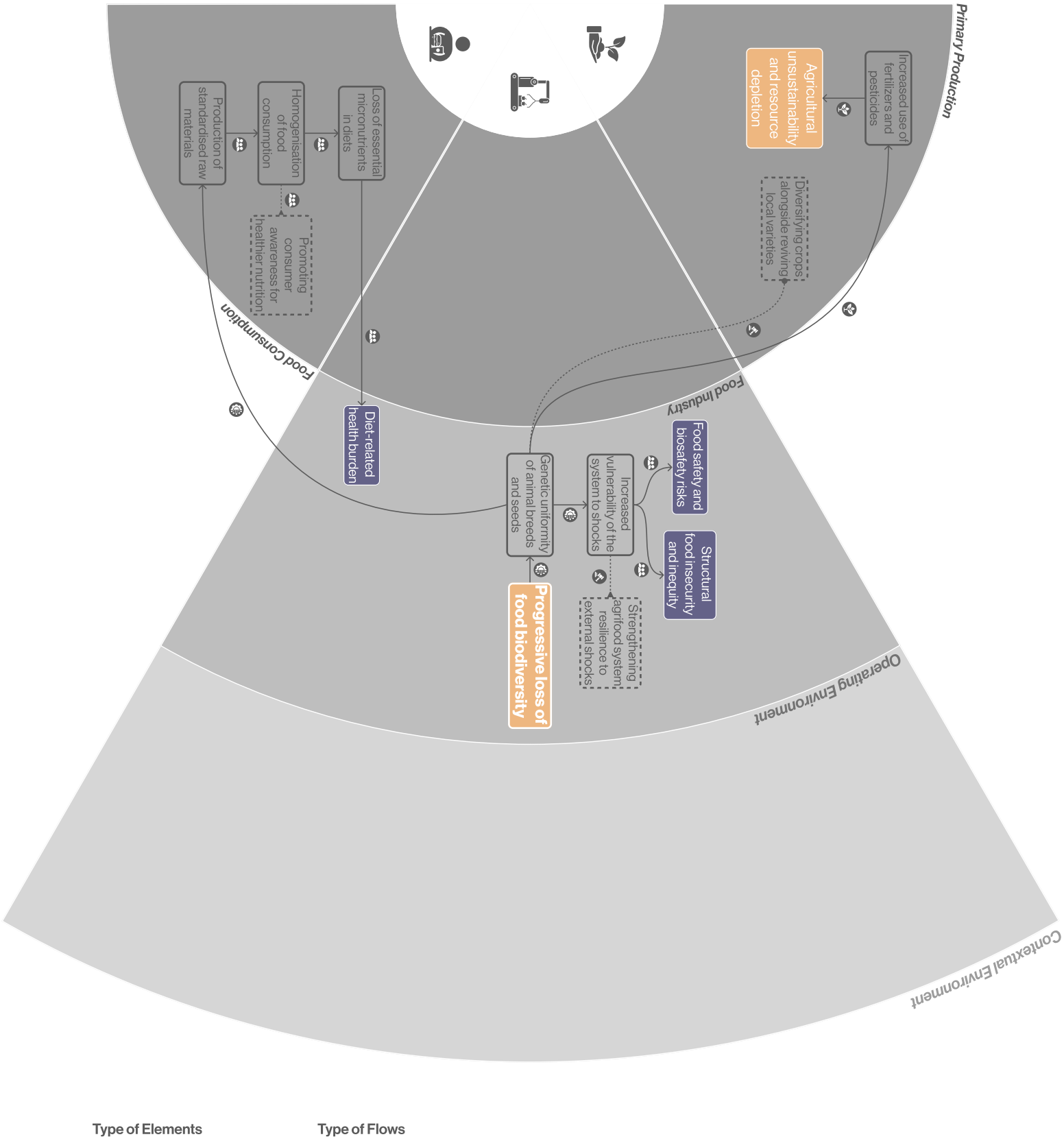


Fig. 3.28 Escalating environmental awareness and regulatory pressure, Systemic Framework.

C11 - Promoting consumer awareness for healthier nutrition.

FoodUnfolded

Lovanio, Belgium

FoodUnfolded is a **multimedia platform** created by **EIT Food** that aims to reconnect citizens with the food system through transparent and science-based communication. The project uses **digital storytelling** to explain the **origins of food**, production processes and innovations in the agrifood sector. Through a widespread presence on social media, the digital laboratory translates academic research into **accessible and visually stimulating content**, stimulating curiosity and critical debate among consumers around the world.

EIT Food
EIT Food is Europe's leading community dedicated to agri-food innovation, supported by the European Union. This ecosystem connects research centres, universities and businesses to promote a healthier and more sustainable food system. Its activities focus on climate neutrality, supply chain transparency and consumer education. By investing in start-ups and technology projects, the organisation accelerates the transformation of the sector to address global health and environmental challenges. (EIT Food, n.d.)

Keywords:
#Digital storytelling
#Food literacy
#EIT Food

Response to the identified challenge:
The project responds to this challenge by using digital channels to **combat the homogenisation of diets**, one of the main factors in biodiversity loss. Through targeted social media campaigns, FoodUnfolded **educates consumers to diversify their food choices**, highlighting forgotten ingredients or lesser-known crop varieties that are essential for the health of ecosystems. The educational approach connects individual health with environmental stability, encouraging people to vary their daily diet. This reduces pressure on the few dominant industrial crops and encourages the protection of biological diversity. In this way, digital awareness becomes a practical tool for changing consumption habits, **transforming citizens into conscious and active players** in the protection of food biodiversity.


FoodUnfolded®

D2 - Systemic inefficiencies of food loss and waste

The inherent inefficiency of the food system manifests itself through a massive waste of resources, affecting about **one third of all food produced globally** . **Target 12.3** of the 2030 Agenda frames this phenomenon by distinguishing between **food loss** (loss that occurs during production, harvesting and distribution) and **food waste** (waste that occurs at the point of sale and consumption) setting the goal of halving food waste by 2030 and reducing food losses by at least 25%. The mapping of these inefficiencies is entrusted to two institutional custodians who analyse different segments of the value chain:

- ***FAO*** is responsible for monitoring **target 12.3.1(a)** on food loss, focusing on reducing losses along production and supply chains, including crucial post-harvest stages.

- ***UNEP***, on the other hand, is responsible for **target 12.3.1(b)** on food waste, with the programmatic goal of halving global per capita food waste at the retail and final consumption levels.

Currently, it is estimated that around **14% of the world's food is lost in the early stages** of the supply chain, a loss that generates an economic cost of around USD 400 billion each year (FAO, 2019). Added to this is a further **19% of food wasted in the retail and consumption stages**, highlighting a structural failure which, according to FAO estimates, deprives **1.26 billion hungry people of potentially sufficient nutrients each year** (UNEP, 2024). These inefficiencies are not only an economic burden, but also a primary driver of ecological instability: the loss of food resources contributes to **8-10% of global greenhouse gas emissions**, fuelling global warming and an increase in extreme weather events (FAO, 2019). Overcoming this linear logic is the first strategic necessity for ensuring food security without exhausting the planet's limits.

FAO
FAO (Food and Agriculture Organisation), based in Rome, is the United Nations agency that leads international cooperation to defeat hunger and ensure food security. Through the involvement of 194 members and a widespread presence in over 130 countries, the organisation works to ensure universal access to high-quality diets. Its mission is to transform global agri-food systems to support healthy and active lives, serving as the main technical centre for the definition of global agricultural standards and policies. (FAO, n.d.)

UNEP
Founded in 1972, UNEP (United Nations Environment Programme) is the world's leading authority responsible for guiding the response to the triple planetary crisis: climate change, biodiversity loss and pollution. Operating as a neutral interlocutor between governments and civil society, it promotes strategic international agreements and coordinates global environmental action for the protection of natural heritage. (UNEP, n.d.)

The Household as a node of Inefficiency

The gravity of systemic inefficiency emerges strongly in the final stages of the supply chain. In 2022, the world generated approximately **1.05 billion tons of food waste** ***(Fig. 3.29)***, combining the retail, catering, and household (UNEP, 2024). This enormous volume

corresponds to an average of **132 kilograms per capita per year**, of which 79 kilograms, or about **60% of the total food waste, was produced within the home** (UNEP, 2024). This concentration identifies the domestic environment as the most critical point in the system, generated by consumer behavior, but above all, it is the result of a model that has separated consumers from the biological cycles of food. In this context, awareness-raising practices and education on the circular economy become fundamental in transforming citizens from the end point of waste to conscious managers of food and resource flows. To this end, the **International Day of Awareness of Food Losses and Food Waste (IDAFLW)** was established in 2019 by FAO and UNEP, with the first official celebration taking place on September 29, 2020. Its creation coincided with the COVID-19 pandemic crisis, a context that acted as a catalyst, exposing the vulnerability of the agri-food system and making coordinated global mobilization urgent. Through this joint commitment, the event promotes the integration of systemic solutions and behavioral changes, elements that are now considered essential for strengthening the resilience of ecosystems and ensuring long-term food security.

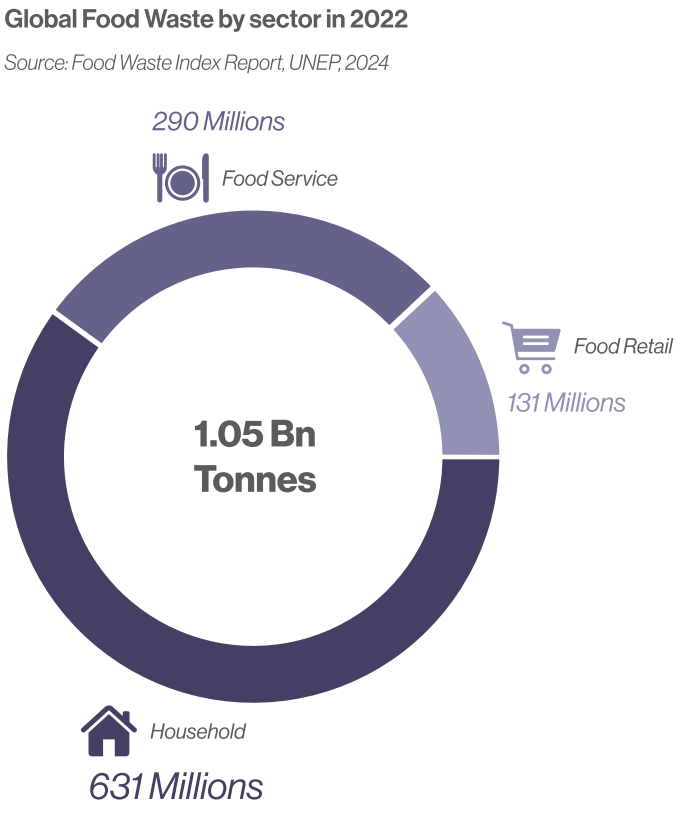


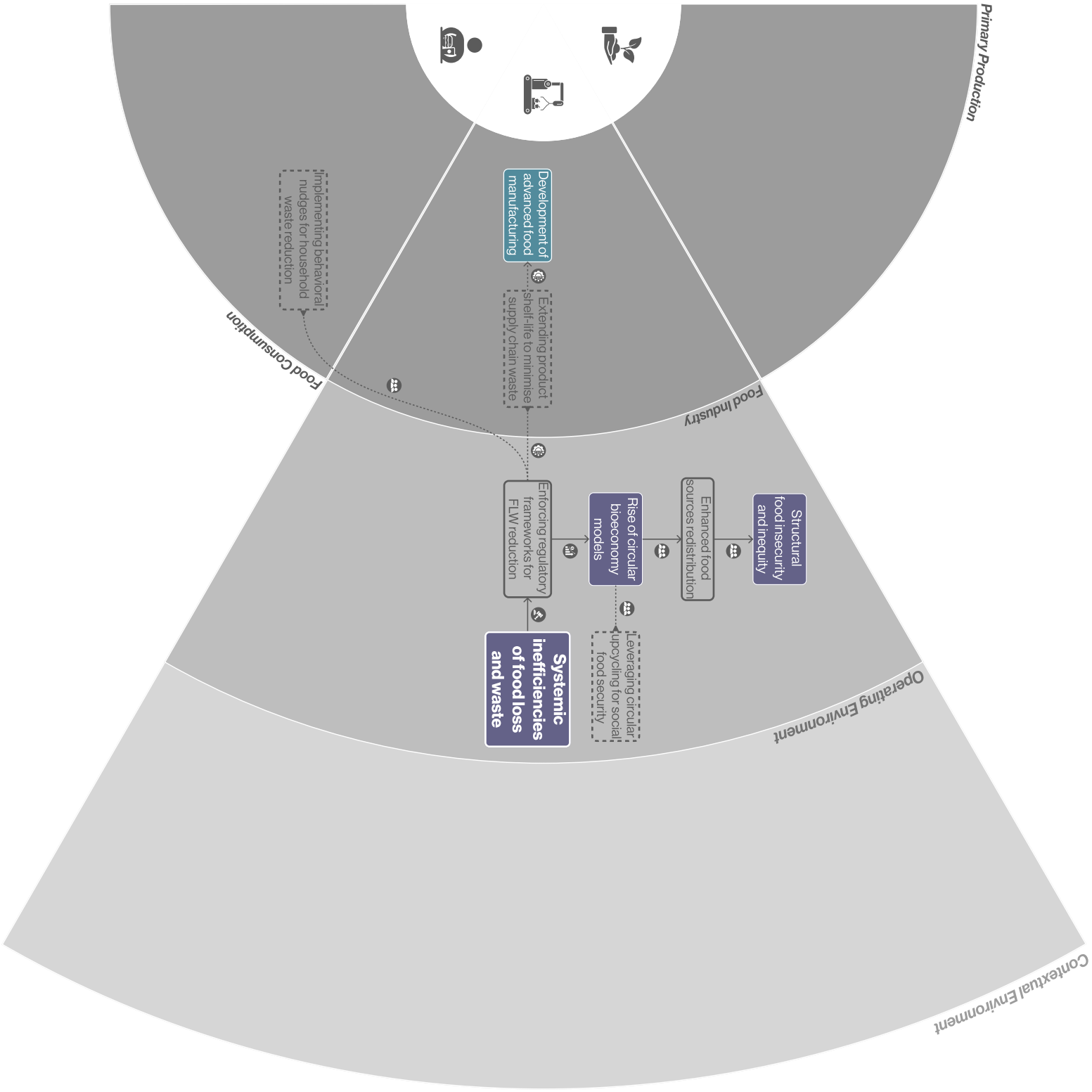
Fig. 3.29 Global food waste by sector in 2022.

Impacts on the Agrifood System

The current agro-industrial system is **profoundly inefficient**, generating **huge amounts of food loss and waste** throughout the value chain, which, to today, are not exploited in any way. In a context characterised by a progressive decrease in available resources, mainly due to global warming and the need to increase production to cope with the growth in the world population, optimising what is already produced becomes a fundamental requirement for the stability of the system. From a regulatory point of view, **Target 12.3 of the 2030** Agenda acts as a driver for this reduction, pushing for the search for new solutions and **circular economy practices** capable of exploiting the by-products of the supply chain. This transition aims to mitigate significant economic and environmental damage by transforming systemic inefficiencies into a strategic resource through **bioeconomy models**. The value of this approach is not only operational but also deeply social. In fact, as highlighted by UNEP, recovering what is currently wasted could provide the nutrients needed to feed 1.26 billion people suffering from hunger worldwide (UNEP, 2024). Within this framework, **reducing inefficiencies becomes a real opportunity in the fight against food insecurity and inequality**, proposing a circular model where waste recovery becomes a lever for ensuring the resilience of the global agro-industrial system.

Identifying Challenges and Opportunities within the Framework

As shown in the framework ***(Fig. 3.30)***, the legislative drive to mitigate food waste and loss presents three primary challenges for the agri-food sector. The first concerns the application of ***upcycling and circular economy practices to valorise food waste (C12)***, providing new nutrients that can be an additional resource to meet global food demand and fight the food insecuruty problem. Within the food industry, this regulatory push has led to the search for solutions that aim to reduce waste, for example by ***extending the shelf life of products (C13)***. The use of advanced technologies for the design of smart packaging makes it possible to extend the shelf life and quality of highly perishable foods (Halloran et al., 2014). Finally, with regard to consumption, since most food waste is generated at home, it is necessary to raise consumer awareness of this issue, bringing them closer to the value of food through ***behavioural nudges to reduce household waste (C14)***.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.30 Systemic inefficiencies of food loss and waste, Systemic Framework.

C12 - Leveraging circular upcycling for social food security.

Upcycled Foods Inc.

Berkeley, USA

Upcycled Foods Inc. is a **B2B company** specialising in creative **recycling that transforms food industry by-products into innovative ingredients** for the global market. The company operates as an innovation laboratory, collaborating with producers and brands to develop solutions that **scale the circular economy in the agri-food sector**. Their commitment focuses on creating products that enhance previously overlooked resources, such as ReGrained SuperGrain+, an ingredient derived from the recovery of spent grain from beer that enriches new ready-to-eat foods with fibre and protein.

Keywords:
#Upcycled food
#Circular economy
#Super food

Response to the identified challenge:
The project responds to the challenge by **recovering nutrients that would otherwise be lost**. By valorising waste streams from large-scale industrial production, the company **increases the nutrient density of products available on the market** without consuming additional natural resources. This circular upcycling approach contributes to social stability by enabling the creation of more resilient and accessible supply chains, capable of transforming production inefficiency into a source of nutritious food for the community.

UPCYCLED FOODS INC™



C13 - Extending product shelf-life to minimise supply chain waste.

Apeel Sciences

Goleta, USA

Apeel Sciences is a Californian company that has developed innovative technology to **combat food waste through materials science**. At the heart of the project is an edible, **plant-based protective film** that is applied to the **surface of fruit and vegetables**. This invisible barrier mimics the **natural functions of the skin**, retaining moisture inside the fruit and **limiting oxygen ingress**. By using components found in the seeds and skins of each plant, Apeel is able to **slow down the oxidation and transpiration processes** that cause premature deterioration of fresh products.

Keywords:
#Shelf life
#Plant based film
#Edible Packaging

Response to the identified challenge:

Apeel's technology **extends the shelf life of products** throughout the supply chain. By **slowing down the natural deterioration process**, the system allows producers and retailers to better manage their stocks, **preventing large quantities of food from being discarded** because it rots before it is purchased. This solution not only reduces physical food waste, but also optimises the environmental impact of logistics. In addition, longer product shelf life allows for **more efficient transport** and **reduces the need for intensive refrigeration systems**, making the distribution chain more resilient and less subject to the temporal inefficiencies of the global food market.

Apeel Sciences™



C14 - Implementing behavioral nudges for household waste reduction.

Mimica - Bump

London, UK

Mimica is a technology company that develops smart solutions to **combat domestic food waste** through the use of dynamic indicators. In particular, its main innovation is **Bump**, a **tactile label** capable of **indicating the actual freshness of a product** in real time. Unlike static expiry dates printed on packaging, which are often conservative estimates, this technology contains a **plant-based gel** that reacts to actual changes in the temperature of the food. As long as the product is fresh, the label remains smooth, but becomes rough and uneven when the food is no longer safe for consumption.

Keywords:
#Behavioral nudges
#Dynamic labelling
#Haptic feedback

Response to the identified challenge:

The project responds to this challenge by using tactile feedback as the main behavioural guidance tool. **Much of household waste comes from consumer uncertainty**, with people discarding food that is still safe to eat based on approximate expiry dates. Mimica introduces a **sensory "gentle nudge"**: the label changes texture from smooth to rough when the product is no longer fresh. This immediate physical signal acts on the user's perception much more effectively than a numerical indication. Communicating the value of food is thus delegated to a **tactile response** that instructs the consumer to trust the actual condition of the product. In this way, **packaging innovation becomes a means of raising awareness**, transforming stock management into an intuitive gesture and reducing waste linked to incorrect assessments of food safety.

mimica


BONELESS
SALMON
FILLETS
Bump helps:
fight food waste
save money
check for freshness
240 g
USE BY:

D3 - Rise of circular bioeconomy models

The rise of bioeconomy models represents the structural response to the inefficiencies of the linear production model. If food waste is a symptom of a systemic crisis, the **bioeconomy** outlines a regenerative solution, shifting the focus from simple waste management to value creation through the use of renewable biological resources. In this scenario, **Europe** plays an important role, having been the first region to adopt a dedicated strategy in 2012 called **"Innovating for sustainable growth: a bioeconomy for Europe"** (European Commission, 2012). This path has recently been consolidated by the new strategic framework presented by the European Commission in November 2025 to further unlock the sector's potential and provide practical, sustainable solutions and alternatives to critical raw materials (European Commission, 2025). According to data from the Joint Research Centre, in 2023 the biomass production and processing sectors generated **17.1 million jobs (7.9% of total EU employment)** and added value of €863 billion, accounting for 5% of the EU's GDP (European Commission, 2025b). Within the **bio-based industry**, which generates a total added value of €583 billion, **more than half, or approximately €305 billion, is produced directly by the food, beverage and agricultural manufacturing sectors.** (European Commission, 2025b). This centrality highlights how the food system is the cornerstone of the bioeconomy, far exceeding the economic impact of sectors such as bio-based pharmaceuticals, paper, bio-based textiles and bio-based chemicals.

Bioeconomy
The bioeconomy encompasses a wide range of activities that utilise renewable biological resources, from agriculture and forestry to biotechnology and bio-based industries, to produce food, materials, and energy, as well as related services. (European Commission, 2025b)

The hierarchy of cascading use of FSLW

The transition to bioeconomy models requires an operational tool capable of guiding project choices, identified in the **circular bioeconomy hierarchy** applied to food system surpluses and residues. This framework goes beyond traditional waste management by proposing an order of priority based on maintaining the maximum intrinsic value of biological resources. However, a key challenge today lies in the inability to correctly **classify different types of waste**. In fact, terms such as "food loss" and "food surplus," or "recycling" and "reuse," are often used as synonyms, creating **terminological confusion** that hinders companies in defining effective strategies upstream of the supply chain. In response to this uncertainty, Teigiserova

propose a model that classifies **FSWL (Food Surplus, Waste, Loss)** practices in a **hierarchical pyramid** ***(Fig. 3.31)***, ordering actions from highest value to least impactful (Teigiserova et al., 2020):

- ***PREVENTION AT SOURCE:*** This is the priority action, as it **avoids the loss of high-impact products** such as meat and dairy products, which have a higher ecological and thermodynamic value than vegetables due to the enormous amount of resources already invested in producing them.
- ***REUSE FOR HUMAN CONSUMPTION:*** This concerns **only surplus food** and is the **most noble approach**, but it is often hampered by **health and hygiene regulations** that make recovery more complex and expensive than the collection of fresh food.
- ***ANIMAL FEED:*** This introduces an ethical distinction, as surplus can be used for human consumption, while safe food waste can only be **reintroduced into livestock supply chains** to keep nutrients in the food cycle.
- ***NUTRIENT RECOVERY:*** Before considering energy, the design aims to **extract nutrients or bio-based molecules**, honoring the molecular complexity of the resource before it loses its identity.
- ***ENERGY RECOVERY:*** This represents the base of the pyramid. While **returning energy or compos**t, it marks the lowest step of valorisation before final disposal.

Cascading Use Hierarchy for Agri-food FSLW

Source: Towards transparent valorization of food surplus, waste and loss, Teigiserova et al., 2020

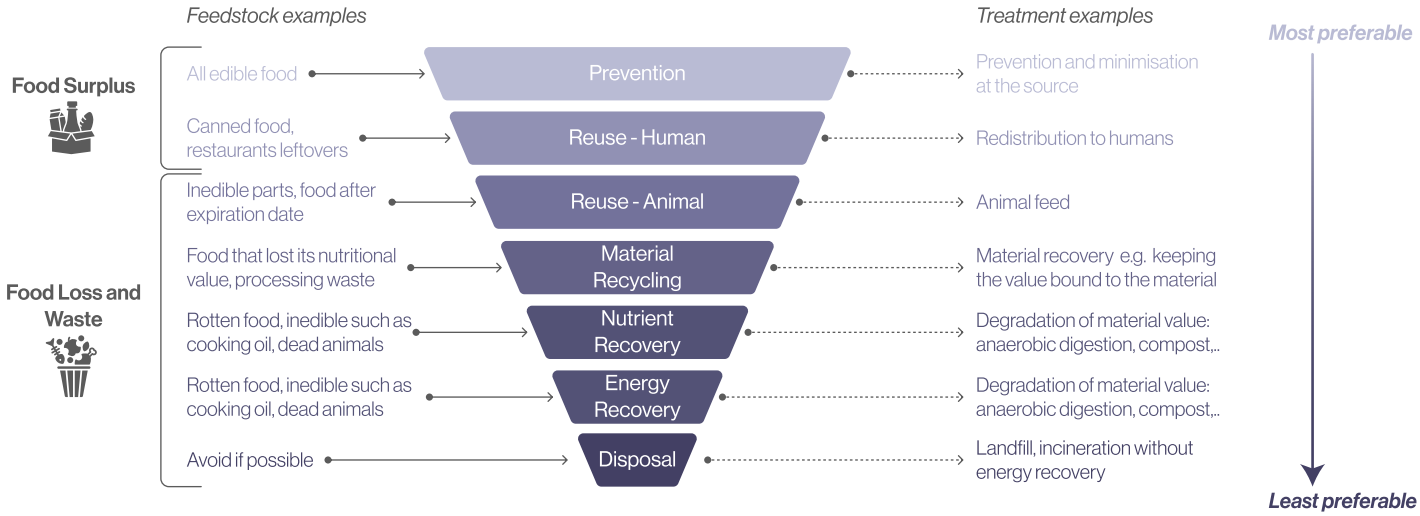


Fig. 3.31: Food waste hierarchy pyramid for FSLW management.

Impacts on the Agrifood System

As shown in the framework on the right ***(Fig. 3.32)*** rise of bioeconomic and circular models in the agro-industrial sector represents one of the most significant systemic opportunities currently available, capable of directly addressing the problems of food insecurity and distributional inequality. As highlighted, the r**ecovery of nutrients that are currently discarded could potentially feed over a billion people**. The integration and spread of industrial bioeconomic districts generate profound beneficial impacts: from a socio-economic point of view, the **bioeconomy in the EU** already supports 17.1 million jobs, accounting for 7.9% of total employment, with an **added value of €863 billion** (European Commission, 2025b). At the same time, the circular transition makes it possible to reduce emissions from waste disposal. Such inefficiencies are not only an economic burden, but also a primary driver of ecological instability: **food waste contributes to 8-10% of global greenhouse gas emissions**, fuelling global warming and the intensification of extreme weather events (FAO, 2019) . Finally, by acting on primary production, these models enable primary resource preservation via circular loops. By optimising the resources already extracted and fed into the system, the bioeconomy **reduces the need for new virgin materials**, ensuring more resilient and sustainable management of natural capital.

Identifying Challenges and Opportunities within the Framework

The main challenge that will determine the spread of these circular bioeconomy models lies in the ***regulations governing the various categories of food waste and surpluses (C15)***. These are not yet clearly defined and continue to hinder industries in their practices: the lack of a clear distinction prevents the full use of the various circular solutions available. On the contrary, the main opportunity that can arise from this scenario, if these new practices spread throughout the agro-industrial sector, will be the ***construction of Industrial Symbiosis and Bio-based markets (O8)***. This approach will strengthen local production and districts through the strategic centralisation of resources that are currently ignored. Industrial symbiosis intercepts raw materials before they degrade, creating new high-value market outlets. In this way, the creation of bioeconomic districts not only optimises existing flows, but also transforms structural inefficiency into a real lever of resilience for the local economy.

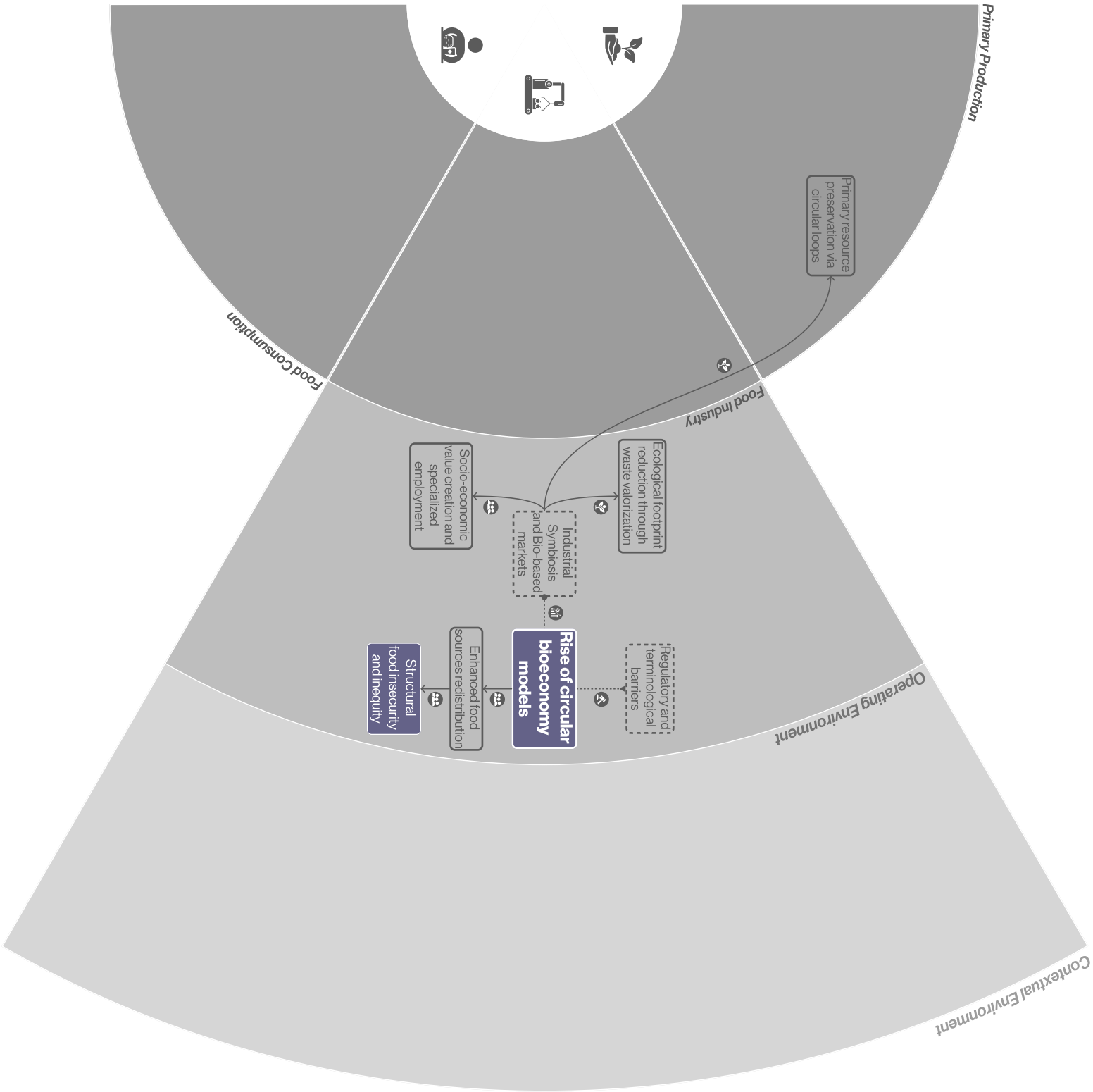


Fig. 3.32 Rise of circular bioeconomy models, Systemic Framework.

C15 - Regulatory and terminological barriers.

Legge n.166/16 “Gadda”

Italy

Introduced in 2016 following European pressure, the Gadda Law (166/2016) defines an operational structure of **Circular Governance aimed at limiting waste through social solidarity**. The measure acts across the production, processing, and distribution phases, **facilitating the recovery and donation of food** and pharmaceutical surpluses. In addition to **incentives for reuse and recycling**, the law establishes an interministerial coordination committee involving Health and Social Policies, emphasizing the multisectoral nature of the challenge. This systemic approach integrates **research and awareness-raising activities**, especially among the younger generations, to embed the value of recovery in institutional and consumer dynamics.

Keywords:
#Food surplus management
#Circular governance
#Surplus-to-Resource

Response to the identified challenge:
The urgency of these models is confirmed by the **paradox between food insecurity and the 87.6 million tons of food that are lost or wasted every year just in Europe**. This inefficiency reflects the **inability of the current system** to guarantee access to healthy diets, despite the abundance of biomass produced. In this scenario, Industrial Symbiosis represents a strategic opportunity to convert agro-industrial residues into high-value bio-based markets. Through nutritional upcycling, waste streams are transformed into functional ingredients or protein flours, optimising the cascading use of materials and offering concrete responses to the challenges of malnutrition and environmental sustainability.


REJECT

08 - Industrial Symbiosis and Bio-based markets.

Kaffe Bueno

Rødovre, Denmark

Kaffe Bueno is a **Danish startup** based in Rødovre that has redefined the **concept of organic waste**, treating coffee not as a simple beverage, but as a complex biological resource. Based on the assumption that only 1% of the bioactive compounds in the bean end up in the cup, the company focuses on the remaining 99%: used coffee grounds. These residues, traditionally considered waste, are actually rich in antioxidants, fatty acids, proteins, and sugars. Through the world's first **coffee biorefinery**, Kaffe Bueno transforms this biomass into **high-performance natural ingredients** (such as KAFFOIL and KAFFAGE) for the personal care, animal health, and nutraceutical sectors, replacing synthetic ingredients and reducing CO2 emissions associated with waste decomposition.

Keywords:
#Coffee upcycling
#Circular biorefinery
#Nutraceuticals

Response to the identified opportunity:

The heart of the project lies in **creating a collaborative network with hotels**, **offices** and **coffee chains**, which cease to be simple waste producers and **become logistics hubs for a valuable raw material**. By intercepting the **grounds** before they degrade and sending them for molecular fractionation for bio-based markets, the extraction of oils, fibres and bioactive compounds allows the part of the bean that is usually ignored to be recovered, as only 1% is used for the beverage. Thus, instead of downgrading biomass, industrial symbiosis maintains resource potential, demonstrating how circular processes of this type can convert structural inefficiency into a lever of resilience for the agro-industrial sector.

KAFFE BUENO



D4 - Structural food insecurity and inequity

Food insecurity and structural inequality are major issues, so crucial that they have become the core of **SDG 2 "Zero Hunger"** of the 2030 Agenda. Data from the FAO, taken from the report "The State of Food Security and Nutrition in the World 2025", paint an alarming picture: around **828 million people are in a state of severe food insecurity**, affecting 10% of the world's population (FAO et al., 2025). However, the challenge is not limited to a simple shortage of food, but extends to the affordability of quality nutrition. Today, as many as **2.6 billion people globally cannot afford a healthy diet** ***(Fig. 3.33)*** (FAO et al., 2025). This reality highlights a profound gap that varies dramatically depending on the income of the country in question: while in high-income contexts, difficulty in accessing a healthy diet affects 6% of the population, in **low-income countries this figure rises dramatically to 72%** (FAO et al., 2025). This enormous difference confirms that hunger is not just a production problem, but the result of deep-rooted structural inequality that prevents billions of individuals from accessing the food resources they need.

Portion of population unable to afford a healthy diet in 2024

Source: The State of Food Security and Nutrition in the World (SOFI), FAO et al., 2025

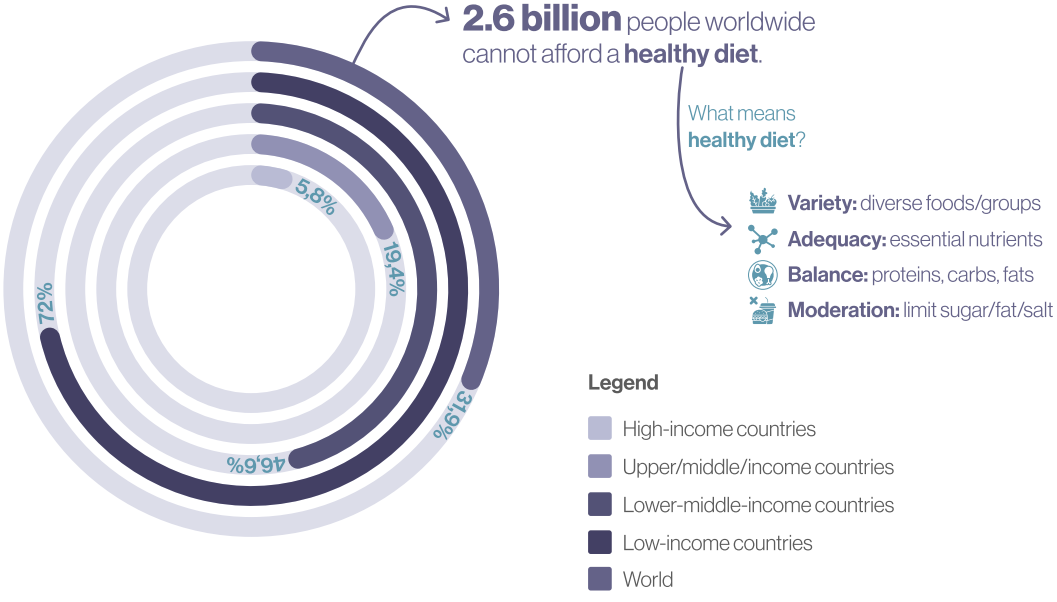


Fig. 3.33 Population unable to afford a healthy diet, 2024.

Geographical disparities and inequities in access to food

The 2024 estimates indicate that **31.9% of the world's population (2.60 billion people) cannot afford a healthy diet**. Although there has been a downward trend since the pandemic peak in 2020, the recovery is deeply uneven and outlines a **geography of inequality** where affordability varies dramatically from area to area ***(Fig. 3.34)***: from **78% in Central Africa to 5.1% in Southern Europe** (FAO et al., 2025). While inaccessibility has decreased significantly in Asia, the situation in Africa has worsened considerably, with more than two-thirds of the population excluded from proper nutrition. Added to this asymmetry is the fragility of rural areas, which remain systematically more vulnerable than urban centers in almost every region(FAO et al., 2025). While in Asia and Latin America the rates of inaccessibility stand at around 28%, the figure drops to 5% in North America. These data confirm that the problem does not lie in the scarcity of resources, but in **unequal distribution** that penalizes low-income contexts and marginal areas, making the right to a healthy diet a privilege linked to geographical location rather than a shared global goal.

Prevalence of moderatly or severely food-insicure people, 2024

Source: FAO, The State of Food Security and Nutrition in the World 2025

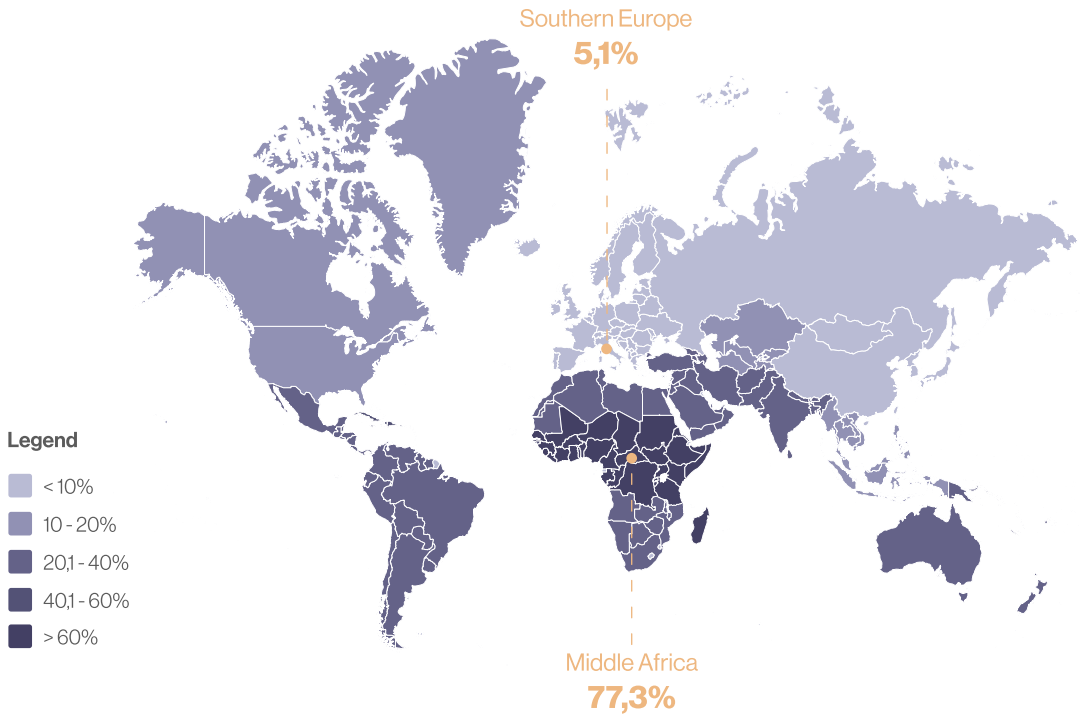


Fig. 3.34 Prevalence of moderate or severe food insecurity by geographical area (2024)

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.35)*** food insecurity and inequality act as catalysts, pushing the agri-food sector to seek effective countermeasures to mitigate these critical issues. From a regulatory perspective, **SDG 2 "Zero Hunger"** of the **2030 Agenda** helps to chart the course, aiming to improve global conditions by increasing the resilience and productivity of the sector. **This driver influences the entire supply chain**, **promoting more sustainable and resilient agricultural practices** in primary production on the one hand, and the adoption of bioeconomy and circular economy models capable of reducing systemic inefficiencies on the other, in order to ensure sufficient resources for all. Looking at consumption, however, an increasingly **marked social divide emerges**, highlighting a structural paradox. While innovation is driving personalised and functional nutrition solutions, basic inequality makes these technologies completely inaccessible to a large part of the world's population. A real **"gap"** is being created that risks widening more and more, exacerbating the contrast between those who can afford advanced consumption and those who, on the other hand, cannot even obtain basic nutrients. If this continues, this gap will **transform technological progress into a factor of inequality**, clearly separating advanced consumers from populations that remain in a state of chronic food insecurity.

Identifying Challenges and Opportunities within the Framework

The adoption of models based on ***Industrial Symbiosis and Bio-based markets (O8)*** represents a strategic opportunity. These approaches go beyond traditional linear production logic to embrace circular logic, optimising the system's resources. This evolution is not only a technical optimisation but also a fundamental lever for alleviating food insecurity, making resources more accessible and the system as a whole more equitable. At the same time, the crucial challenge lies in the ***implementation of agricultural resilience and productivity (C16)***, a key objective of SDG 2 applied to primary production. This need drives the adoption of technological solutions such as CEA technologies, precision farming and biotechnologies, but also towards more environmentally friendly production models such as organic and regenerative agriculture. The transition to more efficient and sustainable models thus becomes an indispensable solution to ensure the productivity needed to feed a growing global population.

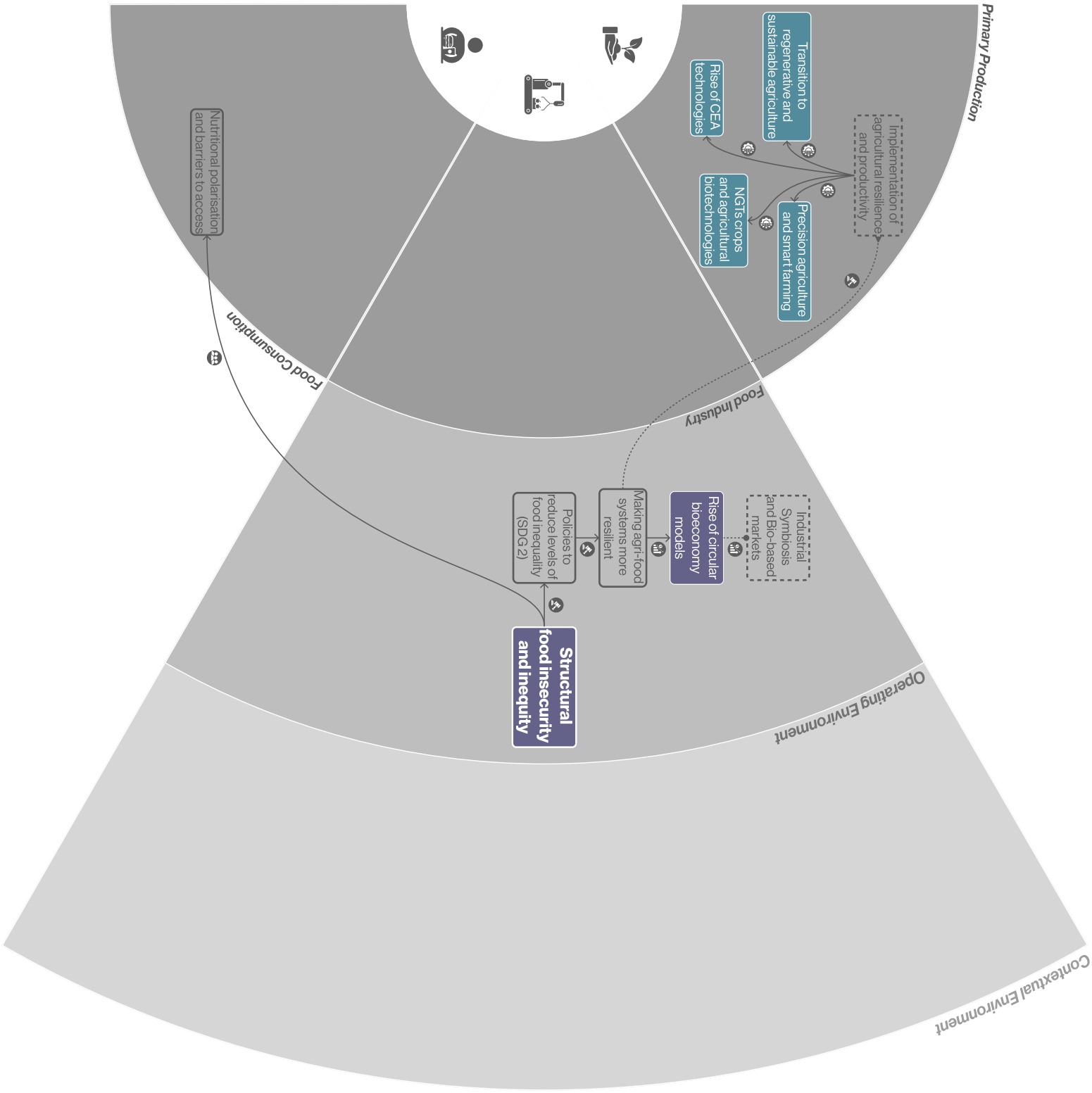


Fig. 3.35 Structural food insecurity and inequity, Systemic Framework.

C16 - Implementation of agricultural resilience and productivity.

Plenty

South San Francisco, USA

Plenty reimagines food production by freeing it from the constraints of soil and climate. Based in South San Francisco, the company uses vertical towers and a proprietary technology platform to **grow fresh produce in controlled environments**, without the use of pesticides or GMOs. **This system yields up to 350 times more per acre than traditional agriculture**, using just **1% of the land and drastically reducing water consumption**. The goal is to bring nutritious, high-quality food directly to urban centres, **shortening the supply chain** and **ensuring maximum freshness**.

Keywords:
#Vertical farming
#Resource efficiency
#Urban nutritive resilience

Response to the identified challenge:

The answer to the challenge of food security lies precisely in this ability to **produce more with fewer resources**, transforming efficiency into a tool for equity. **Plenty breaks down the geographical and economic barriers that currently limit access to a healthy diet**, acting directly on the causes of food inequality. By saving 99% of water and soil, the company stabilises the supply of nutrients regardless of external crises or climate disasters, contributing concretely to the **Zero Hunger goal**. By producing locally and with minimal environmental impact, Plenty demonstrates how innovation can narrow the global nutrition gap, **making quality food an accessible** right and no longer a privilege linked to geographical location.

Plenty®

D5 - Diet-related health burden

Within the framework of Agenda 2030, and specifically in the objectives related to SDG 2, global targets have been defined to **monitor the health status of populations**, which in some cases highlight the difficulty of the system in translating food availability into real nutritional well-being. These goals place a priority on particularly **vulnerable groups**, such as children under 5 and women of childbearing age (15-49). Analysis of the data ***(Fig. 3.36)*** shows that, while there has been a gradual decline in problems such as stunting and wasting among children, childhood overweight remains an unresolved challenge that shows no sign of abating (FAO et al., 2025). However, the most critical issues emerge among adults and women of childbearing age.

Global Nutritional Indicators Towards 2030

Source: FAO, The State of Food Security and Nutrition in the World 2025

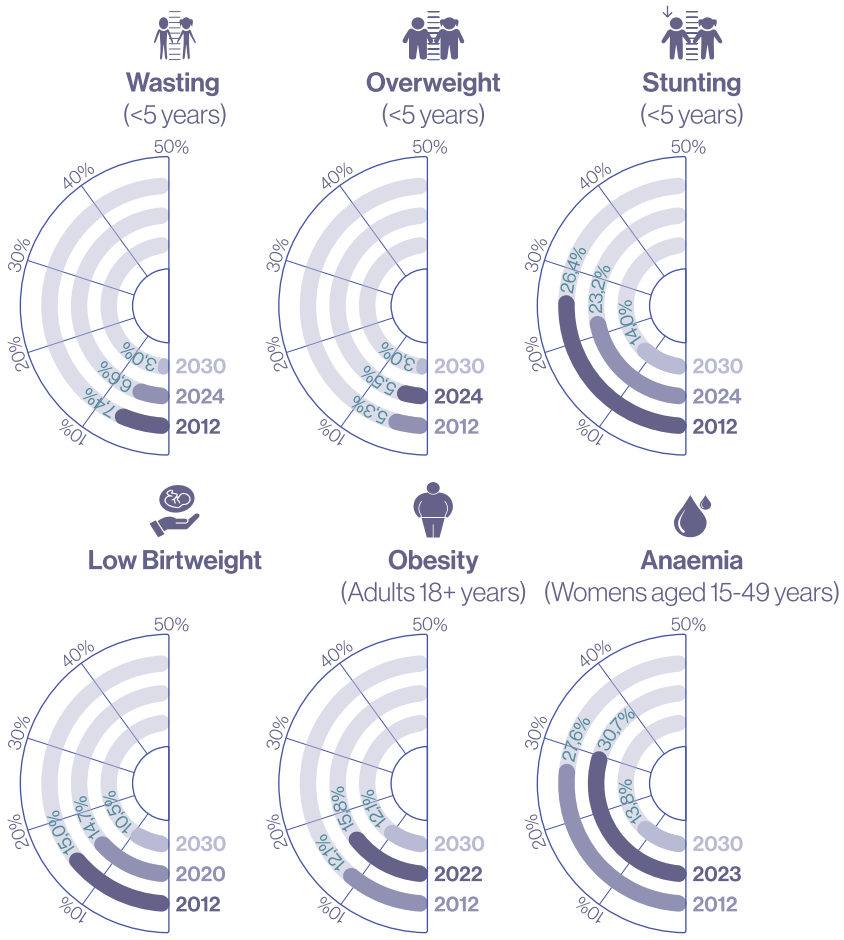


Fig. 3.36 Global Nutritional Indicators towards 2030.

The prevalence of anaemia and the number of obese adults are constantly increasing, marking a worrying gap between the current figures and the targets set(FAO et al., 2025). With this trend, achieving the 2030 targets appears extremely complex, highlighting a health "gap" that the agri-food system has not yet managed to close.

The double burden of malnutrition

Monitoring affordable access to a healthy diet is the starting point for understanding the extent of the global health burden linked to nutrition. Although the number of people who cannot afford a balanced diet fell to 2.6 billion in 2024, the post-pandemic recovery appears to be deeply uneven (FAO et al., 2025). This disparity reflects an economic divide where, in low-income countries, the inability to feed the population properly has been steadily increasing since 2017. A diverse diet is essential for SDG targets 2.1 and 2.2, as it prevents both child malnutrition and **non-communicable diseases (NCDs)**. However, when the **minimum cost of nutrients (COHD)** exceeds consumers' means ***(Fig. 3.37)***, the system slips towards the consumption of **empty calories**, i.e. cheap, high-calorie foods that fill the stomach without nourishing the body (FAO et al., 2025). This mechanism in turn fuels the so-called **Double Burden of Malnutrition**, a paradox where undernutrition and obesity coexist in the same social context or family group. Inaccessibility turns health into a geographical privilege, forcing vulnerable populations into nutritionally deficient diets that generate hidden hunger in children and women. Without policies to reduce the cost of nutrients compared to **ultra-processed products**, the gap between excess weight and chronic deficiencies will continue to widen, making the goals of Agenda 2030 increasingly distant (Popkin et al., 2020).

Non-communicable diseases (NCDs)
Noncommunicable diseases (NCDs), also known as chronic diseases, tend to be of long duration and are the result of a combination of genetic, physiological, environmental and behavioural factors. The main types of NCDs are cardiovascular diseases (such as heart attacks and stroke), cancers, chronic respiratory diseases (such as chronic obstructive pulmonary disease and asthma) and diabetes. NCDs disproportionately affect people in low- and middle-income countries, where nearly three quarters of global NCD deaths (32 million) occur. (WHO, 2025)

Global Cost of a Healthy Diet(COHD), 2020-2024
Source: FAO, The State of Food Security and Nutrition in the World 2025

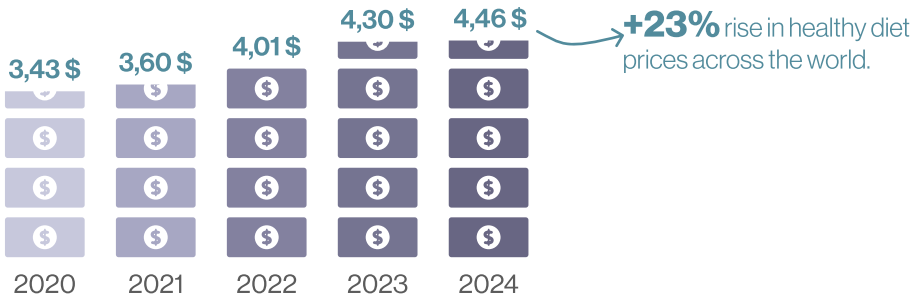


Fig. 3.37 Global cost of a healthy diet, 2020-2024.

Impacts on the Agrifood System

Nutritional problems, such as obesity, anaemia and non-communicable diseases (NCDs), represent a global health burden directly linked to **unhealthy eating habits**. As shown in the framework ***(Fig. 3.38)***, this situation has necessitated structural intervention within the **2030 Agenda**, leading to the activation of **SDG 2.2** to effectively combat these vulnerabilities. The main impact of these chronic diseases is the **implementation of targeted policies**, where the achievement of specific nutritional goals becomes the fundamental tool for reducing the global health burden. Through SDG 2.2, the system aims to define standards that guarantee balanced nutrition, seeking to **democratise access to healthy and diversified diets**.

Identifying Challenges and Opportunities within the Framework

The implementation of global policies translates operationally into the challenge of ***democratising access to fair nutritional standards (C17)***, a mission directly linked to the goals of SDG 2.2 to ensure that food health is a universal right and not an economic privilege. At this institutional level, there are also critical issues related to consumption, where there is an urgent need to ***improve the accessibility of healthy diets (C18)*** through solutions that make quality nutrients economically sustainable for all social groups. At the same time, ***promoting consumer awareness of healthier nutrition (C11)*** is crucial to countering the metabolic risks associated with unbalanced diets. This awareness-raising process, supported by clear and straightforward labelling systems, enables citizens to make informed purchasing choices, unlocking new market dynamics. A more educated and nutrition-aware consumer acts as a driver for the expansion of functional and personalised nutrition, while demanding verified transparency that empowers decision-making. In this context, education and transparency become the necessary pillars for transforming demand, steering the entire supply chain towards more ethical models focused on preventive wellbeing.

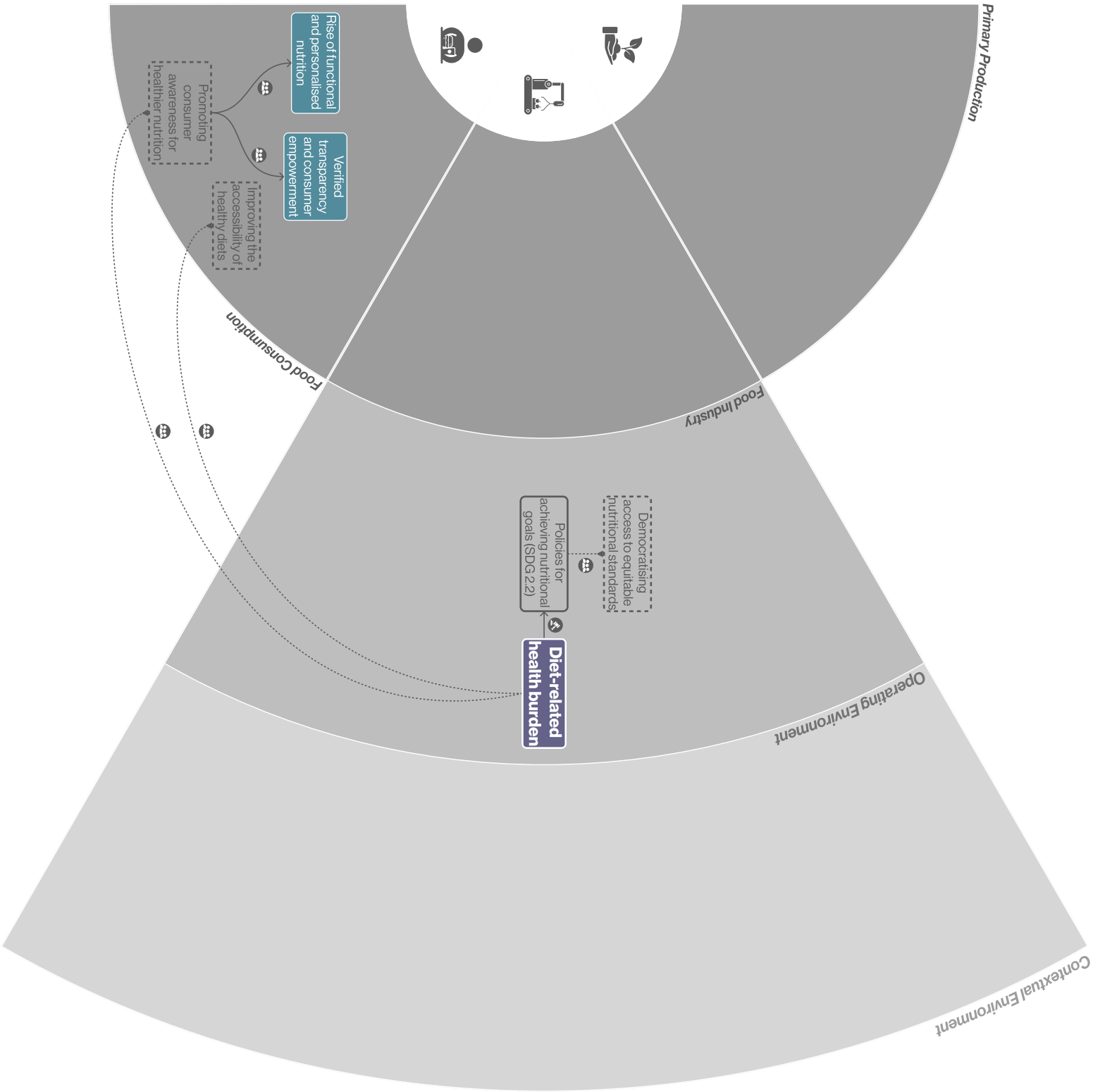


Fig. 3.38 Diet-related health burden, Systemic Framework.

C18 - Improving the accessibility of healthy diets.

Community Shop

UK

Community Shop is a **British social innovation model managed by Company Shop Group**, structured as a network of 15 stores based on a free membership system reserved for citizens receiving state benefits. The project is divided into **three interconnected functional spaces**: the **Community Store**, which distributes surplus quality food at reduced prices; the **Community Hub**, focused on training and personal development; and the **Community Kitchen**, where balanced meals are served at nominal costs. The locations are strategically distributed in areas of high socio-economic vulnerability in the United Kingdom, with a significant presence in the North of England, in cities such as Barnsley, Liverpool, Grimsby, Sheffield, Leeds and the London borough of Lambeth.

Keywords:
#Social supermarket
#Surplus food redistribution
#Healthy food

Response to the identified challenge:
In response to challenge C18 (Improving the accessibility of healthy diets), Community Shop **tackles the economic barrier by making essential nutrients such as fruit, vegetables and bread accessible at minimal prices**, often set at around 20 pence per product. This approach allows members to purchase a full week's groceries at around one-third of market value, preserving purchasing dignity and autonomy in food choices. By reinvesting profits in the Community Hub, the model not only provides immediate nutritional support, but also addresses the root causes of food insecurity by providing tools to improve participants' long-term financial condition and stability.

Community Shop

BIG FEAST SUMMER FESTIVAL



D6 - Food safety and biosafety risks

Food safety is a systemic issue with a huge human and economic impact. Every year, around **600 million people fall ill due to contaminated food**, resulting in **420,000 deaths** (WHO, 2024). This health burden disproportionately affects **children under the age of five**, who account for 40% of foodborne illnesses with 125,000 deaths annually. In low- and middle-income countries, this instability translates into an estimated **USD 110 billion in lost productivity and medical expenses**, hindering socio-economic development and placing a burden on national health systems (WHO, 2024). The main categories of threats that compromise food safety are divided into a complex variety of infectious and toxic agents:

- ***BACTERIA:*** these are the most common cause of foodborne illnesses, with **Salmonella**, **Campylobacter** and **enterohemorrhagic Escherichia coli** among the most significant, often transmitted by undercooked meat or contaminated fresh produce.

- ***VIRUSES:*** agents such as **Norovirus** and **Hepatitis A virus** cause acute infections or chronic liver disease through the consumption of raw seafood or vegetables.

- ***PARASITES AND PRIONS:*** organisms that enter the food chain through **contaminated water and soil**, including **infectious protein agents** responsible for serious neurodegenerative diseases such as **BSE** (bovine spongiform encephalopathy).

- ***CHEMICALS:*** these include **natural toxins** (mycotoxins), persistent **environmental pollutants** and **heavy metals** that can cause neurological and kidney damage and cancer.

The impact of these threats is set to increase due to the synergy between **climate change** and **globalisation**. Environmental changes, by altering air and water temperatures, favour the proliferation of toxins and pathogens in new geographical contexts. At the same time, the complexity of international supply chains makes the system vulnerable, and a local outbreak of contamination can quickly spread across borders, turning an isolated incident into a global health emergency (WHO, 2024).

BSE (bovine spongiform encephalopathy)
BSE, known as "mad cow disease", is a cattle disease first diagnosed in the United Kingdom in 1986, caused by prions that make the brain tissue of these animals spongy. Originating from the recycling of infected animal meal in animal feed, the disease became a global emergency due to its ability to make the 'species jump' to humans through the Creutzfeldt-Jakob variant. This phenomenon marked a turning point, requiring the adoption of permanent surveillance and traceability protocols to restore confidence in the markets. (Istituto Superiore di Sanità, n.d.)

The One Health plan for food safety

Access to safe and appropriate food is a right of every individual, officially recognised since **1992** by the United Nations and the WHO (Angela Sorbo et al., 2022). Protecting this entitlement is a complex challenge, as contamination can occur at any stage of the supply chain, from pesticides in the fields to chemical residues during processing or storage. To address these risks, in 2000 Europe introduced the White Paper on Food Safety, launching the **Farm to Fork strategy**. This approach aims to ensure high standards at every stage, from producer to consumer, based on the principle that there can be no food safety without product safety. To this end, **"One Health"** is the concept that the health of humans, animals and the environment are interconnected ***(Fig. 3.39)***, and the "One Health" approach consists of multidisciplinary teams (academics, producers, consumers and government agencies) working together to achieve food safety for the global population, preserve natural resources and improve health through the safeguarding of food safety (Angela Sorbo et al., 2022).

The One Health approach

Source: WHO, One Health

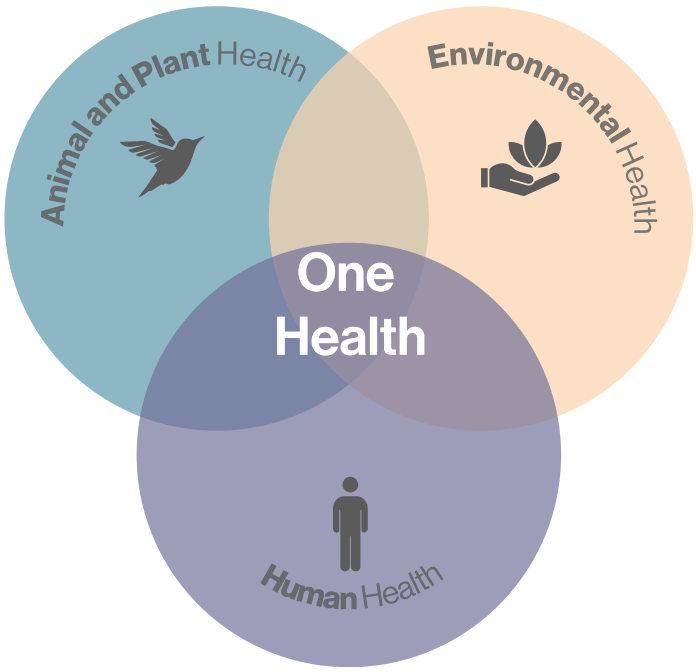


Fig. 3.39 The One Health approach.

Impacts on the Agrifood System

The starting point is the awareness that **food safety risks are not isolated problems**, but **events that set the entire supply chain in motion**. When a chemical or biological hazard arises, the response translates into concrete strategies such as Farm to Fork or the One Health approach, designed to monitor every step, from production to consumption. This intervention by institutions is not just a bureaucratic exercise; it also responds to a **deep-seated need among people**, who today **demand certainty about the quality of what they put on their tables**. Transparency ceases to be a simple label and becomes a tool for awareness, allowing consumers to regain control over their choices. In this context, the accuracy of measurements and new traceability technologies act as silent guarantees, ensuring that data is accurate and that the bond of trust between producer and citizen is based on verifiable facts.

Identifying Challenges and Opportunities within the Framework

As shown in the framework ***(Fig. 3.40)***, the most important opportunities for solving food safety issues come from new technologies that are changing the way we produce and control what we eat. In industry, ***Technological innovation for safe food manufacturing (O9)*** uses nanomaterials, and these tiny particles measuring between 1 and 100 nm allow us to work in different ways. Nano inside applications are used to encapsulate nutrients or immediately detect any traces of chemical and biological contaminants in the food system, while nano outside packaging uses active packaging with antimicrobial substances and smart sensors capable of detecting bacteria or fungi before they become visible (Angela Sorbo et al., 2022). As for consumption, ***Solutions for monitoring product integrity and safety (O10)*** focus on supply chain transparency. Using tools such as blockchain and smart labels, every step can be tracked so that data remains unalterable. This is not just a technical issue, because above all it serves to give people the awareness and power to verify for themselves whether a product is safe and authentic.

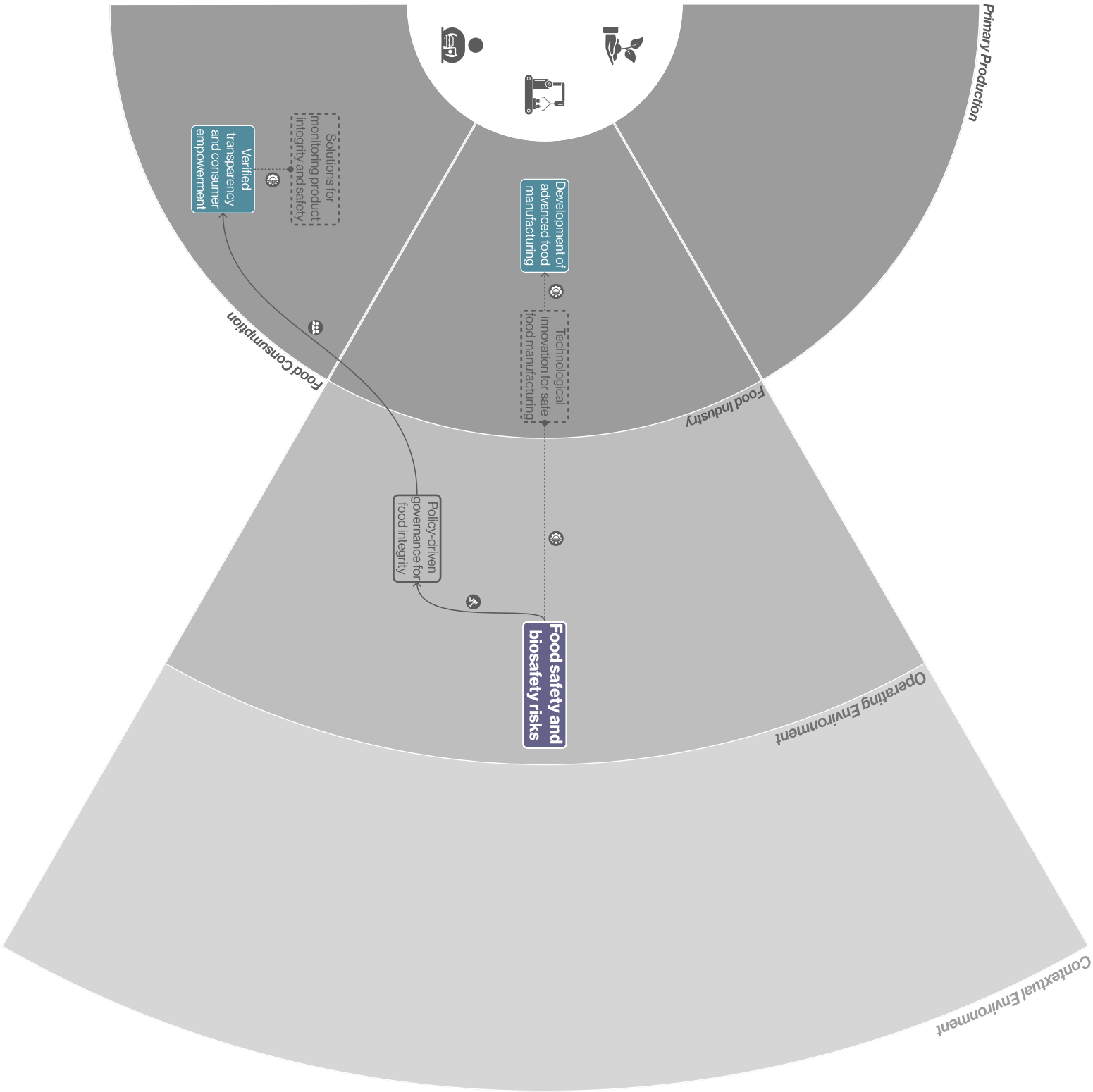


Fig. 3.40 Food safety and biosafety risks, Systemic Framework.

09 - Technological innovation for safe food manufacturing.

NanoPack

EU

The NanoPack project is an initiative funded by the **European Horizon 2020 programme** that aims to reduce the 1.3 billion tonnes of food wasted each year and prevent the spread of foodborne diseases. The technology is based on the use of **halloysite nanotubes**, a natural mineral that acts as a safe container for bioactive essential oils with antimicrobial and antifungal properties. These nanotubes are specifically designed not to migrate into food due to their size, instead acting in the empty space of the packaging where they slowly release small amounts of natural vapours approved by the EU. This system ensures **prolonged preservation and superior safety** compared to traditional materials, placing European research at the forefront of nanotechnology applied to food protection.

Keywords:
#Active packaging
#Antimicrobial release
#Shelf-life extension

Response to the identified opportunity:

The NanoPack project shows how technological innovation can **protect food from outside the packaging**. It is not an additive mixed into the food but an active packaging that harnesses the power of nature. The technology uses halloysite nanotubes, which are tiny natural mineral containers inserted directly into the plastic film. These tubes slowly release essential oil vapours into the empty space inside the packaging. It is these vapours that combat the growth of microbes and mould, **extending the shelf life of the product** without altering its original qualities. In addition to reducing food waste, this system is extremely safe because the nanotubes are designed to remain trapped in the material without ever migrating to the food.

nano pack



010 - Solutions for monitoring product integrity and safety.

Carrefour

France - Italy - Spain

The initiative that best represents the drive towards **total transparency is the Filière Qualité Carrefour** (FQC) Blockchain, created as part of the broader Act for Food transformation programme. First launched in France in 2018 with Auvergne chicken, this technology was a pioneer in Europe and quickly spread to the group's main markets, successfully establishing itself in Italy and Spain. The main objective is to **respond to the growing demand for safety among citizens**, transforming traceability from an internal process into an experience of open and accessible transparency.

Keywords:
#Digital transparency
#Blockchain
#Consumer empowerment

Response to the identified opportunity:
Carrefour has integrated **blockchain technology throughout the entire supply chain** for products such as eggs, milk, citrus fruits and salmon. Each package has a **QR code** that allows consumers to instantly access a **digital "identity card"** for the product directly from their smartphone. In just a few seconds, they can **verify certified information on the origin**, farming methods, treatments carried out and health checks, with the guarantee that all recorded data is unalterable and secure.

Carrefour


ALLEVATORE DI POLLO ALL'APERTO
A JESI, MARCHE,
CON NOI DA OLTRE 10 ANNI
ALIMENTAZIONE
VEGETALE
Con la tecnologia
BLOCKCHAIN
scopri subito la storia
dei nostri prodotti
SCARICA
l'app
myCarrefour
UTILIZZA
il lettore QR Code
nel menu
INQUADRA
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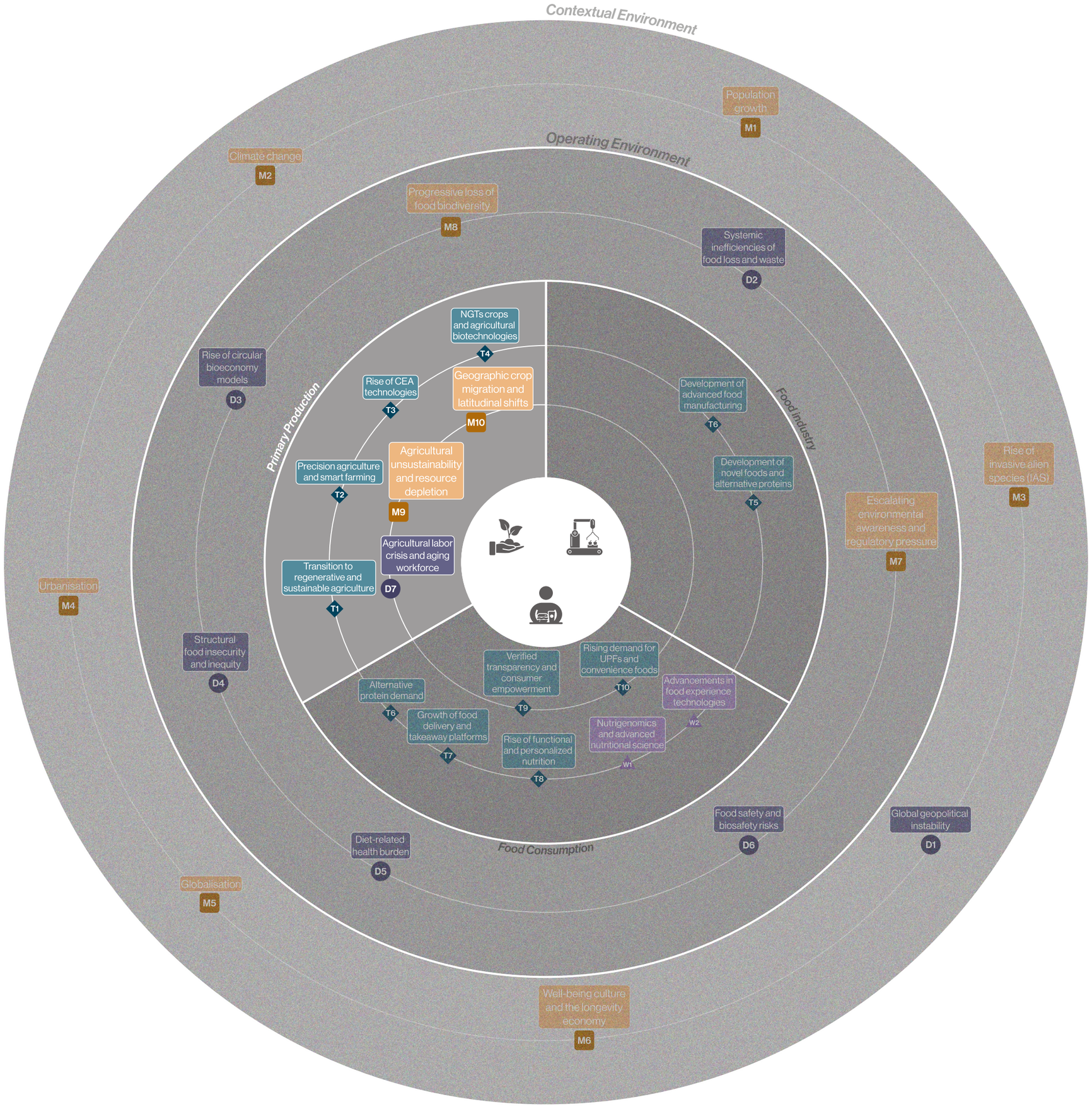
3.4 Primary Production Scan

The Primary Production analysis has identified the factors that characterise the **foundations of the agro-industrial supply chain**. This study highlights both the structural drivers and global megatrends that will influence the sector's performance in the coming years, as well as a series of current trends that are emerging as solutions, some more technological than others, influenced by the major forces that are defining the new rules of the game. These trends often stem from the critical issues of current models: the crisis in traditional agriculture, for example, is becoming the necessary impetus for the adoption of precision farming or the transition to regenerative practices.

The **main factors analysed** are:

1. *Agricultural unsustainability and resource depletion*
2. *Geographic crop migration and latitudinal shifts*
3. *Agricultural labor crisis and aging workforce*
4. *Transition to regenerative and sustainable agriculture*
5. *Precision agriculture and smart farming*
6. *Rise of CEA technologies*
7. *NGTs crops and agricultural biotechnologies*

This section highlights the factors belonging to **Primary Production** ***(Fig. 3.1)***, which are the elements that characterise the initial phase of raw material production in the agro-industrial system. Each factor is examined methodically: first through the visualisation of relevant data confirming the trend, followed by the Understanding Complexity phase to identify relationships, impacts and interdependencies within the agrifood system. Finally, the Tackling Challenges phase serves to identify the challenges and opportunities generated by each factor; for each of these, real case studies have been reported which, acting as concrete solutions or suggestions, confirm the emergence of these conditions in the sector.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal

Fig. 3.1 Scanning map.

M9 - Agricultural unsustainability and resource depletion

The entire agri-food system is now responsible for around one third (31%) of global **greenhouse gas emissions** (FAO, 2021), with direct agricultural activity accounting for 12% of the world total ***(Fig. 3.41)***. The greatest impact comes from **livestock farming**, particularly ruminants, which alone accounts for the largest single component of emissions in the sector. However, the pressure is not limited to the atmosphere but also has a major impact on soil and forests. Indeed, around **33% of the planet's arable land is now moderately or severely degraded**, a phenomenon that affects 1.66 billion hectares and compromises the food security of **over 1.5 billion people** (FAO, 2021). This degradation is fuelled by soil erosion, which carries away between 20 and 37 billion tonnes of fertile soil each year, drastically reducing the soil's ability to retain nutrients and carbon (FAO, 2021). At the same time, agricultural expansion continues to be the main driver of global **deforestation**, with the conversion of natural ecosystems into cultivated land generating annual emissions of around 2.8 Gt CO2eq. Water management is also critical, as agriculture accounts for an average of **72% of all global freshwater withdrawals**, exceeding 90% in many developing countries (FAO, 2021).

Global agricultural Greenhouse Gas Emissions, 2000-2022

Source: Our World in Data (2024), CO2 and Greenhouse Gas Emissions

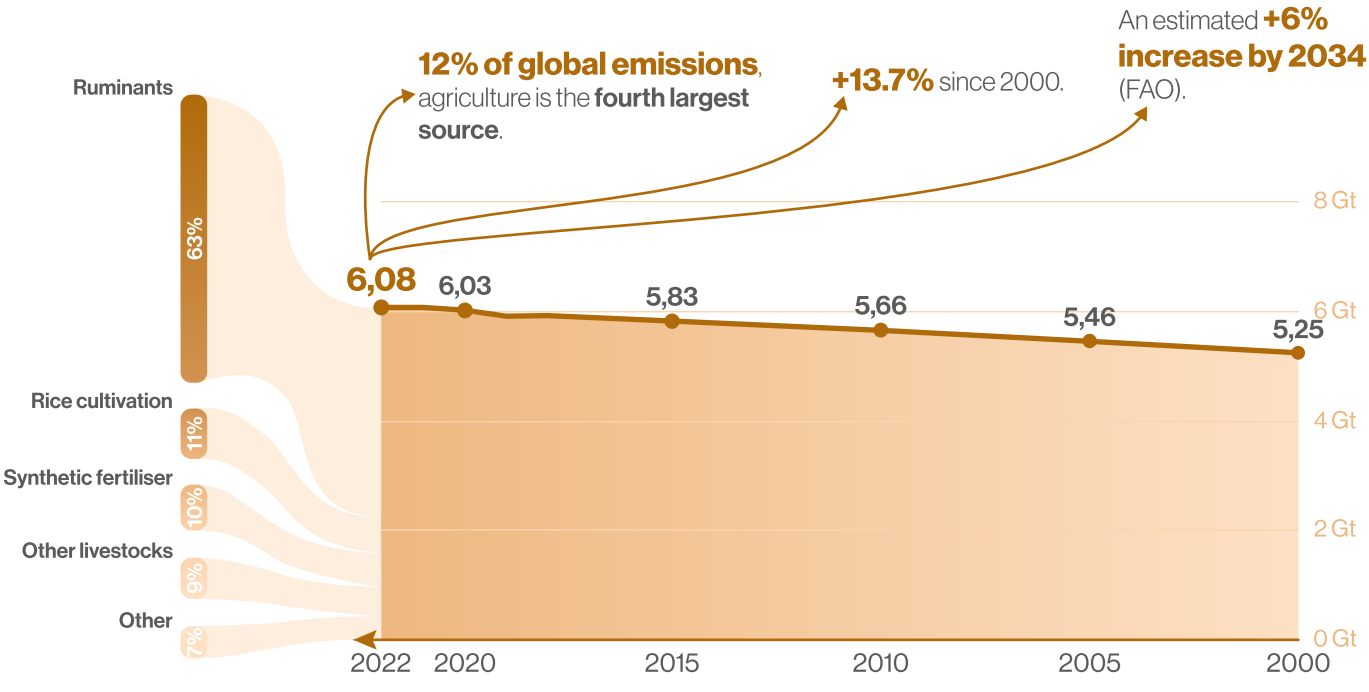


Fig. 3.41 Agricultural Greenhouse Gas Emissions, 2000-2022.

The vicious circle of the traditional agricultural model

The vulnerability of the current agricultural system is the result of applying linear logic to a complex biological system. Faced with declines in fertility or pathogen attacks, the industrial model responds with **massive inputs of external chemicals**, triggering a powerful **reinforcing loop** that progressively **degrades the ecosystem's self-regulating** capacity and **accelerates climate change**. The excessive use of nitrogen fertilisers, in particular, saturates the absorption capacity of plants and soil. Excess nitrogen is transformed by microbial processes into **nitrous oxide (N2O)**, a greenhouse gas with a climate-changing power almost 300 times greater than CO2, which is now responsible for one third of the sector's total emissions. At the same time, the abuse of pesticides eliminates the functional biodiversity of the soil and pushes pests and weeds towards rapid biological evolution, developing resistances that render treatments ineffective. The combined result of more frequent climate shocks, sterile soils and super-pests leads to a drastic **erosion of the system's resilience**. Paradoxically, in order to maintain yields in this now fragile environment, farmers are forced to further **increase the doses and frequency of chemical treatments**, accelerating the race towards structural collapse ***(Fig. 3.42)***.

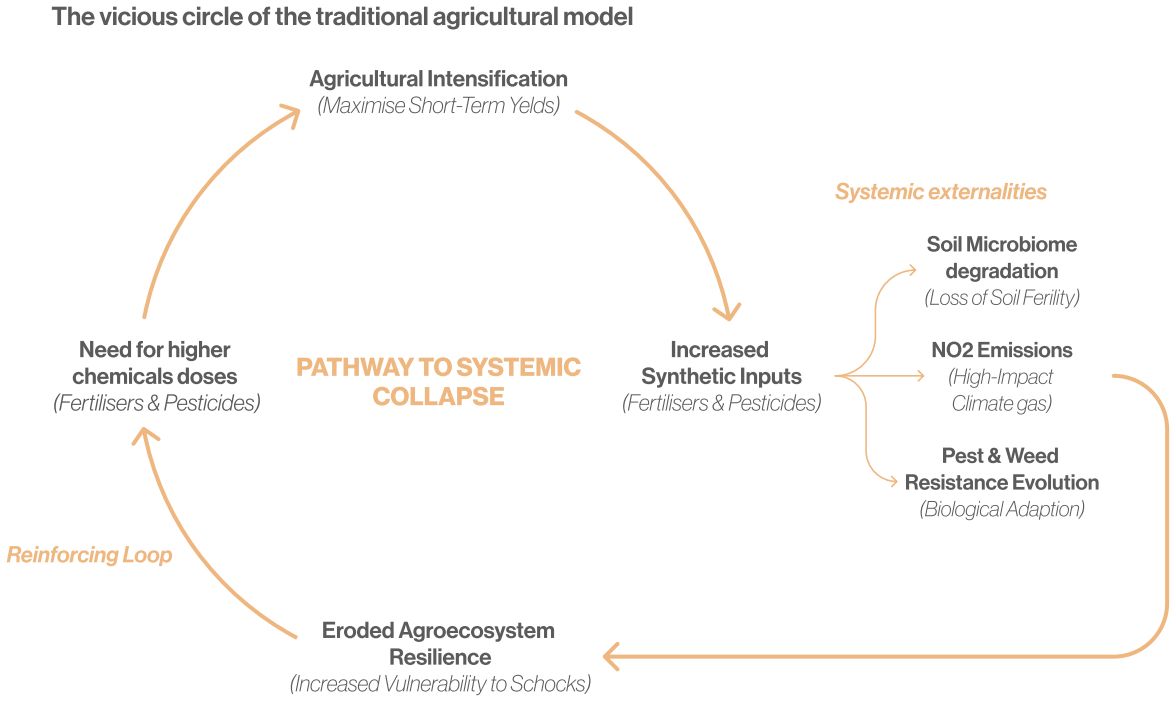


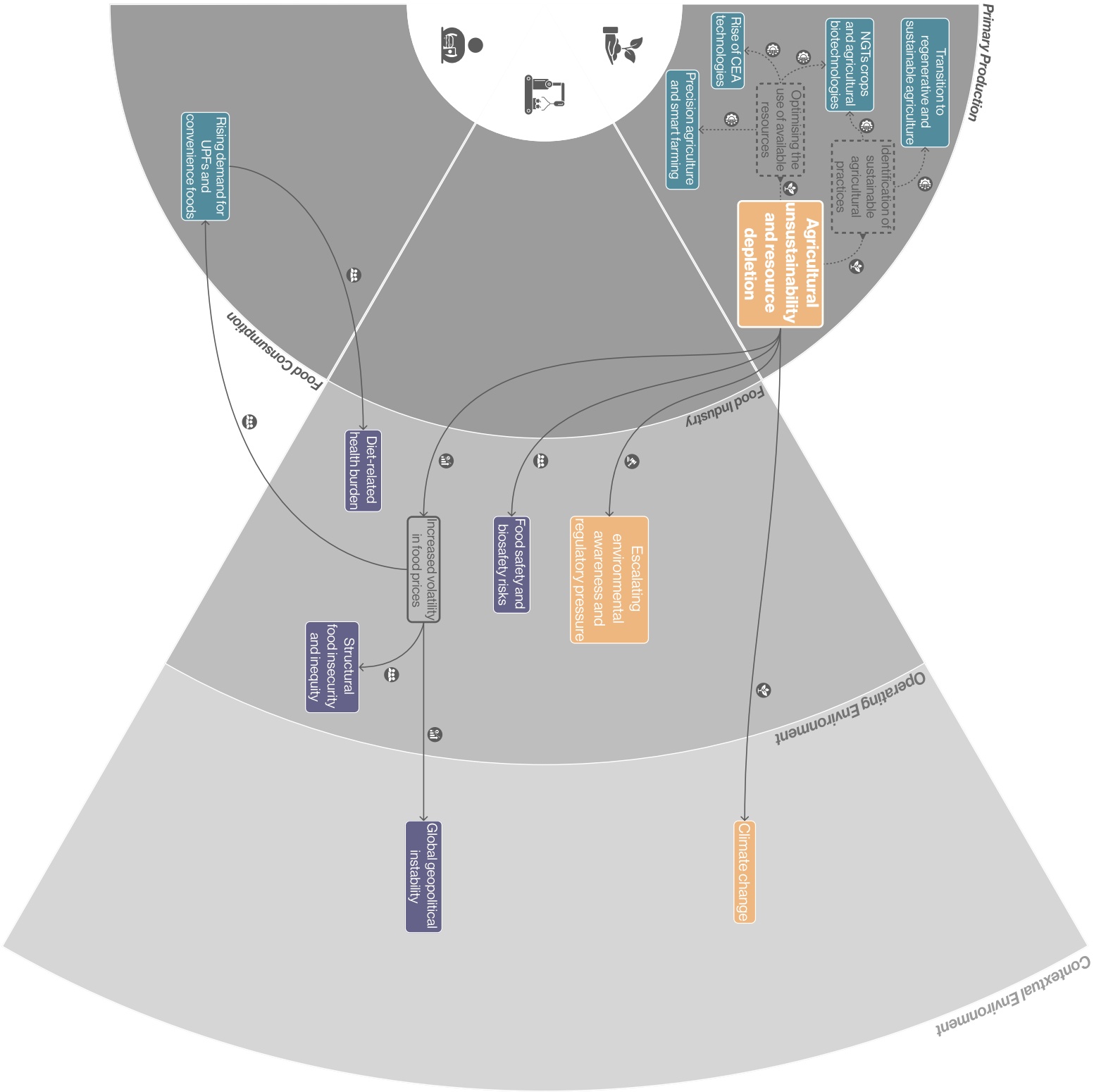
Fig. 3.42 The vicious circle of the traditional agricultural model.

Impacts on the Agrifood System

The unsustainability of the intensive agricultural model and the depletion of resources profoundly undermine the balance of the agro-industrial system, triggering cascading impacts that go far beyond primary production alone. As shown in the framework ***(Fig. 3.43)*** the progressive scarcity of natural capital translates into economic pressure that alters the stability of the entire supply chain, leading to **increased food price volatility**. This shift transforms environmental degradation into a social emergency: cost uncertainty **exacerbates food inequality** and **fuels geopolitical tensions**, reminding us that food security remains a fundamental pillar of international stability. At the same time, rising raw material prices directly influence consumer behaviour, driving **demand towards ultra-processed** and **ready-made foods**. These are often chosen as economical alternatives, despite their negative impact on health and the increase in diet-related diseases. Furthermore, the extreme pace of production and the massive use of chemicals compromise **food safety** itself. In fact, trying to produce more in less time increases the risk of contamination and lowers nutritional values, highlighting the gap between the quality of industrial products and more natural, extensive ones. This situation is fuelling growing environmental awareness, where the call for responsible production and consumption (as indicated by SDG 12) is becoming a strategic necessity. In particular, the depletion of resources is emerging as the real driver of a fragility that requires radical change to ensure the future sustainability of the sector.

Identifying Challenges and Opportunities within the Framework

The traditional intensive model outlines two priority challenges for the future of primary production. On the one hand, there is the need to ***optimise the use of available resources (C1)***, which is addressed by new models of precision agriculture, smart farming and CEA technologies. On the other hand, the ***identification of sustainable agricultural practices (C19)*** pushes towards solutions such as NGT biotechnologies, which can make crops resilient to pathogens by reducing the use of pesticides, for example. This innovation is accompanied by more environmentally friendly models, such as regenerative and organic farming, which are essential for a transition to less impactful and more balanced production systems.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.43 Agricultural unsustainability and resource depletion, Systemic Framework.

C19 - Identification of sustainable agricultural practices.

Demeter

Darmstadt, Germany

Demeter represents excellence in **biodynamic certification** at a global level, based on a method that considers the farm as a true integrated living organism. Unlike conventional agriculture, its guidelines require the **maintenance of a natural balance** between soil, flora and fauna, **eliminating the use of synthetic chemicals** and **promoting soil fertility** through natural preparations and crop rotation.

Keywords:
#Agroecology
#Certification
#Biodynamic agriculture

Response to the identified challenge:

In response to the challenge of sustainability, Demeter proposes a closed-loop model that **minimises the need for external inputs** by **optimising local resources**. This approach actively **combats soil depletion** and **biodiversity loss**, offering a rigorous and verifiable standard for practices that not only preserve the environment but constantly regenerate it.


demeter
Succo
di Pomodoro
100% ITALIANO
Le Lame

M10 - Geographic crop migration and latitudinal shifts

The geographical structure of food production is undergoing a profound transformation, dictated by the need for crops to migrate to more favorable latitudes in order to survive **climate change**. Projections indicate that by 2100, approximately **30% of global production will be operating in extreme climatic conditions** not currently found in any existing agricultural area (Heikonen et al., 2025). This instability affects the entire plant landscape and not just major commodities such as wheat or corn, revealing a particularly acute systemic fragility in **equatorial regions**. Alberto Acquadro , professor of agricultural genetics at the University of Turin, identifies this progressive "migration" of crops as one of the major critical issues for agro-industrial stability, highlighting how the search for adaptive solutions, particularly through **genome editing**, has become a fundamental driver for mitigating the effects of this latitudinal drift and ensuring the resilience of supply chains.

New production geographies and the drift of cultivars

This geographical metamorphosis is now visible in the rapid **tropicalisation of the Mediterranean**. In **Sicily**, the progressive transformation of the climate has created the ideal habitat for the **expansion of avocado cultivation**, which now exceeds 1,000 hectares, mainly located in the provinces of Catania and Messina (Fruit Journal, 2025). This plant, native to Central and South America, is no longer an exotic exception but represents a **real change in local diets** ***(Fig. 3.44)***. In Italy, per capita consumption has risen from around 100 to over 800 grams per year in the space of a decade, signalling a shift in eating habits that incorporates new ingredients into daily diets as production shifts(Fruit Journal, 2025). At the same time, wine is losing its historic Mediterranean exclusivity, with global warming making **viticulture a growing industry even in Denmark, Sweden and Norway**, areas that until a few decades ago were considered unsuitable for vine cultivation. While global production in 2024 is at an all-time low due to extreme climate shocks, these new Nordic vineyards are growing by exploiting **resistant varieties** and **longer ripening seasons** (Gambero Rosso, 2024). When a crop leaves its area of origin, the link between the plant, the characteristics of the

soil and the local knowledge handed down for centuries is broken. The real risk is the **disappearance of the concept of terroir**: excellence that arose from a unique interaction with a specific place risks becoming a simple standardised commodity, devoid of roots and historical value. In this way, the agricultural system ceases to be the guardian of a gastronomic culture and reduces food to a productive resource disconnected from its origin.



Fig. 3.44 Avocado toast.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.45)***, crop migration is a reality already reshaping the agro-industrial balance. If global warming continues at its current pace, this phenomenon will become a dominant factor in the near future, affecting every link in the supply chain. The repercussions are particularly dramatic in equatorial regions, which suffer most from rising temperatures: the inability of crops to adapt to extreme temperatures generates profound **asymmetries in food availability**, **exacerbating food insecurity** and distributional inequalities in these often already vulnerable regions. Within primary production, the shift in arable land causes profound **damage to local agrobiodiversity** and disrupts the link between cultivars and territory. Consumption also reflects this shift through a transformation in diets, as changes in food availability within national borders

are normalising products that were once exotic. In Italy, for example, the tropicalisation of the climate has increased the availability of local avocados, a fruit that would remain an expensive commodity if imported but has now become accessible and commonplace, radically **changing people's purchasing habits** and recipes. Finally, this phenomenon triggers a profound **crisis in specifications and designations**, as quality labels are based on strict regulations that bind the product to a geographical area and its specific historical climate. When production is forced to migrate to other areas for reasons of biological survival, the law is unable to keep pace with rapid environmental changes, creating a regulatory paradox where traditional techniques remain intact but the geography that guaranteed legal protection is lost, thus compromising the economic value and identity of the entire supply chain.

Identifying Challenges and Opportunities within the Framework

The urgent ***need for climate resilience in agriculture (C3)*** is driving the adoption of new genomic techniques to protect local genetic heritage and controlled environment technologies to isolate crops from external shocks. These solutions offer the opportunity to maintain production in places of origin, counteracting the biological need to migrate to new latitudes and preserving the stability of supply chains. The real challenge, however, lies in **redefining labelling standards (C20)**, which is essential to manage the regulatory paradox of products of excellence grown in artificial contexts or emerging territories. Evolving towards more flexible geographical designations is the only way to safeguard the value of historical designations, preventing legal rigidity from rendering them obsolete in the face of new geographical balances.

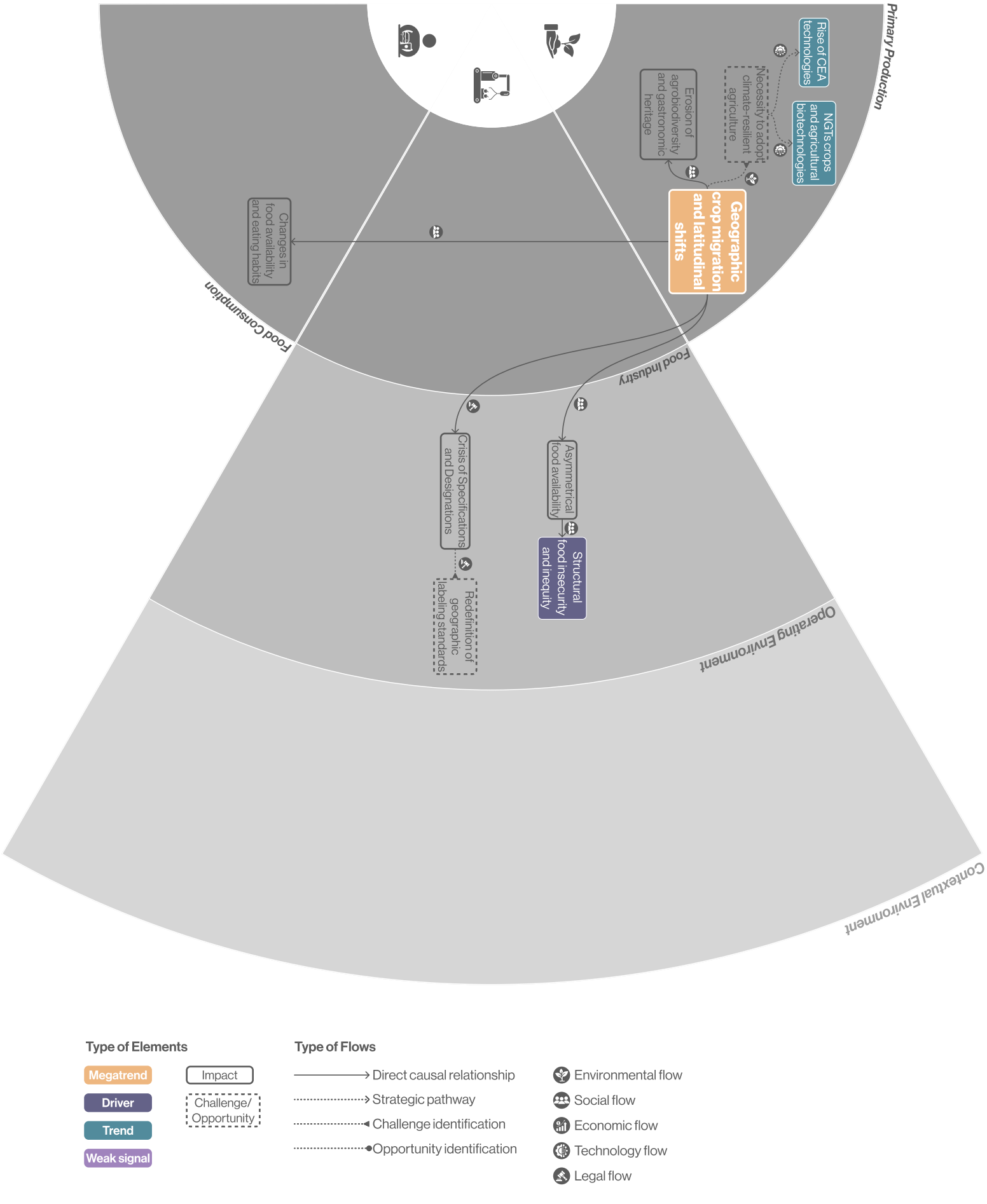


Fig. 3.45 Geographic crop migration and latitudinal shift, Systemic Framework.

C20 - Redefinition of geographic labeling standards.

Sussex Sparkling PDO

Sussex, UK

Global warming has transformed southern England into a region with soil and climate characteristics similar to those of Champagne fifty years ago, making the chalky soils of Sussex a **new frontier for sparkling wines of excellence**. This latitudinal shift has created a paradox where the quality of the product was already present in the field, but there was no legal structure to authenticate its origin and protect its economic value on the global market. Without a specific designation, these products risked remaining confined to generic categories, **suffering competition from industrial products** and losing that link with the territory that is the basis of agri-food value.

Keywords:
#Regulatory resilience
#Adaptive labelling
#Emerging terroir

Response to the identified challenge:

The legislative response came in June 2022 with the **official recognition of Sussex Sparkling as a PDO** (Protected Designation of Origin), the first geographical protection scheme created explicitly to respond to a climatic opportunity. This legislation transformed an emerging agricultural region into a **legally protected brand with strict rules that guarantee its unique identity**. This intervention demonstrates that labelling should no longer be seen as a static constraint on the past but as a tool capable of formalising new production geographies and ensuring transparency in an ever-changing environmental landscape.


SUSSEX
SPARKLING

D7 - Agricultural labor crisis and aging workforce

The crisis in agricultural labour and the ageing workforce represent one of the most pressing structural challenges for the sustainability of the global production system. Demographic ageing is now an inevitable experience for developing countries and has become established as a global social phenomenon. Projections indicate that by 2050, the world's **elderly population will reach 2.1 billion, accounting for 17% of the global population**, a change that will put a strain on the resilience of world economies (Zhang et al., 2023). This demographic transformation is putting critical pressure on national pension systems and related implementation policies, which risk triggering financial difficulties and complex macroeconomic problems. The most direct effect on the primary sector is the drastic **decline in the working-age population** and the consequent drop in labour force participation, factors that fuel a structural labour shortage and hinder the economic and social development of territories. This situation is compounded by **urbanisation**, which continues to draw human capital away from rural areas and towards urban centres, exacerbating the **crisis in rural agricultural production**. Inland areas are experiencing a period of profound fragility, where the lack of generational renewal and the perception of agricultural work as an unattractive sector are accelerating the decline of rural communities. The result is an agricultural system that is ageing along with its workforce, losing the capacity to ensure the continuity of primary production at a time of growing global demand.

Socio-cultural barriers and the decline in rural attractiveness

Over a billion people represent **almost a third of the global workforce employed in the agricultural sector**, a figure that highlights the systemic importance of the sector despite the fact that its share of global employment has fallen from **45 to 34 per cent over the last two decades** (ILO, 2019). This incidence remains significantly higher in many developing economies, especially in East Asia and sub-Saharan Africa, where agriculture is still the mainstay of local livelihoods. However, this vast employment base is now threatened by a profound **lack of attractiveness to younger generations, who perceive the sector as arduous and unrewarding**. According

to analyses by the **International Labour Organisation (ILO)**, the sector suffers from a **negative social image**, with work in the fields seen as a last resort characterised by low wages and poor social protection (ILO, 2019).Young people tend to reject agriculture because they associate it with exhausting physical effort and a chronic lack of technological incentives, preferring to seek opportunities in urban centres where the perception of modernity and economic stability is higher. This exodus of young people **accelerates the ageing of the rural population** ***(Fig. 3.46)***, with multidimensional consequences that threaten the stability of the system. The presence of an increasingly elderly workforce inevitably leads to a decline in human capital and, in many cases, to the abandonment of productive land. The problem is not only one of physical strength but is also reflected in **reduced productivity** and a worrying **resistance to the adoption of new technologies** (Zhang et al., 2023). Older farmers are less inclined to invest in digital tools, and this technical slowdown jeopardises the resilience of the entire agricultural economy in the face of global challenges. If this trend continues, agriculture risks becoming trapped in a vicious circle in which the lack of generational renewal prevents the technological progress needed to make the sector attractive again. Without a change of course that integrates innovation and dignity of work, the agricultural heritage will continue to be depleted, transforming a vital sector into a marginal and obsolete one.



Fig. 3.46 The aging of the rural workforce.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.47)***, the ageing population and the loss of agricultural labour are causing many problems in agricultural production. This phenomenon is **slowing down innovation** in the sector due to the **lack of young people**, who tend to be more proactive and eager to innovate. This, in turn, leads to a **loss of agricultural productivity** due to the failure to use technologies that could optimise and speed up daily work. In addition to reducing efficiency, this situation contributes to making the sector less green because it **reinforces the status quo of the traditional production model** and prevents the adoption of more sustainable solutions. Ultimately, this scenario **exacerbates the problem of food security** because the system is no longer able to respond effectively to the increase in global food demand.

Identifying Challenges and Opportunities within the Framework

To address the operational fragility described above, it is essential to tackle the challenge of ***youth engagement and sector appeal (C21)*** by aiming to radically redefine the image of agriculture in the eyes of the younger generations. The primary objective is to make the sector significantly more attractive by **overcoming the collective perception** of it as an unappealing activity characterised only by exhausting physical effort. Instead of being seen as a sector lacking in ambition, agricultural work must be presented as an area with enormous technological potential and opportunities for professional excellence. In this perspective, the systematic application of **precision and smart agriculture** represents the preferred way to transform the sector into a smart and tech-driven work environment. Only through the integration of these advanced technologies is it possible to raise the profile of primary production and make it an ambitious career choice for young people who want to drive the innovation of the future.

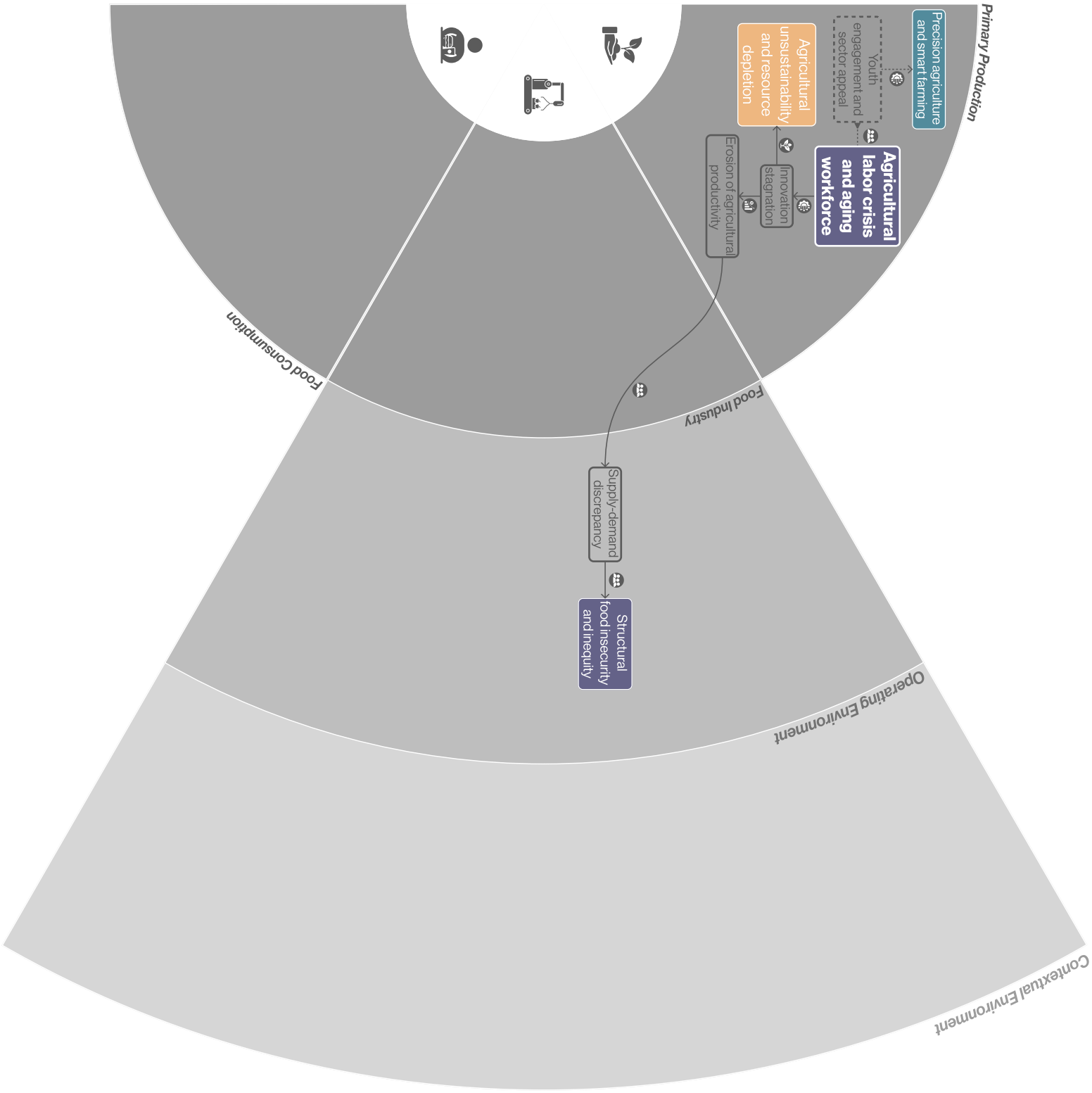


Fig. 3.47 Agricultural labour crisis and aging workforce, Systemic Framework.

C21 - Youth engagement and sector appeal.

xFarm

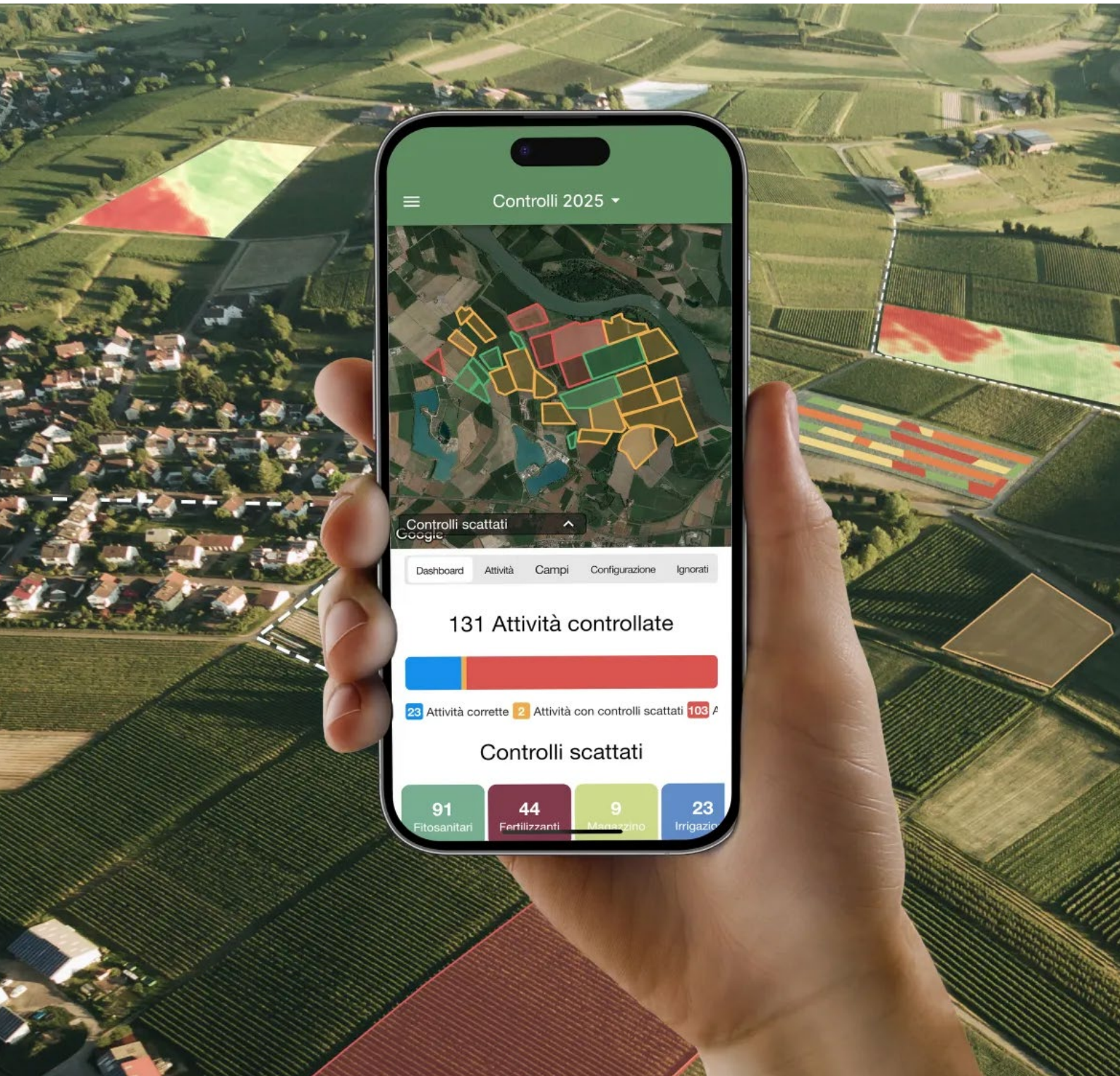
Milan, Italy

xFarm Technologies is an **integrated digital ecosystem** designed to **centralise every aspect of agricultural management** on a single platform. Through the use of IoT sensors, satellite surveys and direct integration with machinery, the system allows **real-time monitoring of field activities, crop protection and water resource use**. With over 600,000 farms and 14 million hectares digitised, the platform optimises decision-making processes by reducing waste and ensuring traceability throughout the entire production chain.

Keywords:
#Data-driven agriculture
#Digital farm management
#Precision farming systems

Response to the identified challenge:
The integration of these technologies radically transforms the nature of rural activity, shifting the focus of value from physical strength to the **analytical management of complex systems**. The digitisation of operational processes acts as a catalyst for **attracting new professional profiles**, elevating agriculture to a high-tech sector where precision and sustainability become the parameters of excellence. This evolution allows primary production to be interpreted no longer as a subsistence occupation, but as an advanced managerial career, capable of attracting multidisciplinary skills and redefining the social prestige of the sector.

FARM TECHNOLOGIES



T1 - Transition to regenerative and sustainable agriculture

The current traditional agricultural system, based on the **unsustainable use of critical resources** such as soil and water, has prompted the sector to engage in profound operational reflection. This need has generated **new production practices** geared towards respecting the environment and reducing the ecological footprint in the territories. The aim is to generate **positive and measurable environmental impacts**, increasing the resilience of production models in the face of growing systemic pressures.

The **main sustainable practices** are:

- ***ORGANIC FARMING*** is the most established model in this transition, showing steady growth in both production and consumption. With around **4.3 million farmers globally** and a retail market that reached approximately **USD 148 billion in 2023**, the sector demonstrates significant economic strength (Meshram et al., 2026). In Europe, organic farming covers 19.5 million hectares, and the objectives of the **European Green Deal,** which aims to have **25% of agricultural land under organic management by 2030**, are accelerating the adoption of this model (Meshram et al., 2026).

- ***THE BYODINAMIC APPROACH*** is distinguished by a holistic vision that considers the farm as a living, complex and self-sufficient organism. In addition to avoiding synthetic chemicals, this method introduces the use of specific preparations to **activate soil vitality** and **follows natural and cosmic rhythms** to harmonise cultivation activities (Rigolot et al., 2022). It is a constantly growing practice that now covers a certified area of approximately **190,000 hectares** worldwide, in addition to a large number of small, uncertified producers who operate according to the same principles (Rigolot et al., 2022). According to the international organisation **Demeter**, biodynamic agriculture is already practised in **55 countries in over 5,500 registered farms**, with a steady increase recorded especially in the **wine sector** (Rigolot et al., 2022).

- ***REGENERATIVE PRACTICES*** focus on combining productive activities with active conservation of natural resources. This

Demeter
Demeter is an **association of producers and distributors** that acts as a certification body for food, cosmetics and textiles from **biodynamic agriculture**. The Demeter label is applied exclusively to products that are already certified organic, acting as an additional and more restrictive standard. Its rules impose higher requirements than European organic regulations, ensuring that the entire supply chain complies with the systemic principles of the biodynamic model. (Demeter, n.d.)

modelsaims not only at sustainability, but also at **regenerating soil health** by **restoring its carbon content** ***(Fig. 3.48)***, which in turn improves productivity in direct opposition to conventional agriculture (Newton et al., 2020). By prioritising carbon sequestration and restoring biodiversity and the water cycle through management practices that minimise soil disturbance, regenerative agriculture aims to transform the sector into a tool for **climate mitigation**. Indeed, it is estimated that regenerative annual crops could sequester **14.5 to 22 gigatonnes of CO2 by 2050**, **increasing yields** through carbon sequestration and **ensuring the long-term resilience of ecosystems** (Newton et al., 2020).



Fig. 3.48 Difference between organic soil (right) and conventional agricultural soil (left).

Impacts on the Agrifood System

The adoption of organic and regenerative practices primarily affects the intrinsic robustness of ecosystems, improving soil structure and promoting biodiversity. As shown in the framework ***(Fig. 3.49)***, these techniques create a form of **productive resilience** that protects crops **from external shocks**, drastically reducing dependence on synthetic inputs and **cutting climate-changing emissions**. This

natural balance is directly reflected in the quality of the final product, where eliminating the chemical part of fertilizers and pesticides is not only an ecological choice but also a conscious food safety strategy. By reducing the toxicological load at the root, the risks of contamination are reduced, transforming the health of the field into a guarantee of biosafety for the consumer. Furthermore, this approach transforms agriculture from a problem to a climate solution. Through the sequestration of organic carbon in the soil, regenerative practices act as an effective **mitigation tool**, capable of removing significant volumes of CO2 from the atmosphere and re-establishing a more harmonious connection between production cycles and natural cycles.

Identifying Challenges and Opportunities within the Framework

However, the success of this systemic transition faces a structural barrier identified in the challenge of ***Bridging the green affordability gap (C10)***. In order for sustainability not to remain an elite privilege, it is essential to reduce the price gap between conventional products and those derived from regenerative and organic agriculture. The challenge is to redesign value chains to democratise access to healthy and safe food, ensuring that the costs of the ecological transition are distributed fairly and do not become an obstacle for consumers or a threat to the economic survival of producers.

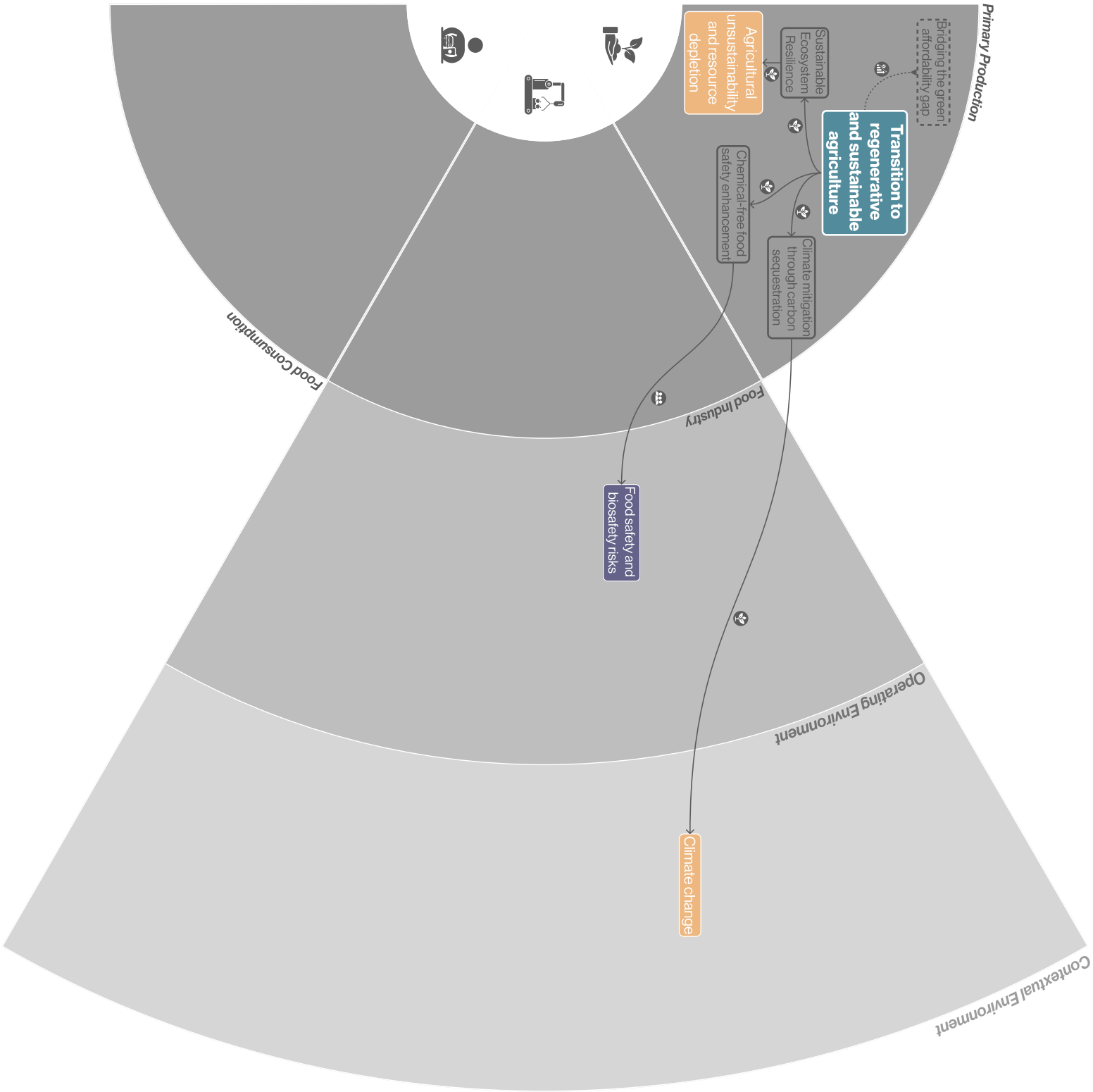


Fig. 3.49 Transition to regenerative and sustainable agriculture, Systemic Framework.

T2 - Precision agriculture and Smart farming

The **evolution of primary production systems** has gone through several historical phases ***(Fig. 3.50)***, following the pace of major industrial revolutions until reaching the current paradigm of **Agriculture 4.0**. While previous models focused on mechanization (2.0) and the introduction of electronics (3.0), today the sector is in the midst of a **digital transformation** where hyper-connectivity and data integration make it possible to respond to resource scarcity and climate pressure (Bazargani et al., 2024). **Agriculture 5.0** evolves this approach by integrating emerging technologies and **green energy sources** to improve farmers' prosperity in the post-pandemic era. Implementing Agriculture 5.0 with green energy sources can lead to reduced costs, increased energy efficiency, and the creation of sustainable, energy-smart farms (Bazargani et al., 2024). To gain a deeper understanding of the technological models that define the current agricultural landscape, it is essential to note that **Precision farming**, **Smart farming** and **Robotics** are the fundamental pillars of the Agriculture 4.0 paradigm. These approaches do not operate in isolation, but are integrated with each other to transform primary production into a hyper-connected, data-driven and highly efficient system.

- ***PRESCISION AGRICULTURE (PA)*** is an innovative approach to farming that uses advanced technologies to optimise yields while minimising inputs and environmental impact, thereby seeking profitability. Unlike traditional methods, it focuses on **managing individual fields** or specific portions of land, aiming for both **economic and ecological benefits** (Sanyaolu et al., 2024). According to (Nabi et al. 2017), precision agriculture is a highly effective system that intervenes in every stage of production, from planning through sowing to harvesting. This strategy requires judicious use of fertilisers and pesticides, optimal crop rotation and low-energy technologies. Thanks to tools such as **remote sensing** and **satellite systems**, it is possible to constantly monitor soil quality, plant health and humidity through a **data-driven approach** that allows informed decisions to be made, making the farm more sustainable and profitable (Nabi et al. 2017).

- ***SMART AGRICULTURE*** represents the integration of **autonomous systems** and **information technology (IT)** in the agri-

cultural sector. Through the use of tools such as the **Internet of Things (IoT)**, big data and drones, this model is ushering in the era of Agriculture 4.0, transforming traditional practices into highly automated, **data-driven systems** (Nettle et al., 2025). It is a purely data-driven approach that allows production to be monitored and managed in real time, dramatically improving decision-making in increasingly complex contexts. In addition to increasing productivity and environmental sustainability, smart farming helps address the **shortage of agricultural labour** by automating the most burdensome tasks. Finally, **digitalisation** plays a key role in product traceability, making the entire food supply chain more transparent and safer for the end consumer (Nettle et al., 2025).

- ***ROBOTICS AND MECHANICAL AUTOMATION*** respond to the need to reduce manual labour and make the sector more technologically advanced. The use of autonomous devices, such as **drones** for **aerial monitoring** and rovers for specific field operations (mechanical weeding, harvesting), allows the growing shortage of skilled labour to be addressed directly. These intelligent mechanical systems guarantee millimetric and constant operational precision, drastically **reducing waste of resources** and **relieving humans of the most tiring and repetitive tasks**, thus reconfiguring agricultural work into high value-added technical management.

Evolutionary trajectory of agricultural paradigms in relation to industrial revolutions

Source: Automation's Impact on Agriculture, Bazargani et al., 2024

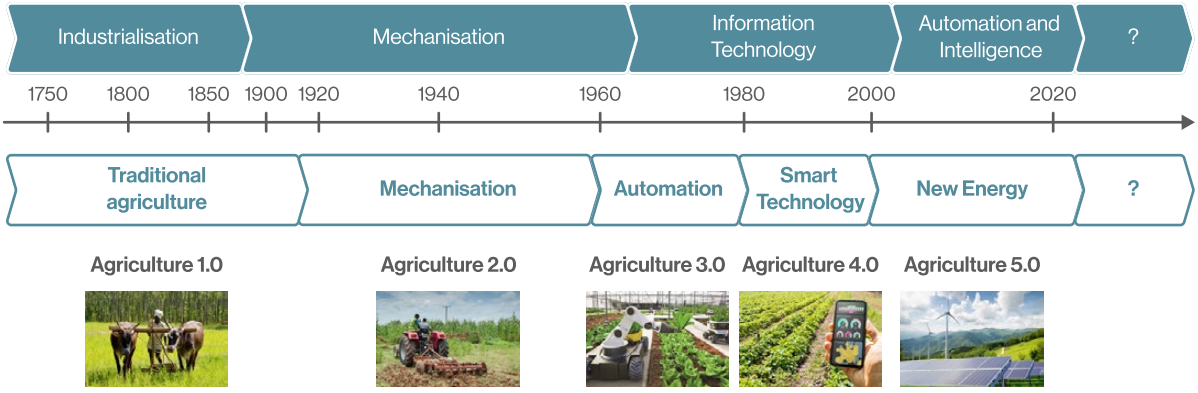


Fig. 3.50 Evolutionary trajectory of agricultural paradigms.

Impacts on the Agrifood System

The integration of Agriculture 4.0 technologies into the production system allows, first and foremost, for **higher sustainability standards** through radical optimisation of natural resources, which are increasingly scarce today. This approach is a solid alternative to conventional agricultural models, transforming the primary sector into a **technologically advanced ecosystem** and, as a result, much more attractive to **new generations** and specialised professionals, who are naturally more inclined towards innovation and change. As shown in the framework ***(Fig. 3.51)***, in addition to the purely ecological dimension, digitalisation and automation make agricultural production not only more sustainable, but also significantly more efficient, automated and faster. This evolution represents a concrete systemic response to the critical issues related to the ageing workforce and the chronic loss of rural labour, the negative effects of which would be mitigated by the introduction of intelligent mechanical devices. This ability to **"do more with less"** also makes it possible to respond more effectively to the growing global demand for food resulting from population growth, alleviating the risks associated with food security. Finally, the surgical optimisation of processes ensures a structural reduction in waste, making the entire agro-industrial system significantly more efficient and resilient than current models.

Identifying Challenges and Opportunities within the Framework

The main challenge that could slow down the integration of these innovations concerns the high initial investment costs, identified as ***high investment costs and technological gap risk (C22)***. These barriers make technological adoption particularly complex for small and medium-sized enterprises that are unable to scale costs, risking exacerbating the digital divide already present in the agricultural sector. At the same time, digital technologies enable a significant opportunity for ***increased transparency in the supply chain (O11)***. Through tools such as blockchain, it is possible to guarantee total and secure product traceability throughout the agricultural supply chain. This technological advancement makes it possible to accurately meet consumers' growing demand for transparency and traceability, transforming technical data into a certified value of trust.

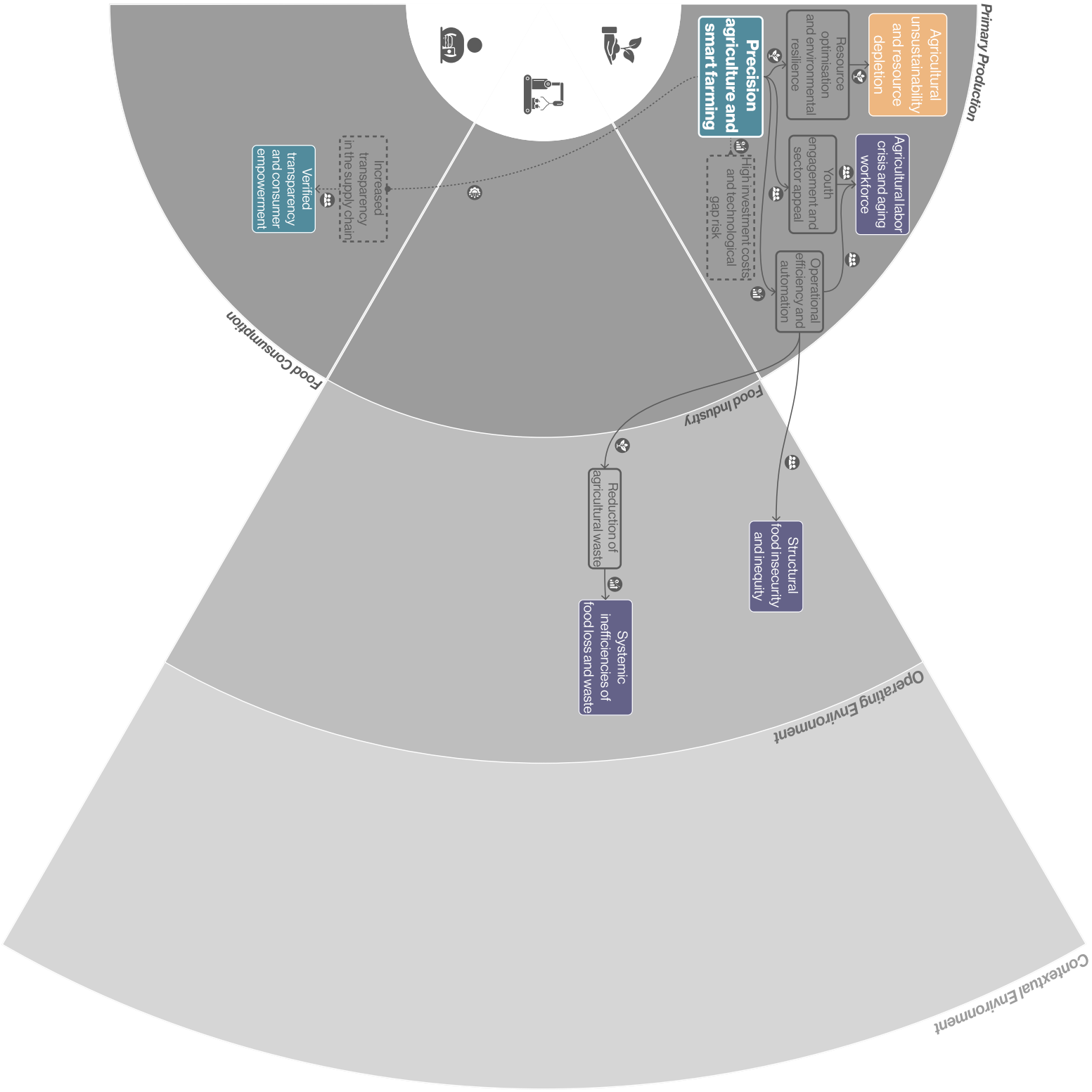


Fig. 3.51 Precision agriculture and Smart farming, Systemic Framework.

C22 - High investment costs and technological gap risk.

Hello Tractor

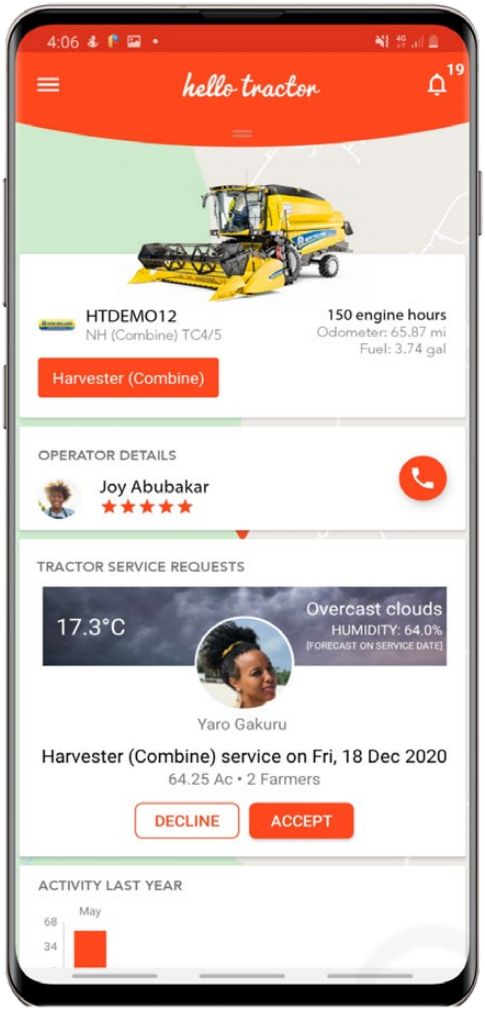
Nairobi, Kenya

Founded in 2014, Hello Tractor is a leading **ag-tech platform** that connects smallholder farmers with tractor owners to **provide accessible and timely mechanisation services**. Through a mobile application and an Internet of Things (IoT)-based fleet management solution, the company enables owners to monitor their assets in real time and farmers to book on-demand agricultural services. Operating in over 18 African countries, the system coordinates fragmented farming communities, transforming the tractor into a hub of digital organisation that aggregates demand and captures valuable data for the entire supply chain.

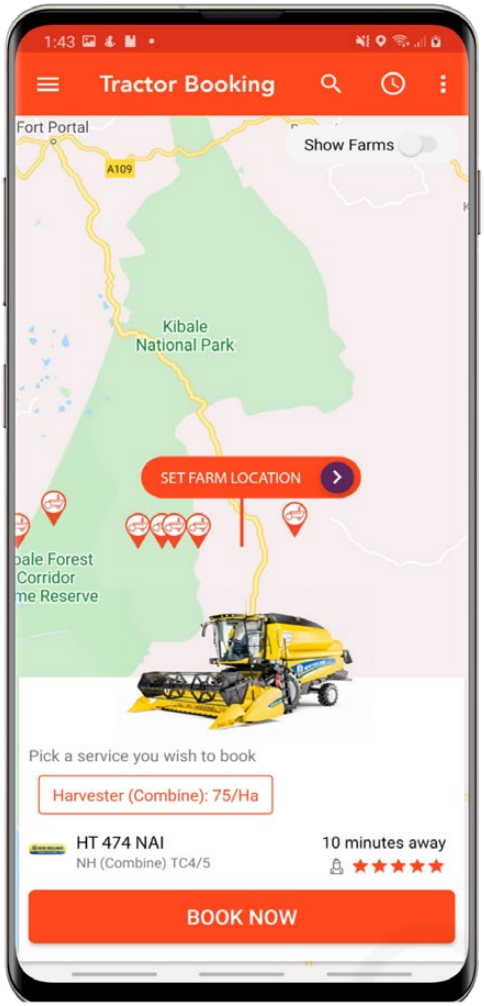
Keywords:
#Farming as a service
#Uber for tractors
#Digital mechanisation

Response to the identified challenge:

Hello Tractor directly **addresses the challenge of high investment costs** and the **risk of a technology gap** by dismantling the concept of asset ownership in favour of **access to services**. In a context where manual labour is up to 40 times slower than mechanisation, but the purchase of a tractor is financially prohibitive for individual smallholders, the Farming as a Service (FaaS) model **democratises technological innovation**. This architecture not only reduces economic barriers to entry, but also actively **prevents the widening of the digital divide**, allowing even unbankable businesses to integrate 4.0 technologies, optimise yields and participate in a modern and scalable agricultural economy.



Contractor App



Booking App

011 - Increased transparency in the supply chain.

AgriDigital

Sydney, Australia

AgriDigital operates as a **cloud-based commodity management platform that digitally connects farmers**, traders and storage operators, with a specific focus on the grain supply chain. The company made history by executing the world's first settlement of a physical agricultural transaction on **blockchain**, integrating data flows, trade and financing into a single secure ecosystem. Through the use of immutable ledgers and digital inventory management, the platform eliminates the use of archaic paper-based systems, ensuring that every transaction and movement of goods is **recorded in real time and accessible to all players** in the supply chain.

Keywords:
#Blockchain
#Digital traceability
#Smart contracts

Response to the identified opportunity:

AgriDigital enables increased **transparency in the supply chain** by transforming trust from an interpersonal variable to an integrated technological certainty. The adoption of blockchain creates a "single source of truth", a **decentralised ledge**r that prevents data manipulation and the formation of information silos between farmer and buyer. This architecture solves the invisibility of the supply chain by providing **end-to-end traceability that validates the origin**, quality and ownership transfers of each batch of grain. The use of smart contracts also ensures instant payments upon transfer of digital title, eliminating counterparty risks and ensuring financial transparency that supports producer empowerment and end-consumer safety.



AgriDigital

T3 - Rise of CEA technologies

The emergence of Controlled Environment Agriculture (CEA) technologies represents a response to the convergence of environmental, demographic and territorial crises that are putting traditional agriculture under severe strain. Currently, the global **food system occupies approximately 38% of the Earth's surface** and is responsible for approximately **70% of global freshwater withdrawals**, making it the main driver of **biodiversity loss** (Cowan et al., 2022). In a context marked by climate change, where models predict a worsening of production conditions due to increasingly frequent and intense droughts and floods, controlled environment production allows crop processes to be **separated from meteorological uncertainties**. These technologies are designed to address urgent challenges such as **water stress** and the **impact of supply chains** which, together with **land use** and **waste**, contribute up to **37% of global greenhouse gas emissions**, bringing agricultural production directly into the urban fabric (Cowan et al., 2022).

CEA's Core **Technologies:**

- ***VERTICAL FARMING (VF)*** represents the three-dimensional evolution of agriculture, developing in indoor structures where cultivation levels are stacked vertically to **maximise yield in small spaces** ***(Fig. 3.52)***. This model responds to the push for urbanisation, bringing food **production closer to consumption** in cities and drastically reducing land consumption compared to conventional methods. The global market for this technology, valued at approximately **USD 7 billion in 2023**, is set to grow by **20% by 2030**, reflecting its rapidly increasing economic importance (Rouphael et al., 2024). Although **Europe holds a share of more than 30%**, political support remains modest compared to the United States, where federal funding for indoor agriculture is much more substantial (Rouphael et al., 2024). However, the **energy challenge** remains critical: high electricity consumption is a significant obstacle to the **scalability of the system**, especially in regions where access to stable and sustainable energy sources is not guaranteed (Rouphael et al., 2024).

- ***HYDROPONICS*** is the most established method in indoor production, with a market value that already reached **USD 1.33 billion in 2020** and an expected compound annual growth rate (CAGR) of 20% until 2027 (Rivera et al., 2023). By **eliminating**

soil and using balanced nutrient solutions, this technique **reduces water consumption by 90%** compared to conventional systems (Rajaseger et al., 2023). Its ability to exploit verticality ensures high yields per unit area, making it a mainstay of high-density urban production.

- ***AEROPONICS*** stands out as an **advanced technological variant of hydroponics** in which the roots remain suspended and are periodically sprayed with a nutrient mist. With a compound annual growth rate **(CAGR) of 21%** (Rivera et al., 2023), this method maximises root oxygenation, accelerating **plant development by 25% compared to traditional methods** (Rivera et al., 2023). The savings in resources are extreme, as it requires even less water than hydroponics, positioning itself as the most precise solution for contexts where every input must be minimised.

- ***AQUAPONICS*** elevates the concept of systemic circularity by integrating **plant cultivation and fish farming into a single symbiotic cycle** (Lama et al., 2025). In this model, aquaculture by-products become organic nutrients for plants, which in turn act as biological filters for the water. A properly designed system achieves extraordinary efficiencies, **optimising water use by up to 99%** and the use of critical nutrients such as nitrogen and phosphorus by 78% and 95% respectively (Lama et al., 2025).



Fig. 3.52 Vertical farming system.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.53)***, the adoption of technologies in controlled environments acts as a catalyst for the entire agri-food system. Firstly, it enables **circular efficiency in soil and water use**, offering a valid alternative to traditional models and mitigating the unsustainability of resources. This is accompanied by an **acceleration of production cycles**, with aeroponics capable of reducing growth times by 25%, making raw material production faster and more consistent. Operating in protected environments, these technologies **free agriculture from climatic and biological risks**, increasing the system's resilience to external shocks. This stability directly contributes to **improving food security**, protecting supplies from heat waves, droughts or invasions of alien species that usually compromise crops in the open field. **Bringing production closer to consumption** is another fundamental pillar: by bringing crops directly into the urban fabric, the supply chain is shortened and the burden of **logistics is drastically reduced**. In an era marked by strong **geopolitical tensions**, this autonomy transforms the city into a more robust production hub that is less susceptible to external disruptions or shocks to the global supply chain. However, from a cultural point of view, there is a critical impact linked to the **erosion of territorial identity and terroir**. By separating the plant from the rural soil and its original geographical context, there is a risk of losing that deep connection between cultivar and territory, **weakening the specificity of the gastronomic heritage** in favour of technically perfect production that lacks territorial roots.

Identifying Challenges and Opportunities within the Framework

The main challenge of these controlled production models lies in the ***high energy costs required to maintain stable environmental conditions in all seasons (C23)***. This operating expense represents a critical obstacle to the scalability and economic sustainability of producers, making it difficult to balance innovation and long-term profitability. A further limitation concerns the limited variety of viable species, which highlights the clear ***constraints on crop diversification in closed environments (C24)***. At present, it is not possible to grow products such as cereals or fruit trees, which limits the ability of these technologies to fully replace traditional agriculture for mass crops.

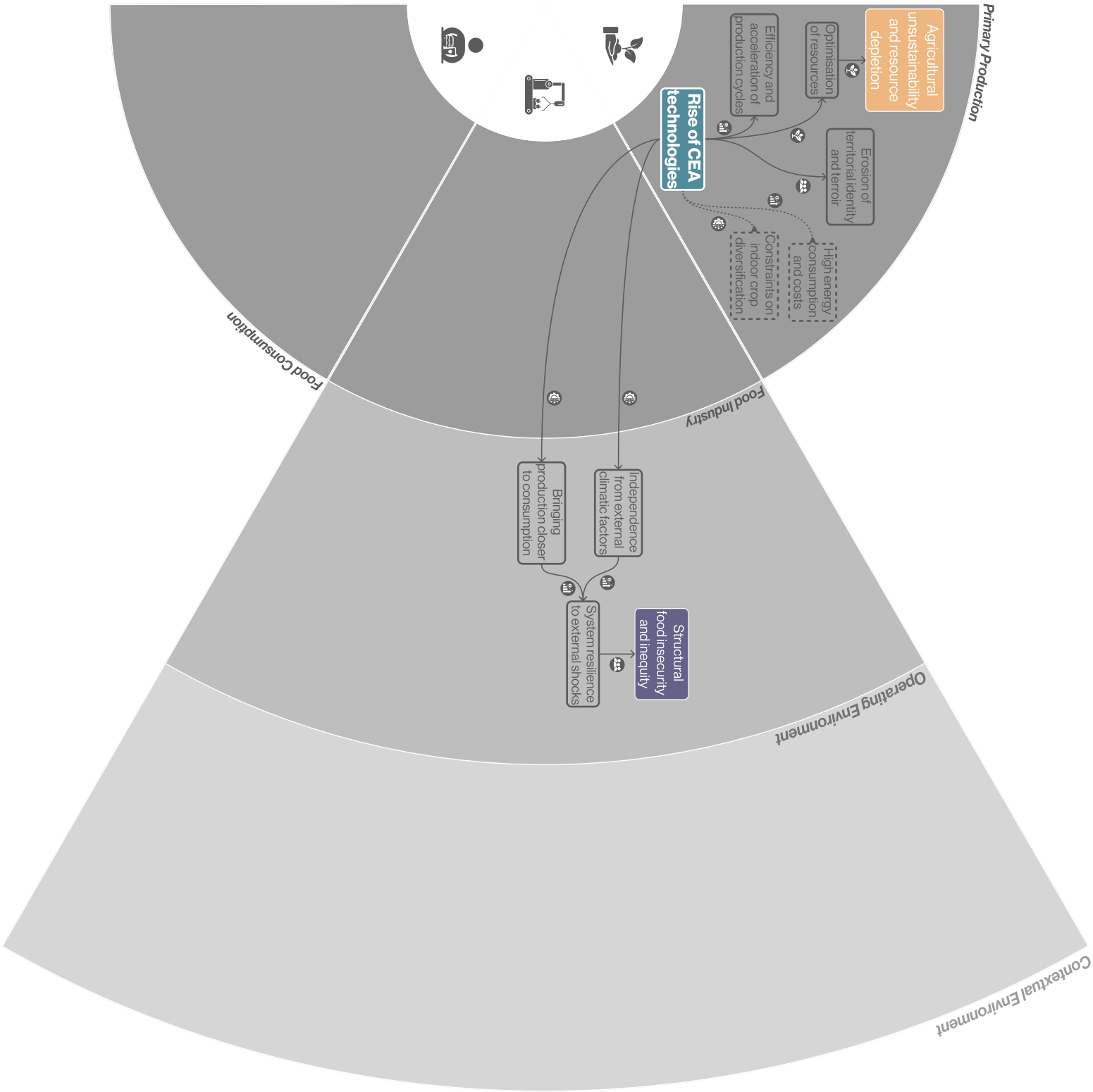


Fig. 3.53 Rise of CEA technologies, Systemic Framework.

C23 - High energy consumption and costs.

Zero Carbon Farms

London, UK

Zero Carbon Farms operates a **hydroponic farming facility located 33 meters underground**, inside former World War II air raid shelters beneath the streets of London. The platform **grows microgreens and herbs** in a **fully controlled environment**, where nutrient flows and LED lighting are optimised to maximize photosynthesis without waste. Through a strategic partnership for the supply of energy from British renewable sources (sun, wind, and water), the company **aims to achieve total decarbonisation** of the production process, integrating food production directly into the urban fabric.

Keywords:
#Underground farming
#Refunctionalised infrastructure
#Urban agriculture

Response to the identified challenge:

The Zero Carbon Farms approach addresses the challenge of high energy consumption and costs by **exploiting the natural thermal inertia of the subsoil**. Unlike above-ground structures, tunnels maintain a constant temperature of around 16°C throughout the year, drastically **reducing energy requirements for heating, cooling, and dehumidification** (HVAC). This design choice transforms an "urban void" into a natural insulator, making the system inherently more efficient and **mitigating the volatility of energy prices** that often compromises the economic sustainability of traditional vertical farms.



C24 - Constraints on indoor crop diversification.

Oishii

Jersey City, USA

Oishii was the first company in the world to **successfully scale up the production of strawberries (the famous Omakase Berries) within a vertical farm**. Unlike most competitors focused on leafy vegetables, Oishii has developed a system that integrates artificial intelligence and biological pollination using bees that live permanently in the controlled environment. Their technology **perfectly recreates the climate of the Japanese Alps**, allowing the growth of fruit with sugar levels and **organoleptic qualities that are impossible to achieve in the open field**.

Keywords:
#High-value crops
#Indoor pollination
#Microclimate creation

Response to the identified challenge:
Oishii responds directly to **crop diversification constraints** by demonstrating that the limitations of CEA are not biological, but primarily technological and design-related. By **overcoming the complexity of indoor pollination** and managing sophisticated microclimates for fruits with complex life cycles, the company is paving the way for a **new generation of vertical farming**. This approach proves that CEA can evolve beyond simple leafy greens, **integrating high value-added crops** into the system that usually require very specific soil and climate conditions.

Oishii



T4 - NGTs crops and agricultural biotechnologies

The evolution of agriculture has always been linked to man's ability to select and improve plant species. Ever since humans began cultivating the land, they have transformed wild types into **domesticated plants**, specimens that are now so dependent on our intervention that they can no longer survive independently in nature. For centuries, this control was achieved through **cross-breeding** and **manual selection**, which took a very long time, often 6 to 7 years to achieve a single significant improvement (Galanakis, 2024). The real breakthrough came in **2012** with the discovery of the **CRISPR-Cas9** system by **Emmanuelle Charpentier** and **Jennifer Doudna**. This precise **genome editing technology** allows us to intervene on the genetic code like a "molecular pair of scissors", reducing development times to less than a year (Galanakis, 2024). Such speed has become essential in **responding to urgent challenges** such as global warming and the increase in food demand due to world population growth, which require immediate solutions that can no longer be postponed. This discovery led to the development of **NGTs (New Genomic Techniques)**, which enable crop evolution to be guided towards specific and diverse objectives, such as:

- ***Climate resilience and resource optimisation:*** Development of varieties that are drought-resistant or require less water and fertiliser to grow.

- ***Resistance to diseases and pathogens:*** Reduction of dependence on pesticides by making the plant intrinsically capable of defending itself against external attacks.

- ***Improvement in nutritional value and organoleptic qualities:*** Controlling flavour and enhancing nutrients essential for health, as in the case of the **Japanese GABA tomato** ***(Fig. 3.54)***, which is enriched with a specific amino acid to help combat stress and regulate blood pressure (Rita, 2021).



Fig. 3.54 Japanese GABA Tomato.

Legislative developments and social perception of NGTs

The regulatory management of NGTs in Europe is undergoing a period of profound change, marked by attempts to move beyond the historic **Directive 2001/18/EC** and the overlap with older **GMOs**. The proposal approved by the **European Parliament** in **February 2024** (European Parliament, 2024) introduces a fundamental distinction between **two categories**:

- ***NGT-1:*** Varieties considered **equivalent to conventional plants**, as their modifications could also occur in nature or through traditional crossbreeding. A simplified procedure is envisaged for these, facilitating their placing on the market.

- ***NGT-2:*** Plants with more **complex modifications** that remain subject to strict GMO regulations, requiring specific authorisations and constant monitoring.

Despite this legislative openness, public acceptance remains a significant obstacle, often hampered by a stereotypical perception of biotechnology. As highlighted by **Prof. Vera Ventura** of the University of Brescia, socio-economic research shows a systemic paradox; in fact, consumers who are most concerned about sustainability are often the most sceptical about genomic innovation. This attitude stems from **cognitive biases** fuelled by sometimes alarmist communication and **misinformation** that tends to confuse NGTs with the transgenic models of the past, leading precisely those segments of the population that are most sensitive to the environment to feel a strong distrust of tools that are useful for ecological transition. Looking beyond European borders, the **divergence with the US model** becomes clear. While **Europe** adopts a **precautionary approach** based on process control and **maximum transparency** of **information for citizens**, US regulation focuses **exclusively on the final result of the product**. This makes the US system inherently faster at innovating, compared to the European vision, which prioritises health protection and the consumer's right to make informed choices.

Impacts on the Agrifood System

The adoption of New Genomic Techniques (NGTs) represents a paradigm shift in the design of agricultural systems, allowing for the **development of crops that are inherently more productive and adaptable**. As shown in the framework ***(Fig. 3.53)***, one of the most significant advantages concerns the **improvement of the resilience and sustainability** of production systems, as genome editing allows for the **optimisation of resource** use and confers **resistance to climatic stress** and **pathogens**, offering a valid alternative to conventional agricultural models. This reduced need for external inputs translates into a reduction in the use of chemical fertilisers and pesticides, promoting not only environmental protection but also social improvement linked to the **food safety** of the food produced. Unlike traditional methods, which are slower and subject to chance, these technologies allow **rapid and precise control of the genes** responsible for **crop yield and efficiency**. The synergy between yield optimisation and crop stability ensures **greater resilience of food systems to external shocks**. In a context marked by strong geopolitical tensions and unpredictable climate change, the ability to quickly adapt raw materials becomes a strategic lever for **ensuring food security** in the face of a constantly growing world population.

Identifying Challenges and Opportunities within the Framework

The main barrier to adopting these genomic techniques lies in ***public acceptance and legislation (C25)***. In fact, many people are still afraid and distrustful because they remember the GMO issue. It will therefore be important to continue raising awareness and developing legislation that helps consumers understand the real potential of these technologies, highlighting the concrete benefits they offer both for their well-being and for environmental protection. At the same time, these biotechnologies make it possible to ***control crop genes to ensure that certain characteristics are developed (O12)***, or not, in the plant and its fruit. In this way, it is possible to satisfy customers, hypothetically generating nutrients tailored to the consumer. This capability can become a valuable tool for providing certain nutrients to people in different forms, helping to significantly improve current food issues. Influencing organoleptic and nutritional quality therefore represents an opportunity to make food production healthier and more closely aligned with the real needs of the population.

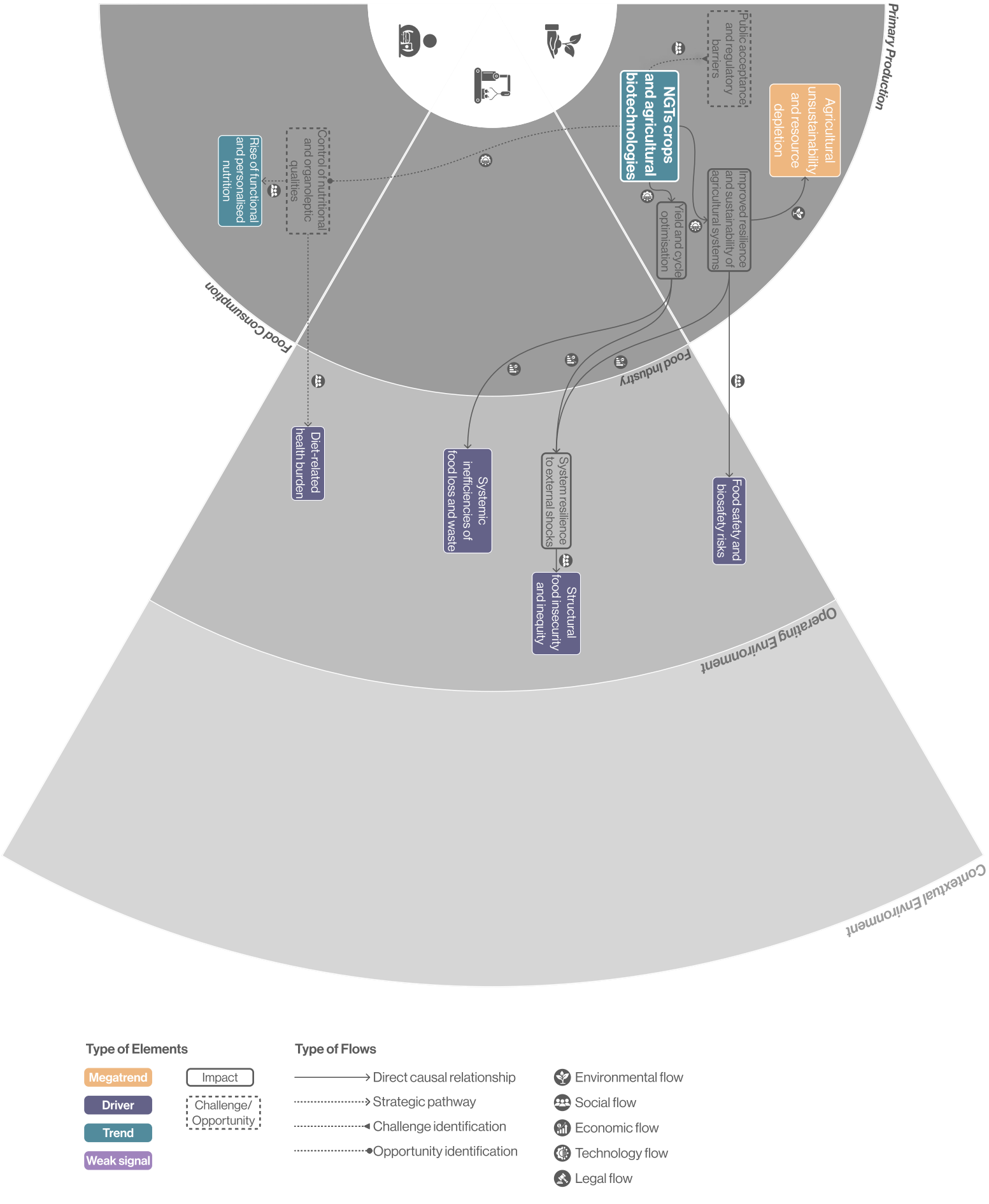


Fig. 3.55 NGTs crops and agricultural biotechnologies, Systemic Framework.

C25 - Public acceptance and regulatory barriers.

Innovative Genomics Institute (IGI)

Berkeley, USA

The Innovative Genomics Institute (IGI), founded by Nobel laureate **Jennifer Doudna**, has developed a public education programme that goes far beyond simple scientific dissemination. Through **interactive exhibitions**, **virtual reality tours** inside the genetic code and "open science" projects on iconic crops such as cocoa and rice, the institute **involves citizens in the process of discovery**. The goal is to explain the "why" behind the use of **CRISPR**: to save iconic foods from disease and protect the livelihoods of smallholder farmers, making the technology transparent and accessible.

Keywords:
#Demystification
#Public trust
#Social Awareness

Response to the identified challenge:

The IGI tackles the challenge of **public acceptance and regulatory barriers** by directly addressing cognitive biases through **demystification**. Instead of top-down communication, the initiative uses storytelling to link NGTs to the preservation of the world's gastronomic heritage (such as chocolate). This approach shifts the perception of technology from "artificial manipulation" to "**conservation tool**", reducing fear of the unknown and building the social trust necessary for legislation to **evolve in a climate of informed consent**.

Innovative Genomics Institute



012 - Control of nutritional and organoleptic qualities.

Pairwise

Durham, USA

Pairwise used CRISPR technology to solve the food paradox whereby many people would like to eat more nutritious vegetables, but avoid them because of their **bitter or pungent taste**. Under the brand name **"Conscious Greens"**, the company has created a variety of leafy vegetables in which the **gene responsible for the perception of bitter taste has been silenced**. The result is a salad with the texture and pleasant taste of lettuce, but with the superior nutritional values typical of Brassica, **making healthy food more appealing to the masses**.

Keywords:
#Taste control
#Nutrient density
#Consumer-centric breeding

Response to the identified opportunity:

Pairwise takes full advantage of the opportunity to **control the nutritional and organoleptic qualities of NGTs** by adapting the plant to the real preferences of modern consumers. This approach demonstrates how NGTs can influence demand, making **functional nutrition** no longer a punitive duty but an **enjoyable experience**. By modifying sensory traits without sacrificing nutrient density, the company creates a direct bridge between agricultural production and public health needs, **facilitating the adoption of healthier diets** on a large scale.

pairwise®



3.5 Food Industry Scan

The Food Industry analysis has identified the factors that characterise the phase following production in the field, focusing on the **transformation processes** that turn raw materials into food ready for human consumption. Within this scenario, two main trends have been identified that could radically change the paradigm of the food industry and the entire agro-industrial system. These innovations have been developed to **respond to new market demands**, but they also represent strategic responses to resolve, at least partially, some of the most urgent systemic issues.

The **main factors analysed** are:

1. *Development of novel foods and alternative proteins*
2. *Development of advanced food manufacturing*

This section highlights the factors belonging to the **Food Industry** ***(Fig. 3.1)***, which represent the elements characterising the **transformation of raw materials into final products** ready for human consumption. Each factor is examined methodically: first through the visualisation of relevant data confirming the trend, followed by the Understanding Complexity phase to identify relationships, impacts and interdependencies within the agrifood system. Finally, the Tackling Challenges phase serves to identify the challenges and opportunities generated by each factor; for each of these, real case studies have been reported which, acting as concrete solutions or suggestions, confirm the emergence of these conditions in the sector.

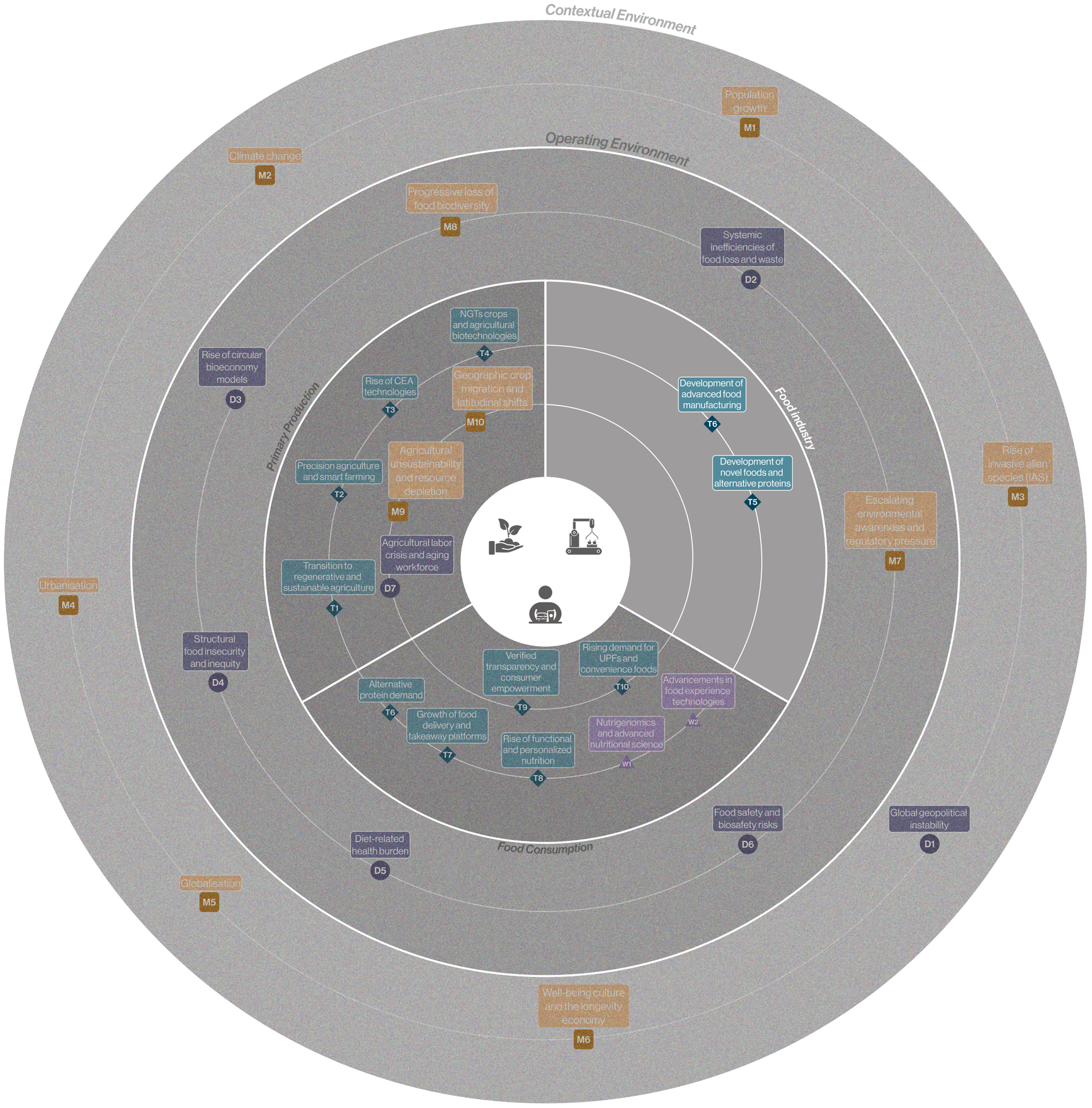


Fig. 3.1 Scanning map.

T5 - Development of Novel foods and alternative proteins

The trend Development of novel foods and alternative proteins represents one of the most effective responses to the pressure that the global food system is under. This evolution stems primarily from the **need to diversify protein sources** to feed a **constantly growing world population**, while reducing the environmental impact of traditional meat production. Conventional **meat production is now considered unsustainable** and often **less healthy** than other sources, contributing to diet-related diseases. In this context, **plant-based solutions** are also driving the market, responding to the search for sustainable alternatives and the growing demand for proteins that do not come from intensive farming. In the **European Union**, the concept of Novel Food is governed by **EU Reg. 2015/2283**, which includes all foods or ingredients that were **not consumed in the EU before 15 May 1997** (EIT Food, 2022). This regulatory framework ensures the safety and correct labelling of products through **EFSA** assessments and inclusion in an authorised list (Union List). The main challenge for the adoption of novel foods concerns **consumer acceptance**. Disgust and **food neophobia**, due to a sense of unnaturalness and cultural inadequacy towards products such as insects and cultivated meat, often block their consumption. On the contrary, this barrier is significantly lower for plant-based alternatives, which are more familiar to consumers (Gunden et al., 2024).

EFSA
The European Food Safety Authority (EFSA), based in Parma, is the body established in 2002 to provide independent scientific advice on risks related to the food chain. It acts as a technical compass for EU legislators, defining the scientific basis necessary to protect consumer health at every stage, from producer to consumer. Through cooperation with stakeholders, it promotes consistency in regulations and transparency in risk communication. Its work ensures that every regulatory decision is guided solely by objective and rigorous evidence. (EFSA, n.d.)

The **main categories** of **Novel Foods** are:

- ***EDIBLE INSECTS:*** The consumption of insects (entomophagy) is an ancient practice involving around **2 billion people, mainly in Asia, Africa and South America** (Henchion et al., 2017). Among the more than **2,000 species used**, the most common are beetles (31%) and caterpillars (18%). Today, the West is also looking to this resource as a sustainable **alternative source of protein**, and **three species of insects** have already been authorised in the **EU**, namely the **yellow worm larva**, the **migratory locust** and the **house cricket**, which can be consumed either whole or in powder form (EIT Food, 2022). Compared to livestock, on average around 80% of the weight of insects is edible and digestible, providing an **excellent nutritional profile for humans**, rich in protein and vitamins B1, B2 and B3, although



Fig. 3.56 Yellow worm larva.

Microalgae
Microalgae are versatile single-celled organisms often cultivated in open ponds. In the European Union, the species most commonly used for human consumption are **Spirulina**

and **Chlorella**, valued for their protein and fatty acid content, such as EPA and DHA. Despite their great potential, their widespread use is hampered by high production costs, complex extraction processes and sensory challenges related to taste. There are also some concerns about microbiological purity and the possible presence of toxins, which is why they are currently used mainly in supplements, cosmetics and animal feed. (Henchion et al., 2017)



Fig. 3.57 Spirulina cultivation.



Fig. 3.58 Fungi farming system.



Fig. 3.59 First cultured hamburger, 2013.

lacking in certain amino acids, including tryptophan and lysine (Henchion et al., 2017). Finally, insects present a **lower zoonotic risk** than animals and birds.

- ***ALGAE:*** marine plants such as **seaweed** and **microalgae** represent a pioneering resource for **bridging the global protein gap**. With an annual production of **24 million tonnes** and a **value exceeding €6 billion**, the sector is booming, with **30% of the harvest dedicated to animal husbandry** as a sustainable alternative to soy(Henchion et al., 2017). Nutritionally, there is a wide variety: **red and green species** can reach **47% protein** by dry weight and are already considered sea vegetables and accepted by consumers in countries such as France, offering amino acid profiles comparable to eggs or soy, unlike **brown algae**, which have **lower values (3-15% protein)** (Henchion et al., 2017). Despite the challenges related to digestibility and the risk of **heavy metal accumulation**, the European Commission is currently developing an initiative "Blue bioeconomy - towards a strong and sustainable algae sector", which aims to scale up the sustainable production of algae and algae-based products, ensure their safe consumption and boost their use in the EU (EIT Food, 2022).

- ***FUNGI:*** With an estimated **five million species**, these organisms, including yeasts and moulds, are establishing themselves as alternative protein sources thanks to their ability to transform waste materials into nutritious biomass and their **benefits for human** and animal **consumption**. (EIT Food, 2022). Fungi are currently entering the European market with advanced solutions, such as **Agaricus bisporus powders** enriched with vitamin D2 for medical purposes (EIT Food, 2022). **Mycoprotein**, derived from **filamentous fungi**, is another economical and nutritionally beneficial alternative protein that serves as a sustainable meat substitute. (Galanakis, 2024).

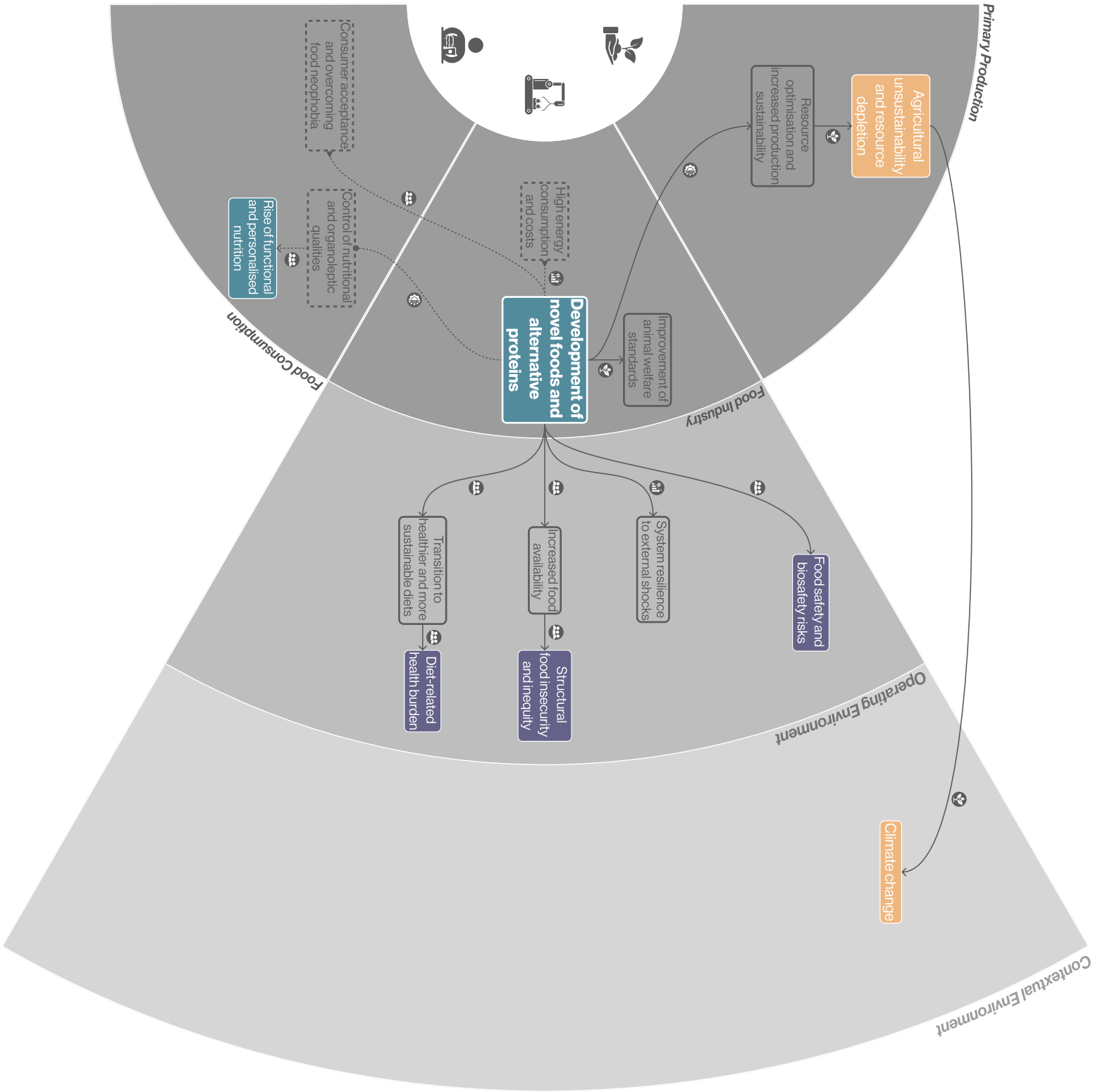
- ***CELLULAR AGRICULTURE PRODUCTS:*** Cell-based agriculture allows **animal proteins** to be produced directly in the **laboratory**, eliminating the need for intensive farming and slaughter. **Cultured meat**, grown in **bioreactors**, is an **ethical and sustainable alternative** that consumes up to **99% less land than cattle**, while offering controlled and customised nutritional profiles (Henchion et al., 2017). Alongside this, **precision fermentation** uses safe microorganisms, such as yeasts and bacteria, to recreate specific ingredients and proteins extremely efficiently.

Impacts on the Agrifood System

The integration of novel foods into contemporary diets is a key lever for **increasing global protein availability**, offering a concrete response to population growth and critical issues related to food security and global inequality. As shown in the framework ***(Fig. 3.60)***, compared to traditional livestock models, these solutions guarantee **resource optimisation and a drastic reduction in emissions**, offering a **more sustainable production alternative**. A crucial advantage lies in production in controlled environments. This approach not only raises food safety standards by **reducing the risks of zoonoses** typical of intensive farming, but also makes the **agri-food system more resilient to climate shocks** and geopolitical instability. At the same time, the development of these proteins facilitates the **transition to healthier diets**, mitigating the impact of diseases linked to excessive consumption of conventional meat.

Identifying Challenges and Opportunities within the Framework

However, the path towards integrating these new production models faces significant structural and cultural barriers. Firstly, the fact that these foods are developed in highly controlled environments requires ***considerable energy, making scalability and economic feasibility a primary obstacle (C23)*** to the stability of these systems in the short term. A second crucial challenge lies in ***consumer acceptance (C26)***: overcoming cultural barriers and food neophobia will not be immediate, especially for products perceived as less familiar, such as crickets or cultured meat. However, the strategic opportunity of this transition lies in the ability to ***calibrate the nutritional profile of foods (O12)***, effectively responding to the growing demand for functional and personalised nutrition expressed by consumers.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.60 Development of Novel foods and alternative proteins, Systemic Framework.

C26 - Consumer acceptance and overcoming food neophobia.

ValuSect

EU

The ValuSect (Valuable inSects) project is a major transnational initiative funded by the **Interreg North-West Europe programme** (2019-2023) with a total investment of €4.02 million. Coordinated by Thomas More University of Applied Sciences, the consortium brings together partners from seven European countries with the aim of strengthening cooperation and research in the field of **insects as a sustainable food resource**. Against a backdrop of population growth and dwindling resources, ValuSect aims to **make insects a stable component of the European diet** by optimising production and processing methods for the development of finished and semi-finished products.

Keywords:
#Entomophagy
#Consumer acceptance
#Sustainable diets

Response to the identified challenge:

With regard to the challenge of **consumer acceptance**, the project **addresses the barrier of food neophobia**, starting from a critical fact: currently, only 30% of European consumers say they are willing to eat insects. ValuSect tackles the problem by improving the quality and perception of products based on specific species such as crickets, locusts and mealworms. Through a voucher programme for SMEs, the consortium has transferred key knowledge on food safety, environmental impact and shelf life, **supporting businesses in making these novel foods more attractive and culturally acceptable**. The aim is to **normalise the consumption of insects** by demonstrating their nutritional value and safety, thereby reducing consumers' emotional and psychological resistance.

Interreg

EUROPEAN UNION

North-West Europe

VALUSECT

European Regional Development Fund



012 - Control of nutritional and organoleptic qualities.

Aleph Farms

Rehovot, Israel

Aleph Farms is a **pioneer in cellular agriculture**, working to strengthen sustainability, food security and animal welfare in the global system. Through the diversification of supplies and decentralisation of the production of quality animal proteins and fats, the company aims to **complement the sustainable methods of conventional agriculture**. Their first iconic product, called **Aleph Cuts**, consists of **cultivated steaks** that **replicate the sensory experience of traditional meat** without requiring intensive farming or the slaughter of livestock.

Keywords:
#Cellular agriculture
#Bio-manufacturing
#Slaughter-free proteins

Response to the identified opportunity:
Aleph Farms uses technology to actively "design" animal products from cells, rather than simply breeding them. This approach allows for strict **control over organoleptic properties**, as demonstrated by their cuts designed to offer the texture of a rib and the juiciness of a ribeye. The ability to grow specific tissues in controlled environments allows for the **optimisation of not only taste but also nutritional value**, overcoming the biological limitations of standard animal production.

Aleph Farms™



T6 - Development of advanced food manufacturing

The evolution of advanced food production technologies represents not only technical progress, but also a systemic response to the critical issues facing modern society. **Chronic conditions** such as obesity and metabolic syndrome, often linked to sedentary lifestyles and the habitual consumption of ultra-processed foods, have prompted organisations such as the FAO and WHO to call for a **change in processing models** (Galanakis, 2021). Today, we are seeing growing awareness and, according to a study by FMCC Gurus, up to **72% of European consumers** are actively **seeking foods that promote health and immunity**, a need that has become a priority in the wake of the COVID-19 pandemic. This quest for well-being translates into a need for **personalised diets**, the development of **foods enriched with bioactive components** to combat nutrient deficiencies, and the **ecological recovery of bioactive compounds** from industrial by-products, transforming waste into a functional resource capable of replacing synthetic additives (Galanakis, 2021). In this scenario, technologies such as 3D printing, non-thermal treatments, and nanotechnologies are emerging as pillars for **ensuring the bioavailability of nutrients** and **customising nutritional intake**, responding to a demand for food precision that is both healthy and sustainable.

- ***3D FOOD PRINTING:*** Considered one of the most disruptive technologies in the industry, 3D food printing is establishing itself with a **global market value of close to one billion dollars** (Galanakis, 2024). This innovation revolutionises food design, allowing the creation of **tailor-made products** with specific nutritional profiles, textures, colours, flavours and consistencies for every **individual need** (Galanakis, 2024). Thanks to multi-material printing and the creation of complex internal structures, it is possible to **develop healthier foods** by reducing the fat, salt and sugar content, while facilitating the **integration of sustainable ingredients** such as insect flour into familiar formats (Galanakis, 2024). Although current applications range from **space food** to **fine dining**, the consolidation of the sector still requires research to optimise extrusion parameters and the rheological properties of materials. Challenges related to process **standardisation** and **consumer awareness** also remain to be addressed, which are key elements in transforming this technology into a widespread production standard (Galanakis, 2024).



Fig. 3.61 3d-printed salmon, Revo Food



Fig. 3.62 HPP system.

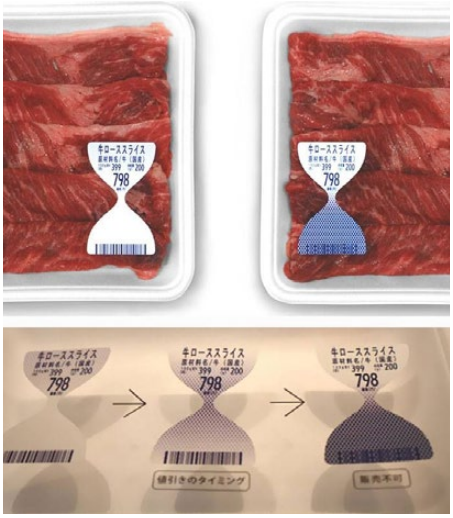


Fig. 3.63 Smart label, TO-GENKYO

- ***NON-TERMAL TECHNOLOGIES:*** At the same time, non-thermal technologies have emerged as a direct response to the limitations of conventional processes, which often degrade the **nutritional quality of food** (Galanakis, 2024). Methods such as **high hydrostatic pressure (HPP)**, **pulsed electric fields (PEF)** and ultrasound-assisted extraction offer extremely gentle treatments that do not destroy the nutritional architecture of the food matrix. The fundamental value of these technologies lies in their ability to positively influence **bioactivity**, ensuring that functional compounds maintain their biological effectiveness, and **bioaccessibility**, optimising the release of nutrients from the matrix for optimal absorption by the body.

- ***NANOTECHNOLOGIES:*** Currently are one of the most advanced technologies for transforming the food system, with the potential to dominate the entire sector thanks to their ability to redefine the production of functional meals and biosafety management. This field operates in three key areas: **processing**, **packaging** and **food safety** (Singh et al.,2023). From a food processing perspective, **nanoencapsulation** stands out for its use of core-shell nanovesicles that protect nutrients and supplements from oxidation and hostile environments, ensuring controlled release based on pH or humidity (Singh et al.,2023). These technologies increase the **bioavailability of nutrients** while masking unpleasant odours or flavours without altering the appearance of the product, as is the case with **nanoemulsions**, which are more stable and digestible than traditional systems. At the same time, the packaging sector is being revolutionised by the integration of **nanomaterials** and **nanocomposites** (polymer matrices incorporating specific nanoparticles such as nanosilver or titanium dioxide) that enhance mechanical barriers and **microbial contamination detection**(Singh et al.,2023). This innovation enables **active packaging**, capable of interacting with food and the environment to extend its shelf life, and **smart packaging**, where nanosensors dramatically raise food safety standards. Tools such as **electronic noses** monitor food in real time and communicate with the user through colour changes, ensuring prolonged **organoleptic protection** and a drastic **reduction in waste** along the supply chain.

Impacts on the Agrifood System

The application of emerging technologies can revolutionise the traditional food industry, enabling profound efficiency gains in the agro-industrial system. As shown in the framework ***(Fig. 3.64)***, these innovations make it possible to **extend the shelf life of food** through solutions such as nanotechnologies applied to active packaging, as well as **optimizing the use of resources** and drastically **reducing food waste** by recovering nutrients from waste products, **increasing the bioavailability of food**, and allowing precise control over its composition. However, the adoption of these technologies has a potentially negative impact linked to the growing **disconnect between the consumer and the original product**. In the case of 3D printing in particular, there is a risk of losing the need to transform fresh food before consumption, profoundly **altering the conviviality and rituality** associated with food preparation. The act of eating thus risks becoming a technical process, distancing itself from the cultural and social value of the raw material.

Identifying Challenges and Opportunities within the Framework

The integration of emerging technologies opens up strategic opportunities for quality management and public health. Nanotechnologies, in particular, enable the ***implementation of advanced systems for monitoring product integrity and safety (O10)*** through the use of smart and active packaging, which raises biosafety levels and minimises the risks of poisoning or critical issues related to storage along the supply chain. At the same time, one of the most interesting features of these emerging food technologies is their ability to ***control and increase the bioavailability of nutrients (O13)***, opening up fundamental scenarios for nutrigenomics and the development of personalised diets. This is a concrete way to alleviate the burden of diet-related diseases by optimising the intake of essential substances and making them more easily assimilated by the body. However, the success of these disruptive innovations depends on overcoming ***food neophobia and gaining real acceptance by consumers (C26)***. As already observed for novel foods, social perception remains the final piece of the puzzle that will determine how successfully these technologies will be integrated into the daily food system.

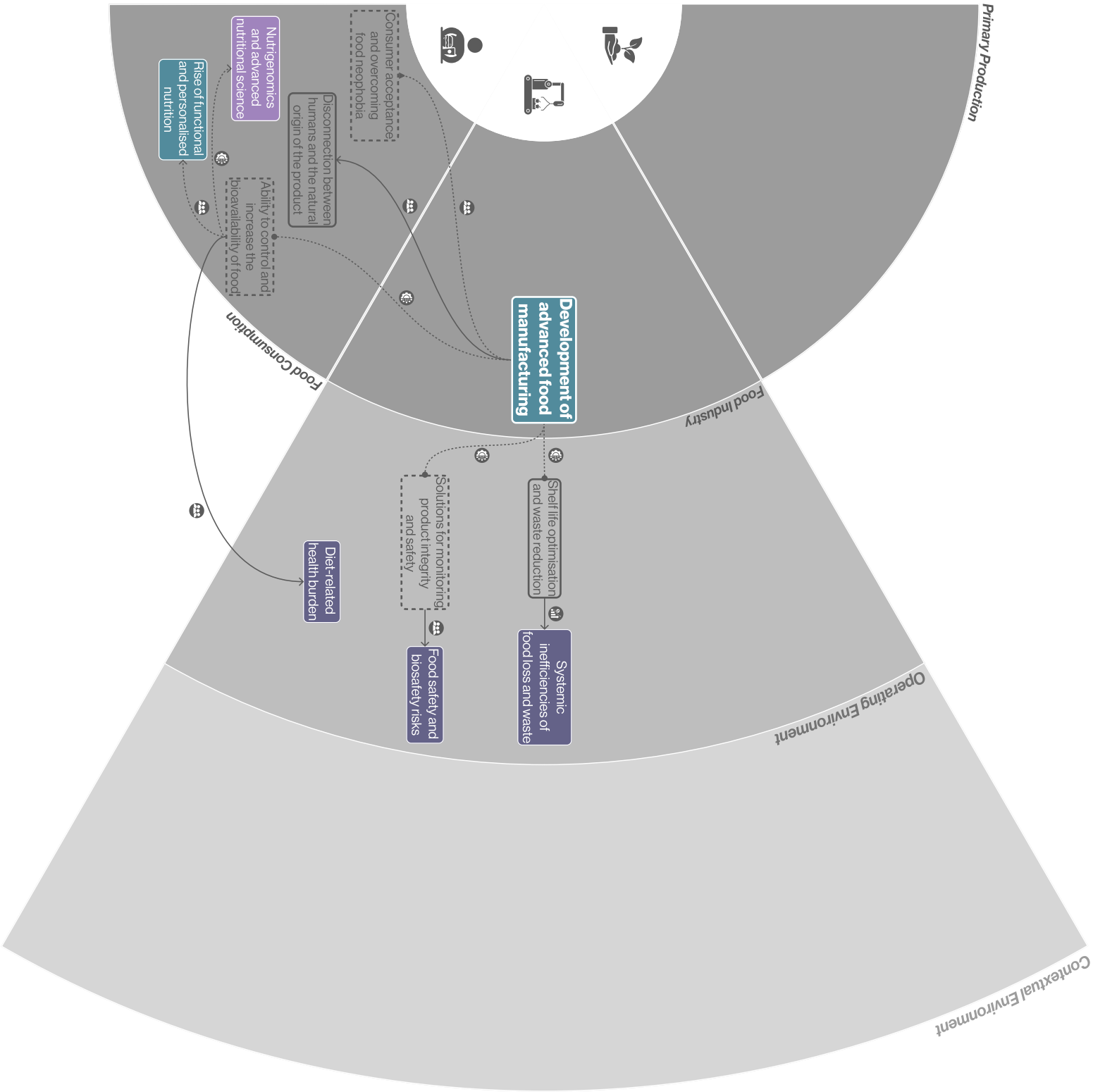


Fig. 3.64 Development of advanced food manufacturing, Systemic Framework.

013 - Ability to control and increase the bio-availability of food.

AnaBio Technologies

Cork, Ireland

AnaBio Technologies is an Irish company specialising in the **microencapsulation of sensitive ingredients for the food**, nutraceutical. The company uses patented technologies to create **protective coatings** at the microscopic level **around probiotics and bioactive substances** such as **vitamins, minerals and oils**. This barrier shields the functional components from critical environmental factors, including heat, humidity and oxidation, **allowing them to be integrated into a wide range of products** (beverages, powders and foods) without compromising their stability or sensory profile.

Keywords:
#Microencapsulation
#Functional foods
#Nutraceutical

Response to the identified opportunity:
AnaBio technology addresses the challenge of bioavailability by **transforming food into a precision delivery system**. The protective coating shields nutrients from stomach acidity, **ensuring they arrive intact in the intestinal tract where absorption occurs**. Clinical studies have shown that this targeted release **increases plasma absorption of nutrients by more than 85% compared to non-encapsulated versions**. This approach maximises the biological effectiveness of the product, ensuring that the **health benefits are effectively absorbed** by the body through controlled release kinetics.


AnaBio
Technologies Ltd.
0–16
year olds
EnCaptimus
Same (Probiotics) Like It Hot
AMBIENT PROBIOTIC DRINK
SPARKLING BLACK TEA
AnaBio
Technologies Ltd.
Probiotics.
Now Serving Hot.

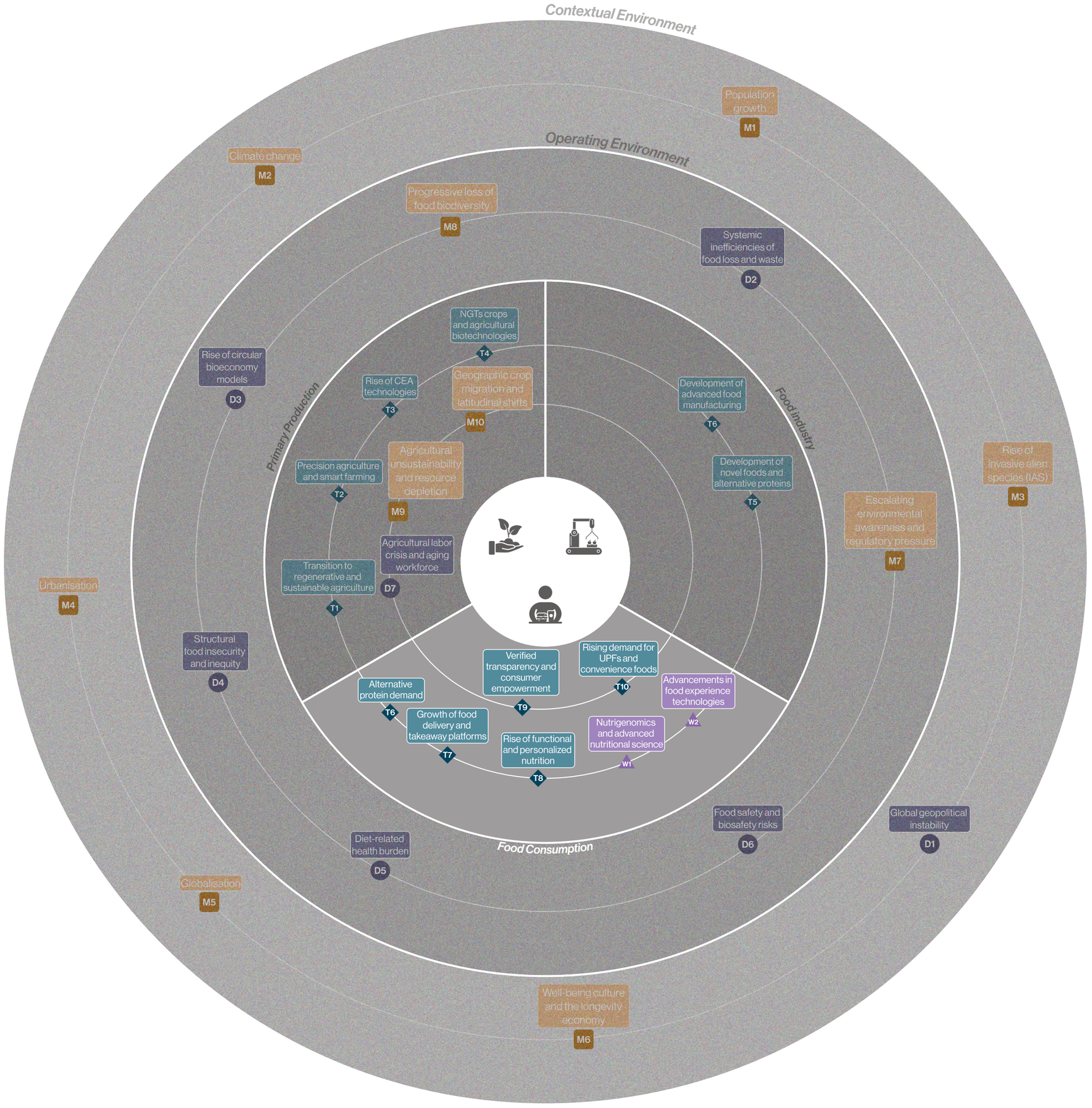
3.6 Food Consumption Scan

The analysis of food consumption moves on to the stage following processing and distribution, focusing on the moment when the **product is purchased and handled by the end consumer** for actual consumption. At this stage, food ceases to be merely an industrial output and becomes the central **element of daily practices and individual choices** that reflect new values and needs. Within this scenario, the main trends that drive the market today have been identified. While some of these trends can now be considered **established and structural in purchasing habits**, two of them are **weak signals**, i.e. signals that are still weak or have not yet fully emerged, but have the potential to transform the system to such an extent that they could have a profound impact and redefine the balance of the entire food system in the near future.

The **main factors analysed** are:

1. *Alternative protein demand*
2. *Growth of food delivery and takeaway platforms*
3. *Rise of functional and personalized nutrition*
4. *Verified transparency and consumer empowerment*
5. *Rising demand for UPFs and convenience foods*
6. *Nutrigenomics and advanced nutritional science*
7. *Advancements in food experience technologies*

This section highlights the factors belonging to the **Food Consumption** ***(Fig. 3.1)***, which represent the elements characterising the final stage of the value chain, where **products are integrated into daily routines and cultural practices of consumption**. Each factor is examined methodically: first through the visualisation of relevant data confirming the trend, followed by the Understanding Complexity phase to identify relationships, impacts and interdependencies within the agrifood system. Finally, the Tackling Challenges phase serves to identify the challenges and opportunities generated by each factor; for each of these, real case studies have been reported which, acting as concrete solutions or suggestions, confirm the emergence of these conditions in the sector.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal

Fig. 3.1 Scanning map.

T7 - Alternative protein demand

The evolution of demand for **alternative proteins (AP)** is one of the most transformative trends in the contemporary food landscape, marking a transition that is affecting global markets at different speeds and with different dynamics. While consumption in high-income countries is now driven by established health awareness, economic development and urbanisation in **low- and middle-income economies (LMICs)** are leading to an increase in demand for traditional animal proteins (Talwar et al., 2024). This scenario outlines the opportunity to integrate alternative proteins to meet the growth in global protein demand without exacerbating the negative environmental impact of intensive livestock farming. Globally, the **alternative protein market is showing steady growth** in every geographical area. The **Asia-Pacific** region stands out as the most dynamic market, with a projected **compound annual growth rate (CAGR)** of **18.5% between 2021 and 2027** (Talwar et al., 2024). This acceleration is fuelled by a combination of cultural and religious factors and a growing focus on functional and healthy food ingredients. The sector has also achieved significant milestones in the **United States**, with the alternative protein market exceeding **USD 50 billion in 2020**, with the **plant-based** component alone exceeding USD **35 billion** in the same year and **projected growth of over 17.5% for the coming years** (Talwar et al., 2024). In this context, sources such as soy, wheat and peas have become staples of daily consumption, finding application in a wide range of products, from meat alternatives to high-protein dairy substitutes. In **Europe**, the trend is growing, with a **CAGR of 12%** expected to bring the market to a value of **USD 7 billion by 2028** (Talwar et al., 2024). These figures confirm that the demand for alternative proteins is not a passing phenomenon, but a response by the system to the need to balance food security with environmental sustainability.

Alternative proteins (AP)
Alternative proteins (AP) include all protein-rich ingredients derived from plants, insects, fungi, algae or animal cells, which represent an opportunity to consume protein-rich foods with a lower environmental impact than conventional livestock products. (Talwar et al., 2024)

Factors influencing consumer demand for alternative proteins

The adoption of alternative proteins in low- and middle-income markets depends on a balance between **affordability**, **cultural acceptance** and **environmental awareness** (Talwar et al., 2024). While in high-income countries the transition is supported by strong environmental and animal welfare awareness, in emerging contexts

priorities remain linked to nutritional value and local traditions. The success of these products is therefore linked to their ability to offer familiar flavours and textures, as demonstrated by the Indian company GoodDot, which focuses on traditional dishes such as kebabs and curries to facilitate the integration of plant-based proteins into existing diets without forcing cultural shifts (Talwar et al., 2024) However, the **main barrier remains the economic factor** (Talwar et al., 2024). Currently, plant-based alternatives are significantly more expensive than conventional meat, making them accessible only to those segments of the population with greater purchasing power. On this path towards cost parity, the **Double Pyramid Model** ***(Fig. 3.65)*** emerges as an awareness-raising tool, allowing consumers to immediately visualise the connection between their **biological well-being** and the **stability of ecosystems**, and elevating plant-based choices beyond mere nutritional considerations. This evolution not only responds to a nutritional need, but also acts as a driver for **more equitable economic progress in emerging economies**. Promoting local protein sources and integrating small farmers into new supply chains creates jobs and strengthens local infrastructure (Talwar et al., 2024).

The "Double Pyramid Model"

Source: Barilla Center for Food & Nutrition "Persone,ambiente, scienza, economia" (2021)

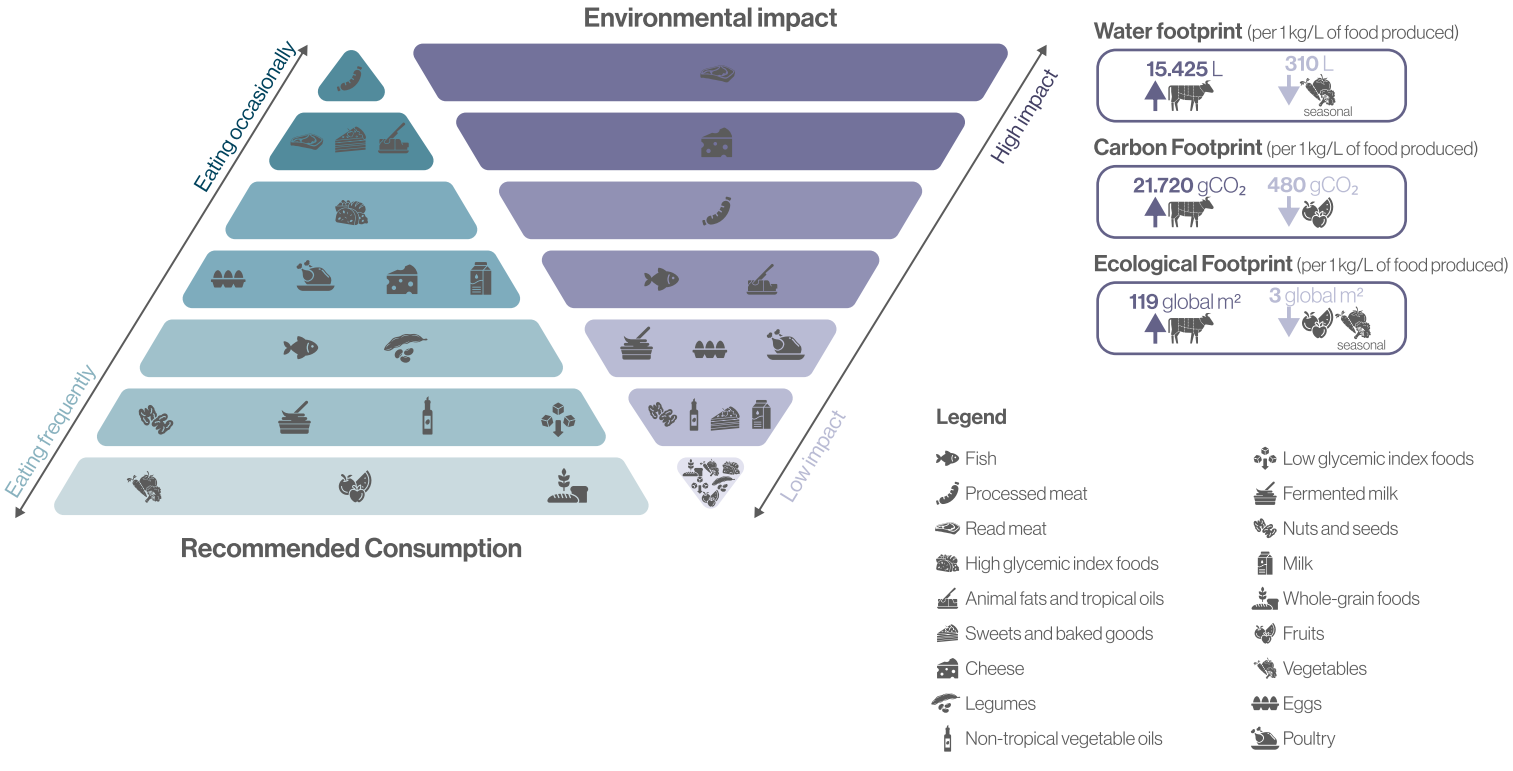


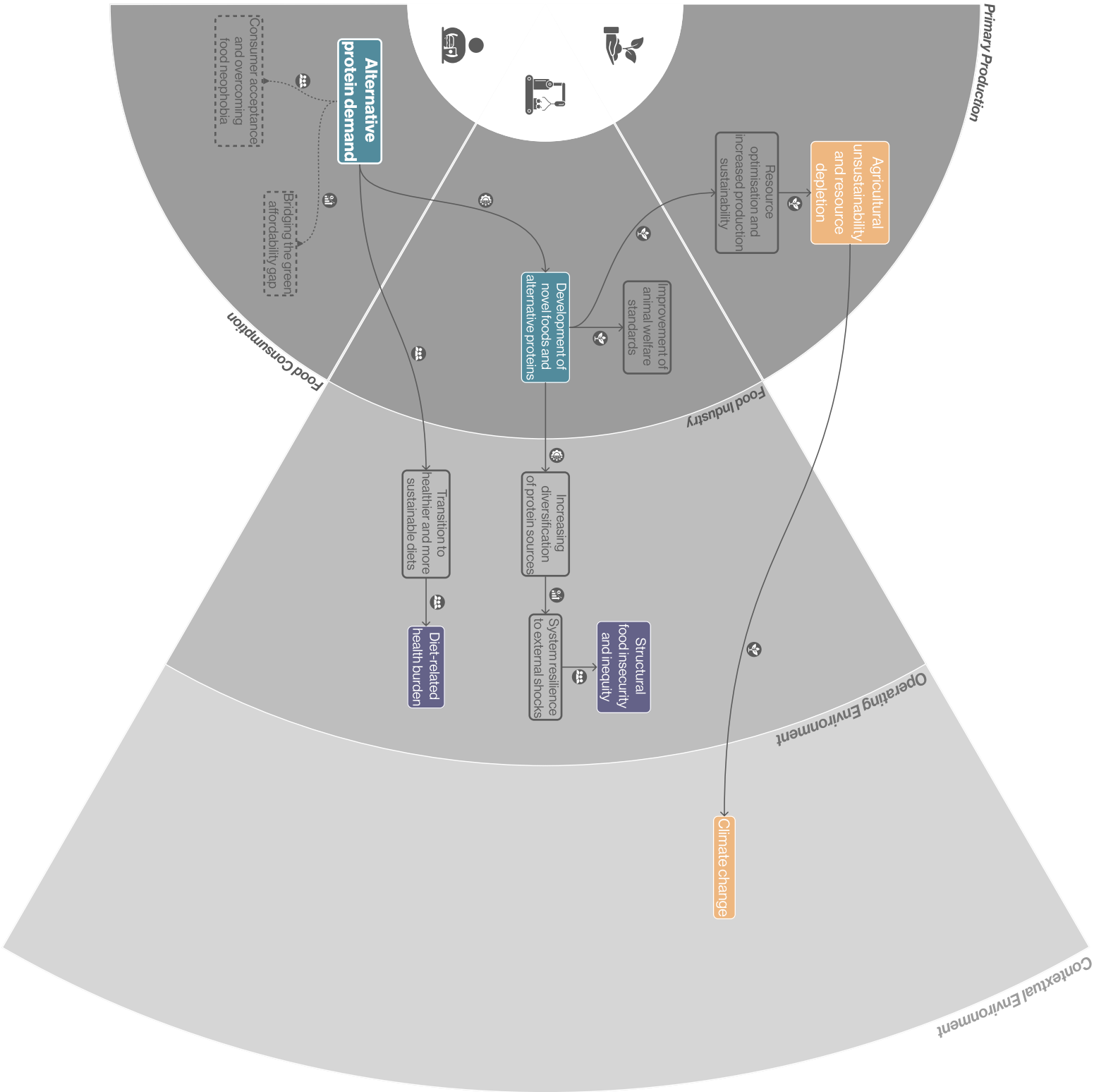
Fig. 3.65 The double food pyramid.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.66)***, the growth in demand for alternative proteins is a key catalyst for the **transition to healthier and more sustainable diets**. In line with the double food pyramid model, replacing red meat, which has a high environmental footprint and fewer health benefits, **promotes dietary diversification** that directly reduces the burden of diet-related diseases. This drive, led by high-income markets, is accelerating the **development of novel foods and alternative proteins**, promoting more ethical production processes that eliminate the need for slaughter and **raise animal welfare standards**. By reducing dependence on intensive livestock farming, the system achieves **resource optimisation and greater environmental sustainability** compared to the traditional agricultural model, with direct positive repercussions on **climate change mitigation**. Finally, the diversification of protein sources acts as a lever of **resilience for the system**, increasing the food system's ability to absorb external shocks, such as livestock epidemics or supply chain disruptions, ensuring greater stability in global food security.

Identifying Challenges and Opportunities within the Framework

The structural integration of these alternative proteins into our diets faces obstacles primarily related to price. Currently, these products are still expensive, and although health is the priority for some people in some countries when making purchasing decisions, in most places cost remains the main determining factor. It is therefore essential to find solutions to ***make these "green" products more affordable for people (C10)***. Secondly, there are cultural factors that should not be overlooked, which vary significantly depending on the context. In places such as Italy, which is based on a very stable gastronomic heritage and traditional products, the integration process will be more difficult than in other contexts. In this scenario, ***cultural acceptance and awareness of the sustainability (C26)*** of these choices will be key drivers in making alternative proteins a permanent part of our daily diets.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.66 Alternative protein demand, Systemic Framework.

C26 - Consumer acceptance and overcoming food neophobia.

GoodDot

Udaipur, India

GoodDot is India's leading producer of **meat alternative proteins**, headquartered in Udaipur, Rajasthan. The company's philosophy is based on the principle of Ahimsa, or non-violence, with the aim of promoting conscious and **ethical eating** through products that respect animal life. The company develops innovative protein solutions, such as **UnMutton** and **Vegicken**, designed to replace animal proteins in any culinary preparation, ensuring a complete and nutritious sensory experience.

Keywords:
#Plant-based food
#Ethical eating
#Culinary tradition

Response to the identified challenge:

GoodDot tackles the challenge of consumer acceptance and overcoming food neophobia through a strategy of cultural mimicry. Instead of imposing foreign consumption patterns, the company integrates its alternative proteins into existing culinary grammar, offering **plant-based versions of iconic dishes** such as UnMutton Keema, Biryani and Dhaba Curry. This approach allows cultural and psychological barriers to be overcome, as consumers can **maintain their eating rituals** and **traditional flavours** without sacrificing the pleasure of familiar tastes. By transforming innovation into a versatile ingredient for classic recipes, GoodDot facilitates a **smooth protein transition** that is not perceived as forced, but as an ethical evolution of the local gastronomic heritage.

good dot®


good dot
VEGETARIAN BYTZ
Step 1. Take out Good
the pieces with hand
Step 2. Make masala/gravy accord
taste.
Step3. Cook GoodDot Vegeterian Bytz pieces in
the masala.
For an even better taste, prepare with RCM Health Guar
Serving suggestion
good dot®
VEGETARIAN BYTZ
READY TO COOK
Net Weight: 250g
No Meat • No Egg • No Dairy

T8 - Growth of food delivery and takeaway platforms

The evolution of the way we eat reflects a **structural change in contemporary lifestyles**, driven by urbanisation and the growing need to optimise time. While twenty years ago home delivery was limited to a few segments such as pizza and Chinese food, today **food delivery** ***(Fig. 3.67)*** has become a global market worth over **USD 150 billion**, **tripling in size since 2017** (Ahuja et al., 2021). The **COVID-19 pandemic** has acted as a catalyst in mature markets such as the United States and Australia, with the sector growing sevenfold compared to 2018 levels, becoming a real "lifeline" for the entire catering industry. This boom is not a passing phenomenon but a structural change, supported by intuitive apps and **technologically advanced logistics networks** that respond to consumers' new expectations of convenience and safety. At the same time, food **e-commerce** is redefining retail, with online spending expected to reach **USD 334 billion by 2025** and an annual growth rate of 17.3% (Deliverect, 2021). In this scenario, convenience is becoming the main driver of choice, with large retailers expanding their **"grab-and-go"** offerings to attract users who are looking for immediate solutions without compromising on food quality, consolidating a consumption model where speed is now an essential requirement.



Fig. 3.67 Food delivery.

The ghost kitchen phenomenon

The **Ghost Kitchen** phenomenon ***(Fig. 3.68)*** marks the definitive transition of catering from a place of conviviality to a true urban logistics hub. This evolution is based on the **phenomenon of "Going Dark"**, an option that originated in the retail sector where physical shops are closed to the public and converted into purely back-of-house operations to boost e-commerce (Shapiro, 2023). These spaces, called **Dark Stores**, act as micro-distribution centres strategically located close to homes, **reducing the costs** and **critical times of last-mile delivery**. Ghost Kitchens apply the same principle to the food sector, where the kitchen foregoes its street-facing "façade", signage and dining room to focus exclusively on fulfilling orders from **online platforms**. In these facilities, space is optimised like an industrial warehouse where several independent stations allow a single operator to manage multiple virtual brands simultaneously. This model allows for diversification of the offering and scaling of the business with minimal fixed costs, completely eliminating expenses related to front-of-house staff or the rental of prime locations. Competition thus shifts from the atmosphere of the restaurant to **"logistical supremacy"** where speed and control of distribution become the pillars of success. However, while this progressive "platformisation" responds to the **frenetic pace of modern cities**, it also reduces the act of eating to a mere technical output, with the risk of **losing the social and convivial dimension** of the traditional restaurant in favour of an invisible infrastructure that supports the explosive growth of food delivery through a **hyper-efficient proximity economy**.



Fig. 3.68 Ghost Kitchen phenomenon.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.69)***, food delivery expansion is linked to the **acceleration of urban rhythms** and leads to a growing dependence on **ready meals** and **ultra-processed foods (UPFs)**. This trend raises significant public health concerns as these products, often characterised by a poor nutritional profile, increase the risk of developing **chronic diseases** linked to **unbalanced diets**. Environmentally, the massive demand for home deliveries forces an increase in **packaging production** and fuels a volume of waste that strains the efficiency of the agri-food system. If not managed through systemic logic and adequate precautions, this flow makes the supply chain less sustainable and deeply inefficient in terms of resource recovery. However, the growth of these distribution networks allows for significant **optimisation of the urban supply** chain through more rational management of delivery flows, mitigating the environmental impact of transporting goods within cities. In addition to the more tangible aspects, the systematic use of online ordering alters the socio-cultural dimension of eating. The habit of isolated domestic consumption **erodes the spaces of conviviality** that historically define the dining experience, also leading to a real **alienation** of the consumer, who loses awareness of the natural origin of the product. Food delivered in ready-made formats and without any narrative about its provenance ceases to be perceived as the result of a biological process and becomes a simple logistical output.

Identifying Challenges and Opportunities within the Framework

The ***transition to circular and sustainable packaging systems (C27)*** represents a challenge to mitigate the environmental impact caused by the enormous volume of waste generated by food delivery. It is not just a matter of reducing pressure on landfills, but of redesigning the systemic efficiency of the entire supply chain through the use of bio-compostable materials or reuse systems. At the same time, the ***implementation of sustainable urban micrologistics models (O14)*** offers the opportunity to make local distribution more sustainable. By integrating electric or light vehicles, urban flows can be reconfigured to make them more streamlined, reconciling the demand for speed with the need to reduce emissions and congestion. This evolution transforms last-mile logistics into an infrastructure that respects the environment and tangibly improves the liveability of contemporary cities.

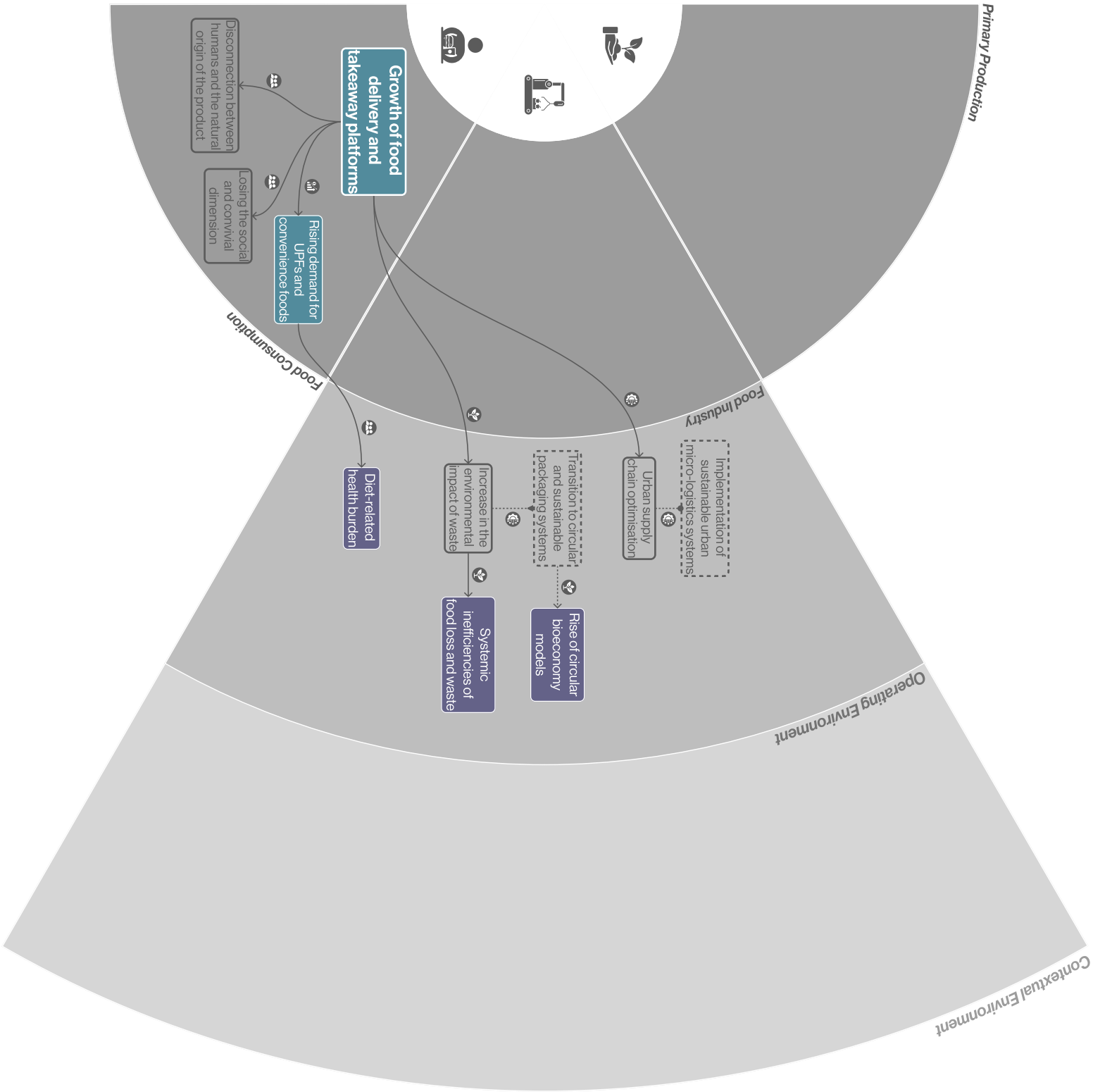


Fig. 3.69 Growth of food delivery and takeaway platforms, Systemic Framework.

C27 - Transition to circular and sustainable packaging systems.

Vytal

Cologne, Germany

Vytal is a German company that has **redefined on-demand consumption** by transforming food containers from inevitable waste into a **shared service**. The company operates through an extensive network of thousands of partners, including restaurants and canteens, offering a **"loan and return"** system managed entirely through a mobile application. At the heart of the proposal are high-quality, **BPA-free containers** designed to last for years, withstanding over 200 professional washing cycles. Unlike traditional returnable models, Vytal eliminates the need for cash deposits, making the sustainable choice simple and frictionless for the end user.

Keywords:
#Packaging-as-a-Service
#Digital traceability
#High quality packaging

Response to the identified challenge:

Vytal solves this challenge by disrupting the linearity of the supply chain and **overcoming the logic of ownership**. Instead of focusing solely on biodegradability, the model guides consumer behaviour through digital traceability. Thanks to unique **QR codes**, each container is **monitored** in a closed loop that guarantees its continuous reuse. This approach transforms packaging into a shared urban infrastructure, **preventing waste production at source** and optimising the inefficiencies of single-use items. By integrating itself into delivery flows, Vytal demonstrates that practicality can coexist with environmental protection, replacing the culture of waste with a circular metabolism based on trust and technological efficiency.

Vytal



014 - Implementation of sustainable urban micro-logistics systems.

Urb-it

Stockholm, Sweden

Urb-it, recently acquired by the Finmile platform, is a model of excellence in **zero-emission last-mile logistics**. With the ambition of generating a positive impact on society and the environment, the company provides sustainable distribution services in major European metropolitan areas. Urb-it, a B-Corp certified company, coordinates a fleet consisting exclusively of **e-cargo bikes** and **couriers on foot**, completely eliminating the use of polluting vans in urban centres. Through an advanced technological platform, it integrates retailer flows with a **network of local micro-hubs**, ensuring maximum punctuality with minimal impact on the urban ecosystem.

Keywords:
#Sustainable logistics
#Local micro-hubs
#Zero-emission delivery

Response to the identified opportunity:

Urb-it proves that distribution efficiency can be **decoupled from fossil fuel** use. By replacing heavy vehicles with a light and agile fleet, the company streamlines urban logistics flows, drastically reducing carbon emissions and congestion for each order fulfilled. This approach reconfigures the **last mile as a smart and silent infrastructure**, capable of responding to the speed required by the on-demand market without compromising the liveability of public spaces. The result is a proximity distribution model that not only reduces the ecological footprint but also actively **contributes to making cities healthier**, less congested and more human.

urb-it


Sustainable and solar-powered deliveries by urb-it
SunRider
SunRider
Sustainable and solar-powered deliveries by urb-it

T9 - Rise of functional and personalised nutrition

In today's nutritional landscape, the traditional notion of "universal" dietary guidelines has given way to a contemporary approach guided by the preferences and biological characteristics of the individual. This transformation has led to the emergence of **personalised nutrition**, based on the assumption that each person is unique and responds differently to the same foods. **In Europe**, this trend is fuelled by an increasingly entrenched **culture of wellbeing**, where choosing a **healthier diet is the top priority for 51% of consumers** ***(Fig. 3.70)*** clearly surpassing any other factor influencing dietary change (EIT Food, 2026). This phenomenon, defined as **"Me-ganism"**, puts the individual and their specific needs at the centre. The concept of health has evolved, with **60%** of Europeans now defining their well-being in terms of **mental health** and **44%** considering **stress management** to be an essential part of their diet.This awareness is driving demand for **functional foods** that offer targeted benefits, from longevity to athletic performance to gut microbiota support. This revolution has been made possible by **technological advances**. Through the integration of wearable devices, biosensors and artificial intelligence-based apps, it is now possible to monitor metabolic signals in real time, transforming the act of **eating into a data-driven experience**. Food scanning applications, for example, use image recognition to instantly analyse the content of meals, providing macronutrient breakdowns, calorie counts and allergen alerts. However, the transition to precision nutrition on a global scale faces several significant challenges. Although technology offers unprecedented awareness, crucial issues such as biometric **data privacy**, the **high cost of tailor-made solutions**, and the need for solid **scientific credibility** remain major barriers to ensuring equitable accessibility.

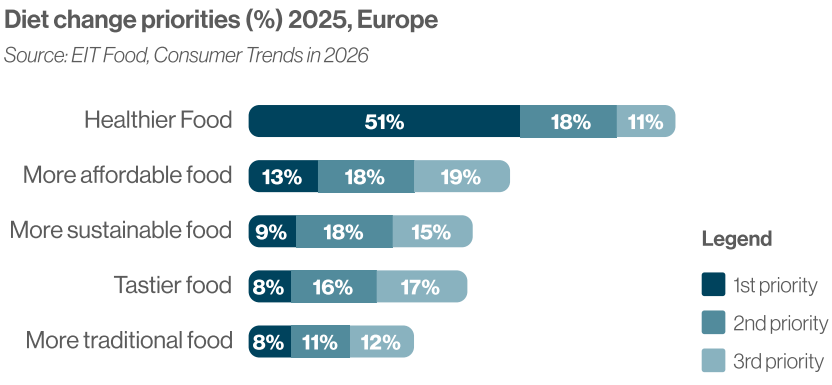


Fig. 3.70 Diet change consumer's priorities.

The rise of Functional Foods

The rise of functional foods marks the definitive shift from the idea of **food** as a simple nutrient to that of a true **preventive health tool**. In this context, the global **functional foods market** is expanding rapidly. According to estimates by Future Market Insights, the sector will exceed **USD 258 billion by 2026**, with a projection of up to **USD 442 billion by 2036** (CAGR 5.50%) (FMI, 2025). This momentum is fuelled by a new generation of products defined as functional because they are fortified, enriched or enhanced with ingredients capable of providing specific physiological benefits or reducing the risk of disease, going far beyond satisfying basic nutritional functions. The growth of the market for these foods is driven in particular by **dairy products**, which account for **32.10%** of the market, and by solutions for **digestive health** (FMI, 2025). Within this new consumption architecture, products are formulated with specific functional objectives. A clear example is the rise of **protein foods**, a category technically defined by a protein component exceeding 12% of the total nutritional value. In addition to these, **superfoods** and so-called **carrier foods** (daily functional foods that improve nutrient absorption) allow health benefits to be integrated naturally and effortlessly into the daily diet. This scenario of growing attention to health has led to the emergence of targeted diets, where functional ingredients are selected to support specific systemic needs of the body. **Mental well-being** has now reached the same level of importance as physical health, and in Europe consumers are looking for solutions that can support mood and cognitive performance, an interest fuelled by new awareness of the effects of alcohol, visible in movements such as **#SoberCurious** (EIT Food, 2026). In this context, solutions such as **Lion's Mane mushroom** ***(Fig. 3.71)*** extract provide high concentrations of bioactive compounds designed to enhance memory and stress resilience. At the same time, the **gut health** trend is also growing. The gut, with its complex **microbiome** composed of over 1,000 species of microorganisms, plays a role that goes far beyond simple digestion and nutrient absorption. High bacterial diversity is now recognised as a key indicator of overall health, with direct links to the immune system, sleep quality and the prevention of chronic or autoimmune diseases. From this perspective, diet becomes the main tool for nourishing and diversifying the bacterial flora, acting on physical and mental health as a single integrated system.



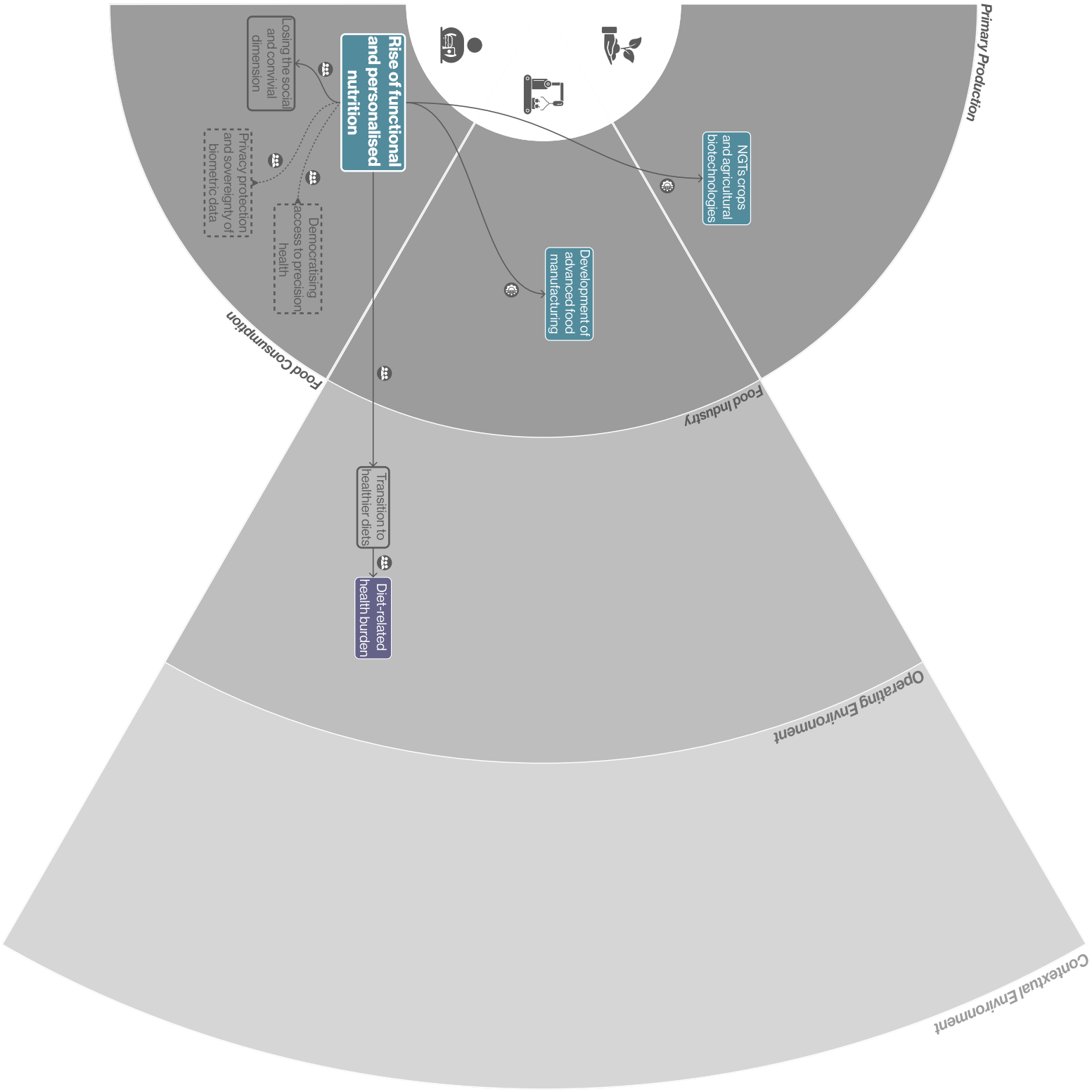
Fig. 3.71 Lion's Mane, KAAPA Biotech.

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.72)***, the progressive adoption of hyper-personalised diets and functional products represents, above all, a systemic opportunity for public health. This approach allows individuals to consciously manage their nutrition for preventive purposes, **improving overall diet quality** and offering a concrete **response to the increase in chronic diseases** linked to poor nutrition. However, this push towards individual precision driven by technology and the meticulous monitoring of every nutrient risks **eroding the social and convivial dimension of food**. When a meal becomes a mere technical administration of personalised biological data, the ritual of sharing and the flexibility of eating together tend to disappear, isolating the consumer in their own nutritional algorithm. Furthermore, the need to meticulously control food composition is driving the **development of NGTs** (New Genomic Techniques) and emerging innovations such as **nanotechnology** and **3D food printing**. These technologies are capable of guaranteeing the level of molecular accuracy required by nutrition that aims to be increasingly similar to tailor-made preventive therapy. In this sense, the trend towards personalisation is redefining not only what we eat, but the entire technological infrastructure that supports the agrifood system.

Identifying Challenges and Opportunities within the Framework

The integration of personalised nutrition into the agrifood system raises critical issues that test the ethical and social sustainability of innovation. The first fundamental challenge concerns the ***management of extremely sensitive biological information (C28)***, given that this model is based on the constant monitoring of metabolic and genomic parameters, the protection of privacy and user sovereignty over their own data become essential preconditions. The main risk is that, in the absence of transparency, the technology will be used as a surveillance tool rather than a support tool, compromising the relationship of trust between the individual and the service provider. Furthermore, if precision diets and tailor-made functional products remain associated with high costs, advanced **health risks becoming an elite privilege, fuelling a form of nutritional gentrification (C29)**. Democratising access means ensuring that advances in nutritional science do not become an additional factor of economic discrimination, but an inclusive tool for improving collective health.



Type of Elements

Megatrend
Driver
Trend
Weak signal

Impact
Challenge/ Opportunity

Type of Flows

Direct causal relationship
Strategic pathway
Challenge identification
Opportunity identification

Environmental flow
Social flow
Economic flow
Technology flow
Legal flow

Fig. 3.72 Rise of functional and personalised nutrition, Systemic Framework.

C28 - Privacy protection and sovereignty of biometric data.

Prifina

San Francisco, USA

Prifina operates as a **technology platform** that overturns the traditional paradigm of data management, placing the individual at the centre of their own information ecosystem. Through the creation of a **"Personal Data Cloud"**, the company allows users to aggregate and **unlock the value of information from wearable devices, sensors and health applications**. Unlike conventional models where data is extracted and centralised on company servers, Prifina enables an architecture where applications run directly on the user's account. This approach transforms data from a passive resource into an active tool for creating personal value, ensuring that information always remains under the direct control of its rightful owner.

Keywords:
#Data sovereignty
#Personal data cloud
##Biometric privacy

Response to the identified challenge:

In a personalised nutrition model, where metabolic and genomic signals are extremely sensitive, **Prifina eliminates the need to share raw information with third parties at source**. Using local computing, the application provides **nutritional advice** and **develops predictive models without the external company** ever having to view or possess sensitive data. This model neutralises the risk of digital surveillance and **rebuilds the relationship of trust** between consumers and technology through structural **transparency**, where privacy is not an option but an intrinsic feature of the architecture itself.

prifina


MOST
INTERESTING
DATA ECONOMY
SOLUTIONS
SERVICES FOR CONSUMERS
PRIFINA

C29 - Democratising access to precision health.

Oviva

Zurich, Switzerland

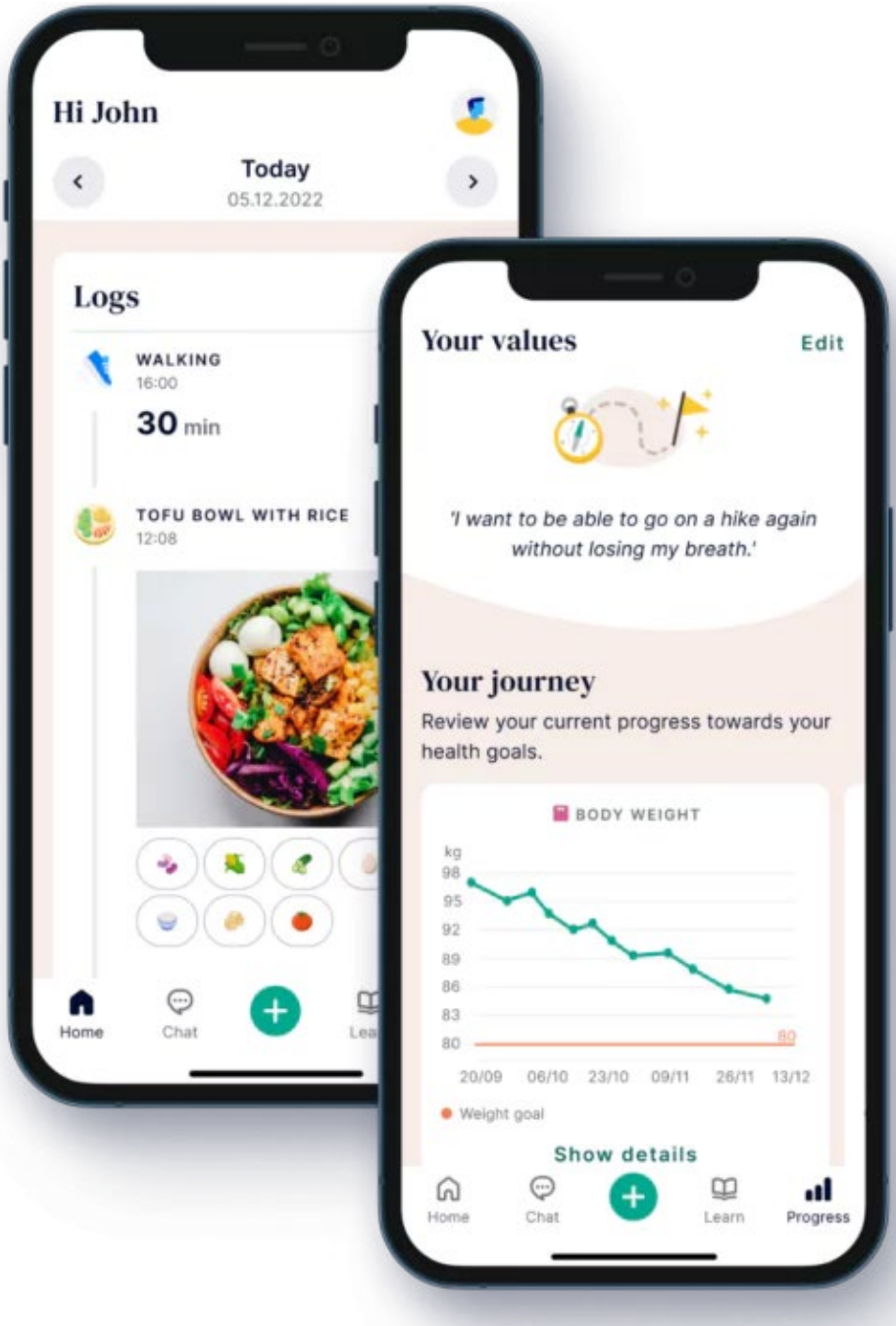
Oviva is a **digital nutritional medicine platform** that integrates mobile technology with clinical support for the treatment of nutrition-related conditions such as type 2 diabetes and obesity. The service provides **hyper-personalised care** through an **app that allows users to monitor their meals**, physical activity and biological parameters, while offering direct **access to qualified dietitians**. Using artificial intelligence, Oviva analyses user data to provide instant feedback and **dynamic nutritional plans**, facilitating lasting behavioural change based on **scientific evidence**.

Keywords:
#Health democratisation
#Accessible nutrition
#Systemic equity

Response to the identified challenge:

Oviva is one of the first digital solutions to be reimbursed by health insurance companies in Switzerland and public health systems in Germany and the United Kingdom, making precision nutrition a free or low-cost service for patients. Instead of remaining a premium product accessible only privately, **the platform democratises access to advanced nutritional therapy**, transforming it into an important component of public health. This model demonstrates how **technology can bridge the wellness gap**, ensuring that nutritional innovation is equitable, inclusive and accessible regardless of individual income.

Oviva


Hi John
Today
05.12.2022
Logs
WALKING
16:00
30 min
TOFU BOWL WITH RICE
12:08
Home
Chat
Your values
Edit
'I want to be able to go on a hike again without losing my breath.'
Your journey
Review your current progress towards your health goals.
BODY WEIGHT
kg
98
95
92
89
86
83
80
80
20/09
06/10
23/10
09/11
26/11
13/12
Weight goal
Show details
Home
Chat
Learn
Progress

T10 - Verified transparency and consumer empowerment

The push towards verified transparency marks a profound evolution in the relationship between individuals and the food system. It is no longer just a matter of reading a list of ingredients, but of understanding the origins of a product within a complex network of values that intertwines **personal health**, **environmental impact** and **social equity** (Sustainability Directory, 2025). This desire for knowledge is fuelled by a growing awareness of the interconnection between food systems and global challenges such as climate change and the public health crisis. For the contemporary consumer, transparency has become a primary indicator of quality, safety and ethical responsibility, **transforming the act of purchasing into an exercise in informed decision-making**. However, the current **landscape appears deeply fragmented**. While health- and sustainability-oriented sectors have proactively adopted advanced tracking technologies and openly share supply chain data, much of the conventional food pathway remains obscured. This opacity stems from heterogeneous data systems, stakeholder reluctance to share information, and a **lack of standardised global regulations**. This lack of clarity not only erodes trust, but also masks the true environmental and social costs of food, hindering effective responses to food safety concerns. This regulatory vacuum has allowed the proliferation of **greenwashing**, where many companies use misleading terminology or selectively highlight partial benefits to mask harmful practices. This unfair competition penalises truly ethical brands and confuses consumers, who find themselves navigating certification standards that vary dramatically from country to country in an interconnected global market. To overcome this confusion, it is necessary to focus on a more intuitive information architecture. As academic research suggests, **transparent labelling** can be a powerful incentive towards healthier and more sustainable diets when it simplifies complexity. A compelling example is the **NuCal system** ***(Fig. 3.73)*** promoted by the **FDA** (Food and Drug Administration), which classifies foods according to their **nutritional density** relative to calorie content, providing clear visual guidance for the user (Sustainability Directory, 2025). Ultimately, the challenge is not just to provide more data, but to design a "contract of trust" with the consumer. Moving from fragmented information to a transparent and accessible system is what truly enables consumers to move from a passive role to becoming conscious drivers of systemic change.

FDA
The Food and Drug Administration (FDA) is the US federal agency responsible for protecting public health by ensuring the safety, efficacy and wholesomeness of food, drugs and medical devices. It serves as a regulatory pillar for the agri-food system, overseeing the accuracy of labelling and the wholesomeness of products in order to strengthen consumer confidence. Its mission is to provide scientifically sound information, transforming complex supply chains into transparent and verified environments for informed decision-making. (FDA, n.d.)

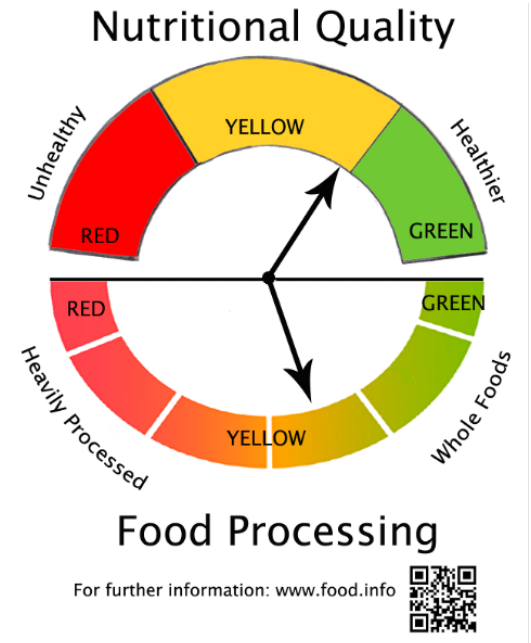


Fig. 3.73 NuCal, hypothetical labelling system.

Technology as a catalyst for transparency and consumer empowerment

Technological advances provide the enabling infrastructure to transform transparency from an ethical ideal into an operational reality. In this scenario, tools such as **blockchain**, the **Internet of Things (IoT)** and **artificial intelligence (AI)** offer unprecedented capabilities for tracking and verifying information flows along increasingly global and fragmented supply chains (Sustainability Directory, 2025). Blockchain, thanks to its decentralised and immutable nature, allows every transaction and product movement to be recorded, **creating a verifiable end-to-end history**. At the same time, IoT sensors monitor critical parameters such as temperature and humidity in real time during transport, ensuring not only traceability of origin, but also the **quality and safety of food reaching the consumer**. However, the integration of these technologies raises challenges related to equity and accessibility. The **high cost of implementation** risks **excluding small producers** and businesses in developing countries, fuelling a **digital divide** that favours large players with greater resources (Sustainability Directory, 2025). Furthermore, the **problem of interoperability** persists: without standardised data protocols, the system risks generating isolated "pockets of information" instead of a cohesive network. A further risk is posed by the so-called **"AI black box"**: if the algorithms used to optimise the supply chain or monitor safety remain opaque, consumer confidence could falter, especially if these tools are perceived as a means of maximising profits at the expense of ethics or actual transparency. The future of transparency therefore depends on the ability to overcome fragmentation through the adoption of **open and accessible platforms**. In a positive scenario, the convergence of technological innovation and harmonised regulatory frameworks makes it possible to transform data into usable knowledge. This change could enable **consumers** to stop being passive recipients of marketing messages and **become active participants**, capable of verifying companies' claims and, through their choices, steering the food system towards greater fairness, resilience and a genuine focus on collective well-being.

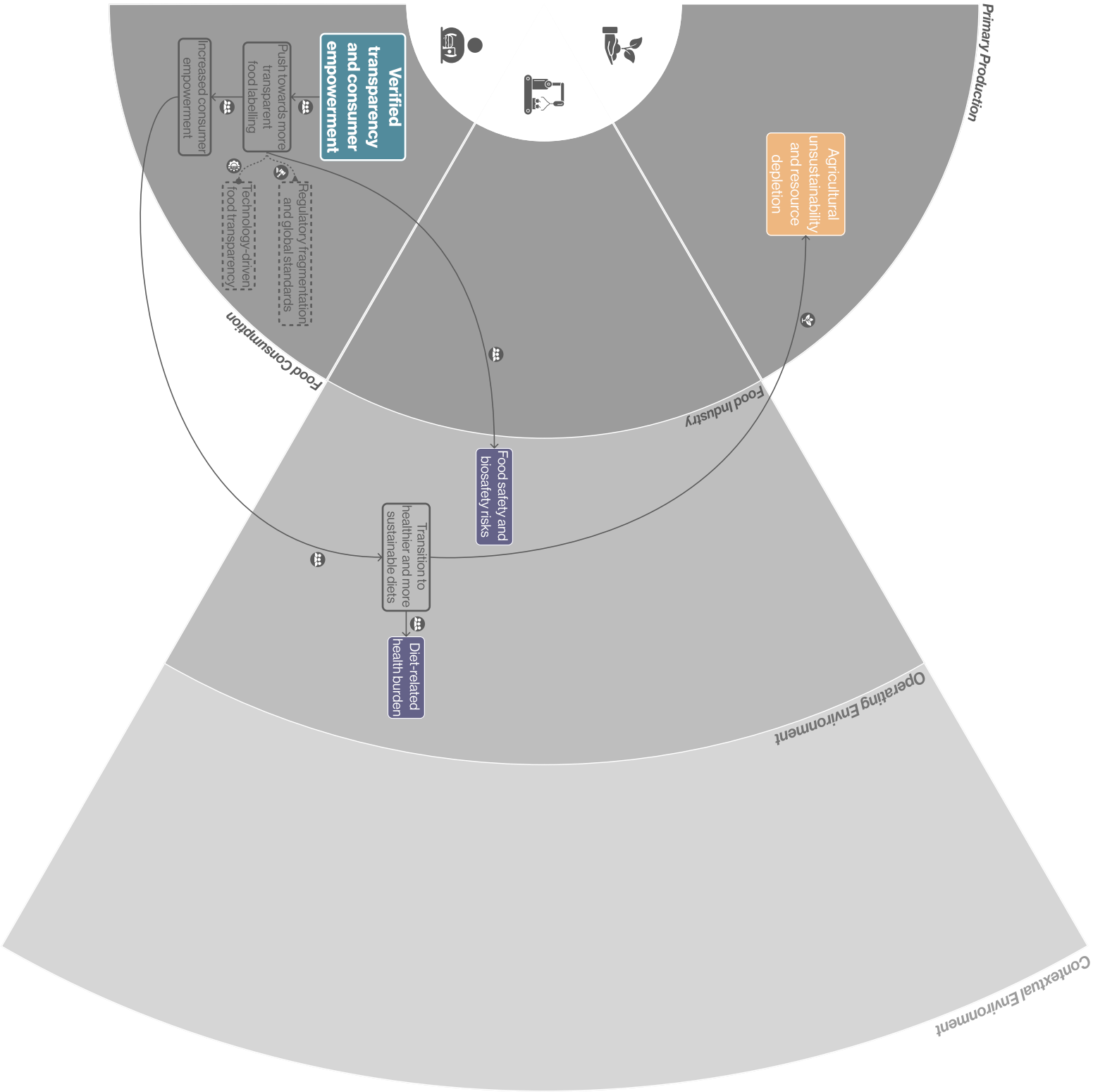
Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.74)***, consumers' growing awareness of transparency and traceability issues is acting as a catalyst, **pushing the agri-food system to adopt clearer and more com-**

prehensive labelling models. This approach allows individuals to make purchasing choices that are truly aligned with their values and biological needs, while improving food safety through the integration of technologies such as the Internet of Things (IoT). In this hypothetical scenario, the act of purchasing ceases to be a passive gesture and becomes a conscious process: granular knowledge of the entire supply chain and nutritional values guarantees a structural **increase in consumer empowerment**, overcoming the current fragmentation of the market and **neutralising greenwashing practices**. Empowering citizens to make decisions triggers a transition towards healthier and more sustainable diets. This change generates direct benefits for public health, helping to **alleviate the burden of chronic diseases** resulting from poor eating habits. At the same time, the new demand for transparency exerts positive pressure on agricultural and production systems, **encouraging them to adopt more environmentally and socially responsible practices**. Ultimately, transparency does more than just inform; it redefines the balance between production and consumption, steering the entire system towards greater resilience and sustainability.

Identifying Challenges and Opportunities within the Framework

The adoption of truly transparent food labelling will be determined primarily by the ***regulatory framework, which currently constitutes a significant obstacle (C30)***. The fragmentation of rules between different countries makes it extremely complex to develop a single system and globally shared standards, making legislative harmonisation one of the most urgent challenges for the sector. In this context, digitalisation represents the main opportunity to overcome these barriers. The ***integration of technologies such as blockchain, artificial intelligence and IoT (O14)*** makes it possible to enhance the transparency of the supply chain through advanced traceability systems and constant monitoring of each stage of production. However, these innovations present critical issues related to their implementation and the need for dedicated regulation, bringing with them the risk of generating negative impacts such as the digital divide, which could isolate producers with fewer technological resources.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.74 Verified trasparency and consumer empowerment, Systemic Framework.

C30 - Regulatory fragmentation and global standards.

“Green Claims” Directive

EU

The Green Claims Directive is the European Union’s regulatory response to the proliferation of ambiguous and unverified environmental claims. In a market saturated with **self-certified labels**, this legislative intervention requires companies to **support any sustainability claim** (such as “eco-friendly”, “biodegradable” or “low-emission”) **with rigorous scientific evidence and standardised methodologies**. The objective is twofold: to protect consumers from misleading information and to ensure that transparency becomes a real competitive advantage for companies that operate ethically, transforming sustainability from a simple slogan into an objective fact.

Keywords:
#Verified transparency
#Market equity
#Anti Greenwashing

Response to the identified challenge:

This intervention directly **addresses regulatory fragmentation** and the **scourge of unfair competition**. By establishing a single, independent verification protocol at European level, the Directive eliminates the confusion generated by a myriad of inconsistent private and national standards. The challenge of standardisation is resolved by **transforming transparency from a voluntary option to a verifiable requirement**, with companies obliged to submit their claims to accredited verifiers before they can display them. This process **neutralises information asymmetry and creates a fair system**, where the complexity of the supply chain is translated into reliable information, allowing consumers to exercise their purchasing power with real awareness.



Green Claims Directive Proposal:

common criteria against greenwashing and misleading environmental claims


© Getty Images

Key measures

- **common criteria** on how companies should **substantiate environmental claims**
- **clear requirements** to address the proliferation and credibility challenges of **environmental labels**
- **sound system** of independent verification and support to SMEs

015 - Technology-driven food transparency.

Provenance

London, UK

Provenance is a **data platform** designed to enable brands and retailers to validate and communicate their **sustainability claims** in a **transparent and accessible way**. Through its "Proof Points" system, the technology transforms environmental and social promises into structured, **verified data throughout the supply chain**. The service acts as a digital infrastructure that links supply chain evidence (certifications, audit data or traceability records) directly to the purchasing interface, making the ethical value of the product visible at the exact moment when the consumer has to make a choice.

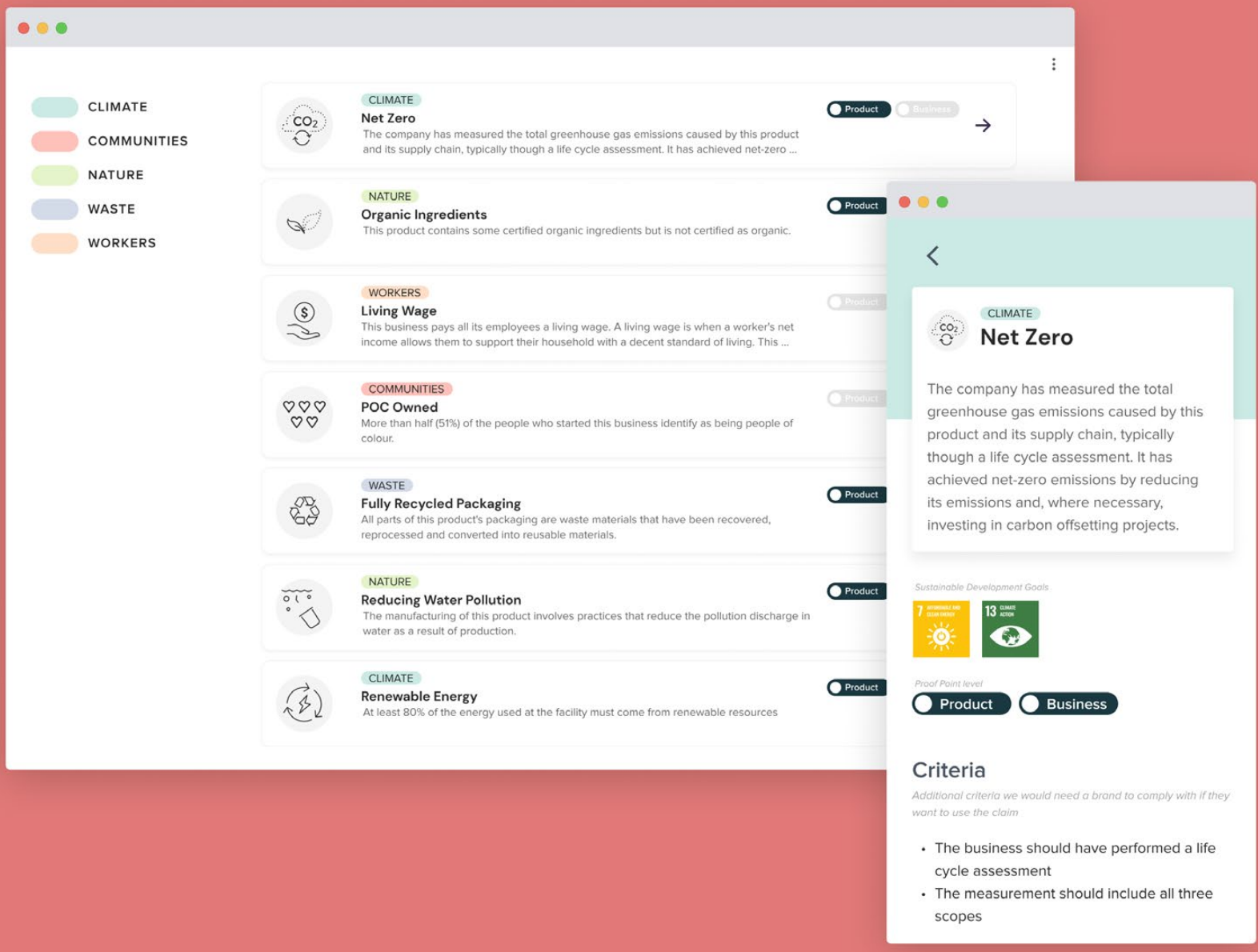
Keywords:
#Verified claims
#Proof points system
#Tech clarity

Response to the identified opportunity:

Provenance tackles the **challenge of data "black boxes" and mistrust of technology** by resolving the **information asymmetry** between producers and citizens. Instead of relying on static and often unverifiable marketing messages, the platform breaks down sustainability into validated, clickable units of information. This approach responds to the need for simplification and credibility: **each "Proof Point" is anchored to tangible evidence** that the **user can consult**, transforming the technical complexity of blockchain and AI into an intuitive tool for transparency. In this way, technology does not add a layer of confusion, but becomes the guarantor of the system's integrity, promoting real empowerment and **neutralising the risk of greenwashing** through accurate traceability.

PROVENANCE®

The Provenance Framework



T11 - Rising demand for UPFs and convenience foods

Ultra-processed foods (UPFs) occupy the lowest rung of the **NOVA system**, which classifies foods according to the purpose of industrial processing ***(Fig. 3.75)***. Although historically processing techniques were used to preserve nutrients and ensure shelf life, today they are **profit-driven** and aim to **replace whole foods with highly palatable ingredients** (The Lancet, 2025). By breaking down low-cost raw materials such as **corn, wheat, soy and palm oil** into a wide range of additives and chemicals, multinationals produce ready-to-eat foods that profoundly alter the original food matrices. This change, which accelerated in the 1980s with globalisation, has generated a market that reached **USD 1.9 trillion in 2023**, according to the authors of The Lancet. Concentration is extreme, with just **eight companies, including Nestlé, PepsiCo, Unilever and Coca-Cola, controlling 42% of global sales** (Monteiro et al., 2025).

Types of Unprocessed and Processed Foods

Source: NOVA classification, Yale Medicine

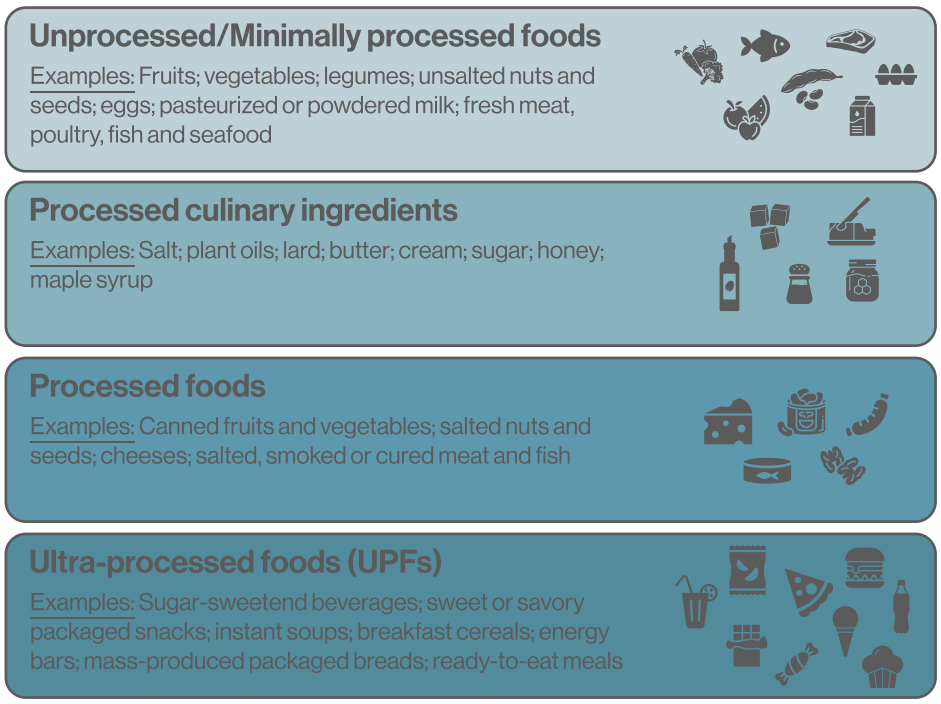


Fig. 3.75 Classification of foods according to their degree of processing.

While UPFs already account for over **50% of total calories** in countries such as the **United States** and the **United Kingdom**, growth is also explosive in low- and middle-income countries. For example, per capita sales in **Uganda** have increased by **60% since 2007**, while consumption in China and Mexico has tripled in recent decades. The impact of this type of food on the system generates **harmful dietary risks**, primarily for consumer health. In fact, UPFs are responsible for approximately **11 million deaths per year from non-communicable diseases**, accounting for **22% of global adult mortality**, with an enormous burden on health systems (Elizabeth et al., 2020). In addition to human health, the damage also affects the environment. Industrial production is highly **fossil fuel-intensive** and generates a **saturation of plastic packaging**, confirming that the rise of UPFs represents a multidimensional threat to the sustainability and resilience of the global food system.

Countering UPF Dominance

The urgency of a **new regulatory framework for UPFs** is pushing public debate towards a radically stricter paradigm, similar to that historically applied to the tobacco industry in the 1950s. Since these products are engineered to be hyper-appealing and highly addictive, many public health experts argue that their regulation should no longer be limited to simple information labels, but should include **advertising restrictions**, **targeted taxation** and **explicit health warnings** (The Guardian, 2026). The **comparison with cigarettes** is not only provocative, but reflects the addictive nature of these foods, making consumer choice less free than one might assume. Supporting this theory, recent studies such as that conducted by the **UNC Neuroscience Centre** have highlighted alarming **neurophysiological impacts**, arguing that chronic consumption of **junk food** can reprogram the memory centre in the brain, significantly increasing the risk of **cognitive dysfunction** (Calabrese et al., 2026). The **saturated fats** contained in these foods not only affect metabolism but also compromise brain plasticity: excess fat **prevents the absorption of glucose**, which is essential for **hippocampal function**, causing **memory deficits** after just a few days of an unhealthy diet. This evidence shifts the problem from the realm of individual responsibility to that of collective safety. If the food system produces substances that alter brain health and metabolic signals, the **transition to healthy diets requires political intervention** that recognises UPFs as a threat to public health comparable to that of smoking.

Junk food
The term junk food is used to describe foods characterised by a high calorie content derived from macronutrients such as fats and sugars. Often associated with high levels of sodium, which makes them highly palatable, these products are almost always deficient in dietary fibre, protein and essential micronutrients, such as vitamins and minerals. Scientifically identified as HFSS (High in Fat, Salt, and Sugar) foods, the term "junk food" retains a derogatory connotation whose historical roots date back to the 1950s. (Wikipedia, n.d.)

Impacts on the Agrifood System

As shown in the framework ***(Fig. 3.76)***, the progressive adoption of ultra-processed foods (UPFs) concerns **consumer health**, contributing to the development of **non-communicable diseases (NCDs)** and aggravating the diet-related health burden. In addition to the nutritional aspect, the dependence of these foods on a few commodity crops, such as maize, wheat, soybeans and palm oil, pushes the sector towards extreme **intensification of production** and strong **market concentration**, as industrial scalability requires standardised raw materials that allow huge volumes to be produced at low cost. This intensification is a serious problem because it worsens the unsustainability of traditional agricultural methods and leads to the **loss of agrobiodiversity**, making the sector increasingly less resilient. As a result, the disappearance of variety in the fields translates into a **loss of food biodiversity** in consumption as well. Diets are thus becoming standardised, which is critical for health, as diversification of food sources is a fundamental pillar of healthy diets. From a sustainability perspective, the processes used to produce UPF are inefficient, as the systems are highly **fossil fuel-intensive** and generate a huge amount of **plastic packaging**. Finally, the consumption of increasingly processed products culturally distances consumers from fresh food, creating a **cognitive gap** that breaks the link with natural raw materials. This detachment not only erases awareness of what we eat, but also turns citizens into passive consumers, increasingly distant from knowledge of the cycles of the earth.

Identifying Challenges and Opportunities within the Framework

The consumption of these foods generates enormous critical issues for the agro-industrial system and global health. It is therefore essential **to *combat their widespread distribution through regulations that limit access to them (C31)***, although opposition from market leaders makes this a complex challenge. At the same time, the progressive disconnection from fresh produce and cooking practices makes it a priority ***to reconnect consumers with unprocessed foods (C32)***. This need is particularly urgent in urban contexts, where the rise of food delivery and ready-to-eat products accelerates profound cultural and behavioural changes. Addressing these issues is vital to ensure that the disconnect between society and food sources does not become an ingrained, irreversible reality.

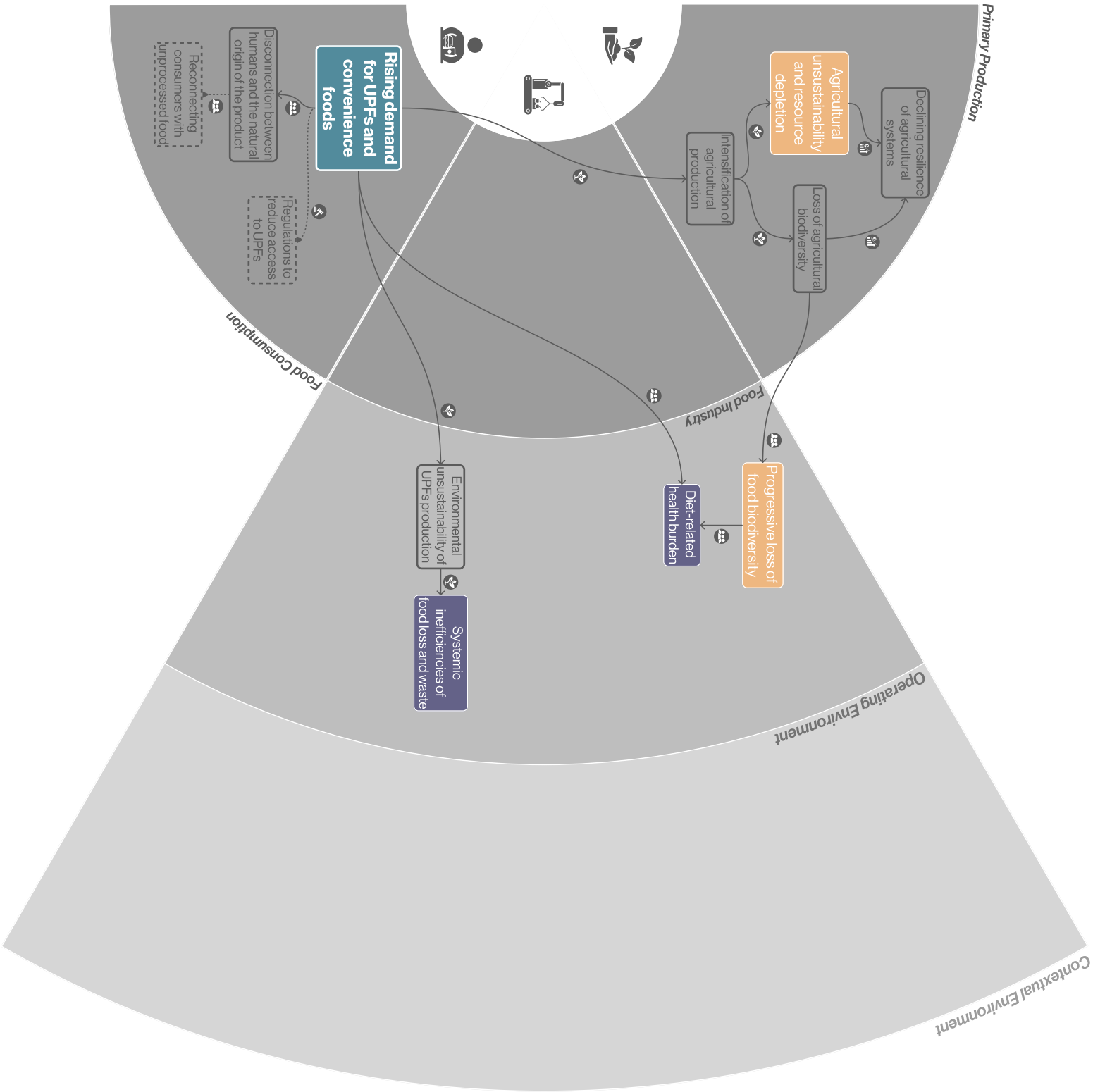


Fig. 3.76 Rising demand for UPFs and convenience foods, Systemic Framework.

C31 - Regulations to reduce access to UPFs.

Ley de etiquetado y publicidad de alimentos

Chile

The legislation introduced in Chile represents a **pioneering intervention to combat the obesity epidemic** and the **rise of ultra-processed products**. The law requires the use of **black octagonal labels on the front of packaging** to immediately **indicate the excessive presence of sugars, saturated fats, sodium or calories.** In addition to providing transparent information, the policy has a drastic impact on the food environment, for example by banning the sale of harmful products in schools and **removing all persuasive marketing elements aimed at children**, such as cartoon characters, mascots and gadgets. The aim is to defuse the mechanisms of addiction induced by industrial sales techniques, promoting instant visual awareness at the critical moment of purchase.

Keywords:
#Public health policy
#UPF regulation
#Nutritional labeling

Response to the identified challenge:

This case study responds to the challenge by directly addressing the availability and appeal of ultra-processed products. The effectiveness of the law is confirmed by concrete data: a **23.7% drop in purchases of sugary drinks** and a reduction in **children's exposure to marketing of between 44% and 67%**. The solution is not limited to transparency, but changes market logic: the requirement for black labels has forced multinationals to massively reformulate recipes to avoid visual stigma and advertising restrictions. From a systemic perspective, Chile's intervention demonstrates that **strict regulatory constraints can de-normalise junk food consumption, rebalancing the food system in favour of public health**.


ALTO EN AZÚCARES
Ministerio de Salud
ALTO EN GRASAS SATURADAS
Ministerio de Salud
ALTO EN SODIO
Ministerio de Salud
ALTO EN CALORÍAS
Ministerio de Salud


ALTO EN CALORÍAS
Ministerio de Salud
ALTO EN AZÚCARES
Ministerio de Salud
ALTO EN GRASAS SATURADAS
Ministerio de Salud
3/4 TAZA
2 1/2 TAZAS
ACTIVA TU DIA
(CDR) para Chile.
Edulcorante:
Sucralosa (mg)
100 g 1 Porción
30,0 9,0
IDA en mg/kg peso corporal:<15
I.D.A.: Ingesta Diaria Admisible según FAO/OMS.
carozzi
Hablemos 800 228 228
CarozziHablemos
www.carozzicorp.com
Elaborado en Chile por / Made in Chile by: EMPRES
CAROZZI S.A., Camino Longitudinal Sur 5201, Nos,
Bernardo, Res. Sanitaria N° 31663 del 08/06/2012
SEREMI de Salud RM.
INGREDIENTES: Harina de Trigo (26%), Semolina de
(24%), Azúcar, Cacao (6%), Harina de Arroz (3%), Ex
de Malta, Manteca de Cacao, Maltitol, Licor de
Suero de Leche, Manteca de Palma Fraccionada,
Entera en Polvo, Aceite de Shea y Palma Fracc
Fosfato Tricálcico, Maltodextrina, Carbonato de
Saborizante Idéntico a Natural, Salvado de Trigo
Descremada en Polvo, Sal, Lecitina de Soja, Bicc
de Sodio, Polricinoleato de Poliglicerol, Sucr
Almidón de Maíz, Antioxidante BHT, Vitamina C,
Aceite de Coco Fraccionado, Ácido Cítrico, Gom
Niacina, Óxido de Zinc, Pirofosfato Férrico, S
Potasio, Vitamina B6, Saborizante Artificial, Vit
Vitamina B1, Ácido Fólico, Vitamina B12.
Contiene Almendras, Gluten, Leche, Mani
Elaborado en líneas que también procesan
Huevos, Nueces, Sésamo y Sulfitos.

C32 - Reconnecting consumers with unprocessed food.

The Edible Schoolyard

Berkeley, USA

The Edible Schoolyard project, founded by **Alice Waters** in Berkeley in 1995, proposes an educational model that **integrates organic gardens and teaching kitchens directly into the public school curriculum**. Through the **"Edible Education" approach,** students actively participate in every stage of the food cycle, from sowing to harvesting, to the collective preparation of meals. The project aims to radically **transform the relationship of the younger generation with food**, turning schools into environments where nutrition and ecology are learned through practical experience, **making young people aware of their own health and environmental sustainability**.

Keywords:
#Culinary literacy
#Experiential learning
#Food culture

Response to the identified challenge:

In urban areas dominated by ready-made products and food delivery, **this initiative combats culinary de-skilling by providing young people with the technical skills to handle and cook fresh, unprocessed foods**. Direct sensory experience with natural ingredients breaks the dependence on the hyper-palatable and standardized flavors of UPFs, re-educating the palate to recognise the value of real food. Furthermore, the model seeks to demonstrate that reconnection is not just an informative act, but a **daily practice capable of generating lasting change** in citizens' eating habits and awareness.

THE EDIBLE SCHOOLYARD PROJECT



WS1 - Nutrigenomics and advanced nutritional science

The global nutrigenomics market is valued at approximately **USD 538 million in 2025**, and is projected to grow rapidly to **USD 2.3 billion by 2034**, at a compound annual growth rate (CAGR) of 17.6%. **North America (38%)** and **Europe (26%)** lead this sector, fuelled by growing demand for preventive medicine and personalised diets (Fortune Business Insights, 2026). At the heart of this emerging factor is the shift from the idea of food as a mere source of energy to a model in which the **biochemical diversity of food acts as a regulator of our molecular health**. The nutrigenomic approach promotes "eating foods that not only your taste buds but also your genes desire", emphasising the role of diet in personalised health (Chaudhary et al., 2025). **Personalised nutrition** is divided into **two complementary disciplines**: nutrigenetics and nutrigenomics, which, although often confused, operate in opposite directions.

- ***NUTRIGENETICS*** analyses how individual genetic variants (the 0.1% of genomic diversity that makes us unique) influence the **body's response to bioactive compounds in food**, providing information on how specific genes or an individual's body respond to what they eat (Chaudhary et al., 2025). A prime example is the study of the **salivary amylase gene (AMY1)**, with historically agricultural populations accustomed to starchy diets having developed more copies of this gene, allowing for more efficient digestion and reducing the risk of metabolic diseases, compared to hunter-gatherer societies with low-starch diets.

- ***NUTRIGENOMICS***, on the other hand, is an **"omic" science** that combines fields such as genomics, proteomics, metabolomics, transcriptomics and nutritional biochemistry to **explain the interactions between genes and bioactive compounds present in food** and their effects at the molecular level (Chaudhary et al., 2025). All analyses of these interactions provide information for prescribing **personalised diets for individuals based on their genotype**.

Omic science
Omic sciences are disciplines that use high-throughput technologies to produce enormous amounts of data used to describe and interpret biological systems in their entirety. This holistic approach allows us to understand how the organism functions not as the sum of isolated parts, but as a complex network in constant dialogue with the external environment. It represents the pillar of systems biology, which aims to create models for data integration and provide predictive models for evaluating the complex functioning of living systems. (Treccani, n.d.)

Technological integration as a market driver for precision nutrition

While nutrigenomics defines the scientific basis of the relationship between genes and nutrients, the specific market for artificial intelligence applied to personalised nutrition is driving its large-scale adoption. This sector is rapidly expanding, with projections seeing global value rise from **USD 4.13 billion in 2024 to over USD 20 billion by 2034** (Balamurugan, 2026). This growth marks the definitive shift towards **data-driven health**, where technology acts as a bridge between biological complexity and everyday consumer choice.
The heart of this evolution lies in the ability of **wearable devices** to transform nutrition into a stream of data that can be monitored and acted upon. A concrete example is **Oura's Meals feature *(Fig. 3.77)***, which, in addition to detecting the nutritional content of meals using AI, also allows you to gather useful information that helps you **understand the relationship between your meals and other aspects of your life**, such as your energy level, recovery, or metabolism (Oura, n.d.). Through machine learning algorithms, these devices do not just count calories, but offer an interpretation of **individual metabolic response**, making visible the impact that each meal has on the biological system. However, integrating such diverse and sensitive data sets raises several **challenges** (Balamurugan, 2026). For example, the transition to data-driven healthcare requires careful consideration of **privacy governance** and the **transparency of algorithms**, which are often perceived as black boxes by consumers. Furthermore, it is essential to address the risk of a **nutritional digital divide**, ensuring that access to these precision technologies does not become a new driver of social inequality. Only through **multidisciplinary collaboration between ethics experts, data scientists and healthcare professionals** can artificial intelligence foster a real transformation towards more inclusive and sustainable food systems.

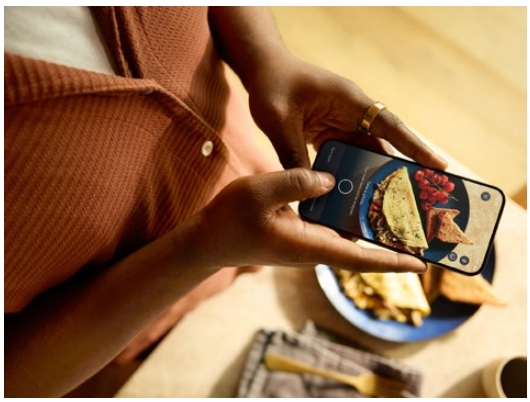


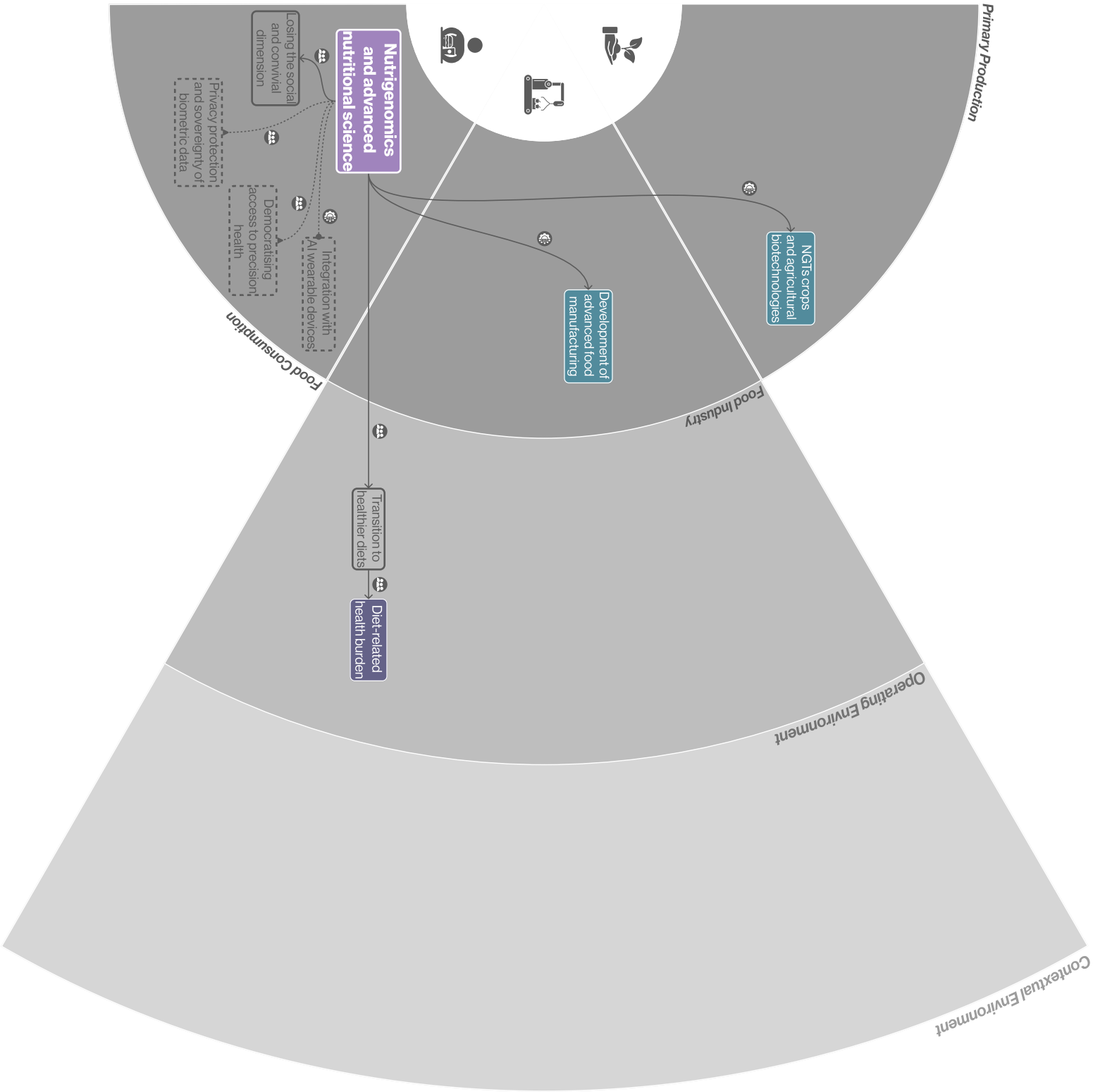
Fig. 3.77 Oura's Meal.

Impacts on the Agrifood System

The establishment of personalised consumption based on nutrigenomics is redefining the entire food system through unprecedented biological precision. From the analysis of the framework ***(Fig. 3.78)***, it emerges that the ability to structure personalised diets based on individual genomes represents a significant opportunity for a **transition to healthier dietary** patterns This approach has a direct impact on the burden of metabolic diseases, such as obesity and diabetes, significantly improving overall health through targeted molecular prevention. At the same time, this science accelerates the adoption of advanced food manufacturing technologies such as **3D printing** and **nanotechnologies**, which allow for millimetric control of bioactive compounds, adapting the structure of food to **individual biochemical needs**. This innovative drive also involves primary production, with the integration of biotechnologies, in particular **NGTs**, which open up the creation of agricultural products tailored to the metabolic profile of the end consumer. However, from a socio-cultural point of view, this data-driven model introduces the risk of a **loss of conviviality**. The fragmentation of consumption based on unique biological needs could transform the meal from a collective ritual to an individual technical management practice.

Identifying Challenges and Opportunities within the Framework

The integration of nutrigenomics with ***wearable devices enhanced by artificial intelligence (O16)*** represents the main opportunity to make this science usable in everyday life. The constant dialogue between the body and technology allows the diet to be calibrated not on statistical averages, but on the actual metabolic fluctuations of the individual. However, this biological transparency raises profound questions about the ***protection and sovereignty of biometric data (C28)***. Managing such sensitive information flows, which touch on genomic and metabolic identity, requires rigorous governance to prevent data from becoming a tool for surveillance or commercial speculation. At the same time, there is an urgent need ***to democratise access to these technologies (C29)*** to prevent precision health from becoming a new driver of social inequality. In this context, we need to develop an approach that makes these innovations accessible and inclusive, transforming genomic prevention into a common good rather than a technological luxury.



Type of Elements

- Megatrend
- Driver
- Trend
- Weak signal
- Impact
- Challenge/ Opportunity

Type of Flows

- Direct causal relationship
- Strategic pathway
- Challenge identification
- Opportunity identification
- Environmental flow
- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.78 Nutrigenomics and advanced nutritional sciences, Systemic Framework.

016 - Integration with AI wearable devices.

January AI

Menlo Park, USA

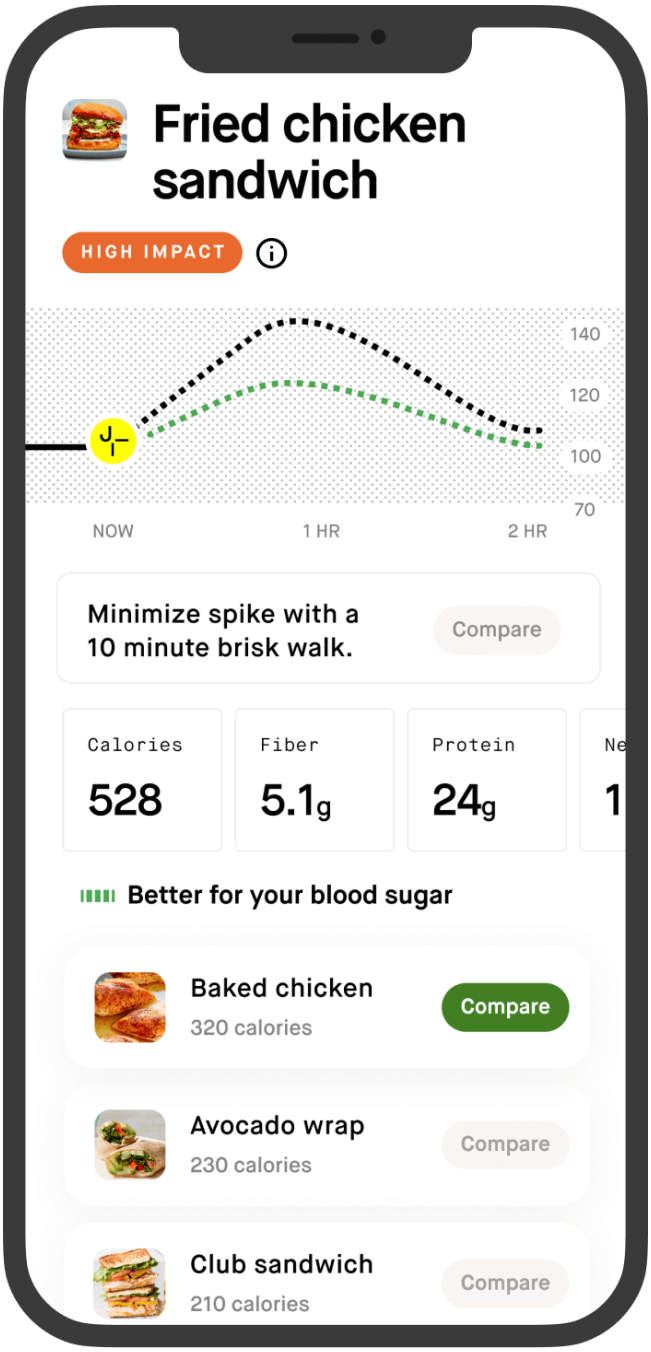
This platform, co-founded by **Noopur Gupta** and **Michael Snyder**, director of the Department of Genetics at Stanford University, represents the cutting edge of precision metabolic health. At the heart of the technology lies the creation of an **Eden**, or Digital Twin, of the user's metabolism. The system uses a two-step approach: first, it cross-references data from a continuous glucose monitor (CGM) with data from an activity tracker to map individual reactions to food, activity and sleep. Next, **artificial intelligence** is able to **predict the glycaemic response to millions of different foods** before they are even consumed, allowing the user to virtually test meals through the app.

Keywords:
#Digital Twin
#AI precision nutrition
#Predictive wellness

Response to the identified Opportunity:

This solution directly responds to the opportunity for integration between AI and wearable devices, transforming hardware from a simple data recorder to a simulator of future scenarios. The added value lies in the ability of algorithms to fill in **information gaps**, making the user experience smooth and much less burdensome for the consumer. January **AI reduces friction between humans and technology**, translating the complexity of systems biology into practical and immediate guidance. Prevention ceases to be a reactive process based on what has already happened and becomes a guided navigation, allowing users to visualise the impact of a food choice even before making it.

January


Fried chicken sandwich
HIGH IMPACT
140
120
100
70
NOW
1 HR
2 HR
Minimize spike with a 10 minute brisk walk.
Compare
Calories
528
Fiber
5.1g
Protein
24g
Better for your blood sugar
Baked chicken
320 calories
Compare
Avocado wrap
230 calories
Compare
Club sandwich
210 calories
Compare

WS2 - Advancements in food experience technologies

The act of eating is rapidly evolving towards the paradigm of **interactive dining** ***(Fig. 3.79)***, a field in which the integration of digital technologies transforms the **meal into a narrative and dynamic experience**. In this scenario, which is still mainly associated with fine dining, the integration of technologies such as **AI**, **virtual reality** and **augmented reality** are no longer simple management accessories but have become tools for **designing the experience** (Shrauner, 2024). The use of **digital menus** and advanced applications now offers consumers unprecedented control, allowing them, for example, to view 3D models of dishes before ordering or to watch virtual cooking demonstrations directly at their table (Shrauner, 2024). Through techniques such as **projection mapping**, the table surface itself is reconfigured as an interactive canvas where animated stories enhance the cultural value of food and enrich the **gastronomic narrative**. This development has led to the emergence of **smart dining rooms**, capable of **adapting the atmosphere**, lighting and background music in real time, calibrating them **to the mood or specific preferences of diners** through the analysis of sensory data. In addition to the playful and hedonistic component, interactive catering also offers an opportunity to **educate the public**; customers can be guided to discover the **ethical origin of ingredients** or involved in sustainable choice processes, making the act of eating a moment of profound social and environmental awareness.



Fig. 3.79 Whimsy, immersive dining experience.

Gastrophysics in the design of sensory experiences

In this context, we also find **Gastrophysics**, the discipline theorised by **Charles Spence** in his famous book **"Gastrophysics: The New Science of Eating"**, where he demonstrates how taste is not purely a chemical event that occurs on the tongue, but rather a complex construction of the brain resulting from the integration of multisensory stimuli. Since **eating is one of the most multisensory perceptual experiences** in everyday life, it is possible to act on sensory signals (visual, auditory, tactile, olfactory) to radically alter the perception of taste through the **design of stimuli defined as off-the-plate**. For example, the phenomenon of **sonic seasoning** ***(Fig. 3.80)*** highlights how listening to specific frequencies can **alter the chemical perception of food**: the use of high-pitched, tinkling sounds can increase the **perception of sweetness** by up to 10 or 15%, offering an innovative strategy for reducing sugar use without compromising consumer enjoyment (Lloyd, 2019). Furthermore, the integration between humans and technology now allows us to use digital devices that **stimulate taste by coordinating it with other senses**, such as sight and hearing (Velasco et al., 2021). This allows us to **design the taste experience outside of rigid and artificial research environments**, bringing it directly into the real context of the table, where technology blends with the spontaneous gestures of everyday meals. From cutlery designed to stimulate touch and smell in a coordinated way, such as the famous **heavy, talcum-scented spoon** used for Heston Blumenthal's Counting Sheep dish, to the **modulation of taste through mixed reality**, technology enables an experience design where digital and physical interfaces merge. This meticulous control of sensory stimulation is not only intended to amaze, but also to build a **bridge between neuroscience and gastronomy**, allowing the human sensory system to be orchestrated to **improve well-being and satisfaction during the act of eating**.



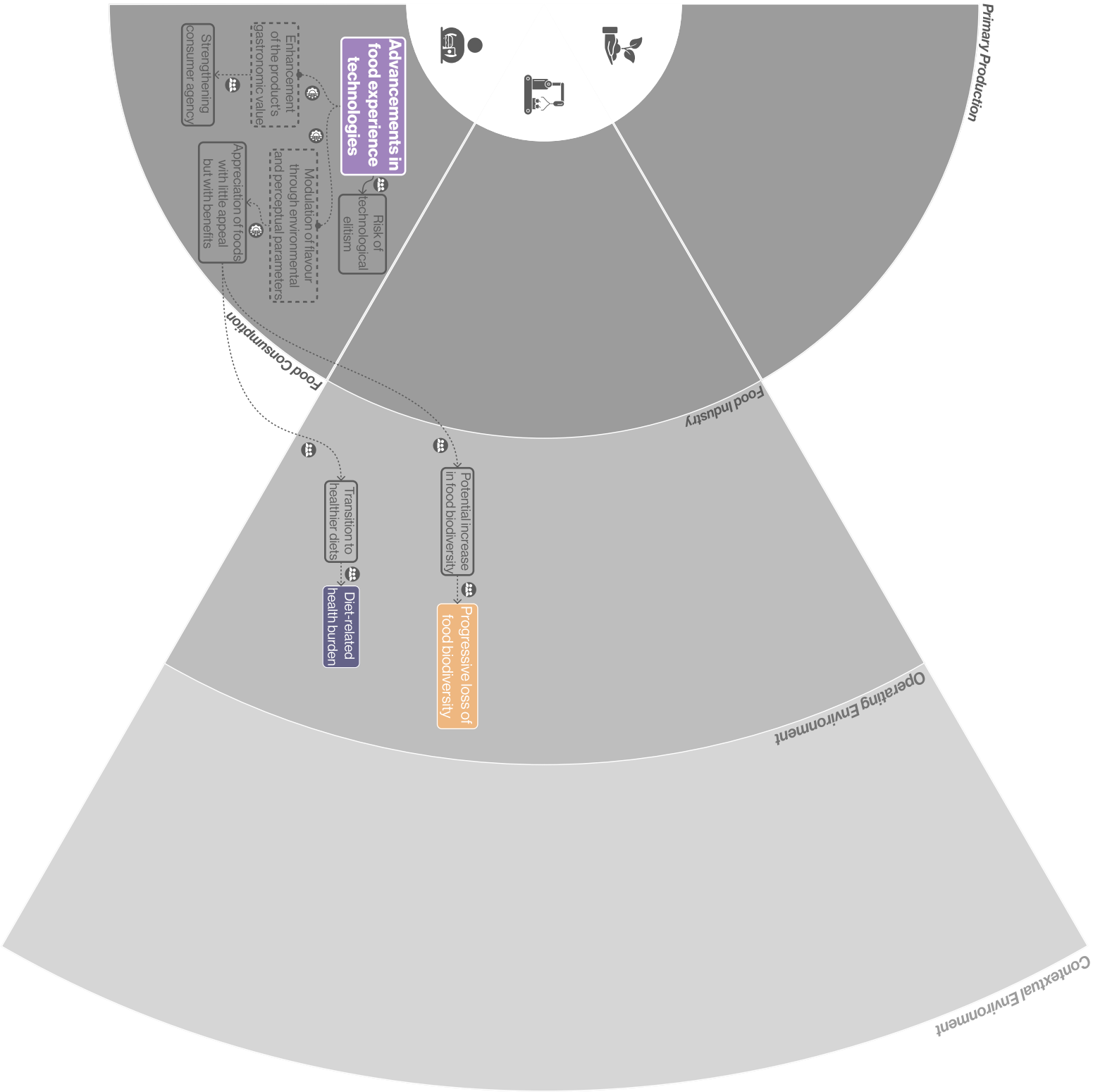
Fig. 3.80 Sonic seasoning events.

Impacts on the Agrifood System

From the analysis of the framework ***(Fig. 3.81)***, the progressive adoption of digital technologies to **enhance the food experience** revolves around two main opportunities that **redefine the act of consumption**. Firstly, controlling flavours by manipulating environmental and perceptual parameters provides an opportunity to **encourage the appreciation of foods** that would otherwise be unpalatable, by altering their sensory perception. When used ethically, this tool can **improve people's diets**, for example by encouraging children to appreciate foods that are usually rejected for cultural reasons, thus promoting healthier diets and **increasing biodiversity in diets** as a lever to combat diet-related health burdens. At the same time, the use of virtual and augmented reality allows us to **enhance the gastronomic history** and sustainability aspects of products, strengthening their narrative to **increase consumer awareness** and agency, a practice which, if conducted transparently, can significantly improve the current situation of the food system. However, the effectiveness of these impacts must be weighed against the risk that such technologies will remain the preserve of a small **elite**, perhaps confined to high-end catering circuits and preventing the technology from expressing its democratic potential for the well-being of the community.

Identifying Challenges and Opportunities within the Framework

Technological innovations applied to the consumer experience offer the possibility of ***modulating the flavour of food by directly influencing perceptual and environmental parameters (O17)***. This capability represents a strategic opportunity to encourage the consumption of beneficial or sustainable products, improving the quality of diets and, consequently, overall health, as illustrated in the reference framework. Alongside this aspect, these technologies have the potential to ***enrich the enjoyment and narrative dimension of food products (O18)***. Especially in the catering sector, enhanced storytelling managed according to ethical principles can strengthen consumer agency, providing the tools necessary to make more informed and conscious purchasing choices.



Type of Elements

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- Impact
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Type of Flows

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- Social flow
- Economic flow
- Technology flow
- Legal flow

Fig. 3.81 Advancements in food experience technologies, Systemic Framework.

017 - Modulation of flavour through environmental and perceptual parameters.

Electric Salt Spoon

Tokyo, Japan

The Electric Salt Spoon was developed through a collaboration between Professor **Homei Miyashita**'s laboratory at **Meiji University and Kirin Holdings**. This device addresses the challenge of **reducing sodium intake in modern diets without sacrificing taste satisfaction**. The spoon uses a weak electric current, completely imperceptible to the user, to stimulate the taste buds and intensify the perception of sodium ions already present in food. This electric taste technology increases the perceived flavour by about 1.5 times, offering a concrete solution for those who must follow low-sodium diets but do not want to give up the pleasure of taste.

Keywords:
#Sodium reduction
#Taste electrostimulation
#Perceptual bio-hacking

Response to the identified opportunity:

The Electric Salt Spoon case demonstrates how flavour modulation can occur through **external perceptual parameters** rather than acting exclusively on the chemical composition of the product. This tool acts as a **behavioural facilitator**, not forcing consumers to make punitive sacrifices, but **redesigning sensory interaction to maintain high food palatability**. This approach allows meals lower in sodium to be integrated into the daily diet, directly counteracting the health burden of chronic diseases and promoting a transition towards more balanced and sustainable consumption patterns for the healthcare system.



018 - Enhancement of the product's gastronomic value.

Le Petit Chef

Leuven, Belgium

The Le Petit Chef project is the brainchild of **Skullmapping**, a studio founded by **Antoon Verbeeck** and **Filip Sterckx** that has revolutionised the ***dining experience*** through the use of **3D projection mapping**. This technology brings to life a **tiny virtual chef**, just 60 millimetres tall, who is projected directly onto the tablecloth in front of diners. The viewer witnesses a **veritable cinematic performance** in which the little protagonist interacts with the tableware to **prepare the dish in real time**, transforming the minutes of waiting into a moment of immersive entertainment that precedes and describes the serving of the actual course.

Keywords:
#Projection mapping
#Interactive dining
#Food entertainment

Response to the identified opportunity:

This initiative uses technology to exponentially **increase the gastronomic value** of the product through **augmented storytelling**. Instead of limiting itself to the physical presentation of food, the system constructs a narrative that **enriches the enjoyment of the meal and enhances its symbolic and narrative dimension**. The integration of these digital tools into catering makes the creative process behind each recipe visible, strengthening the agency of the consumer who is actively involved in the story of the food. When geared towards transparency, this technology can guide the user towards a **deeper understanding of the quality and history of the product**, transforming the meal into a conscious act that goes beyond simple consumption.





3.7 Semi-Structured Interviews

To support the desk research carried out to identify all the factors that will influence the future of the agro-industrial system, **semi-structured interviews** were conducted with a number of experts from various sectors. The primary objective of this phase was to explore in depth most of the disciplines covered during the research, involving individuals who could offer a **cross-cutting view of the entire agro-industrial system framework**, from the initial stages in the field right through to the final dynamics of consumption. It is important to emphasise that the individuals involved were not chosen at random. This approach enabled us to engage with **experts who are involved in different areas** of the production and social network, ensuring that every signal identified in the scanning process was reflected or explored in greater depth through the expertise of the professionals consulted. The aim was to **build a bridge** between the theory emerging from the desk research and the reality experienced by those working in the sector on a daily basis. Specifically, the interview strategy involved contacting **seven key figures**, most of whom were from the academic sector, although two individuals working in the private sector were also contacted in order to incorporate their specific perspective into the work, which is often more focused on market dynamics and practical applications in the field. This distinction was sought to balance scientific rigour with the operational needs of the contemporary agro-industrial sector, in an attempt to understand how global trends are perceived by the various stakeholders. Unfortunately, of the seven individuals initially identified and contacted, it was only possible to conduct interviews with three of them. Specifically, these were **Maria Pia Genesin**, **Alberto Acquadro** and **Paola de Bernardi**, all three professors at the University of Turin (UniTo). Their contribution proved crucial in lending credibility to the research, enabling the data collected during the desk-research to be translated into concrete insights. Despite the smaller sample size compared to the initial planned sample of seven people, the quality of the discussions with the three professors ensured a comprehensive multidisciplinary overview, covering topics from food regulations and agricultural genetics to economic and consumer aspects. As can be seen in the summary chart on the right ***(Fig. 3.82)***, the initial sample reflected this ambition for comprehensiveness, including both the responses received and the attempts to contact individuals which, for reasons of time or availability, could not be followed up with a face-to-face interview.

Semi-structured interviews
The semi-structured interview is a qualitative research method that combines a set of pre-determined open-ended questions with the flexibility to explore new topics or delve deeper into details that emerge during the conversation. Compared to a rigid interview, this approach allows the order of the questions to be adapted to the flow of the conversation, taking the form of a guided dialogue capable of bringing out unexpected nuances and connections.

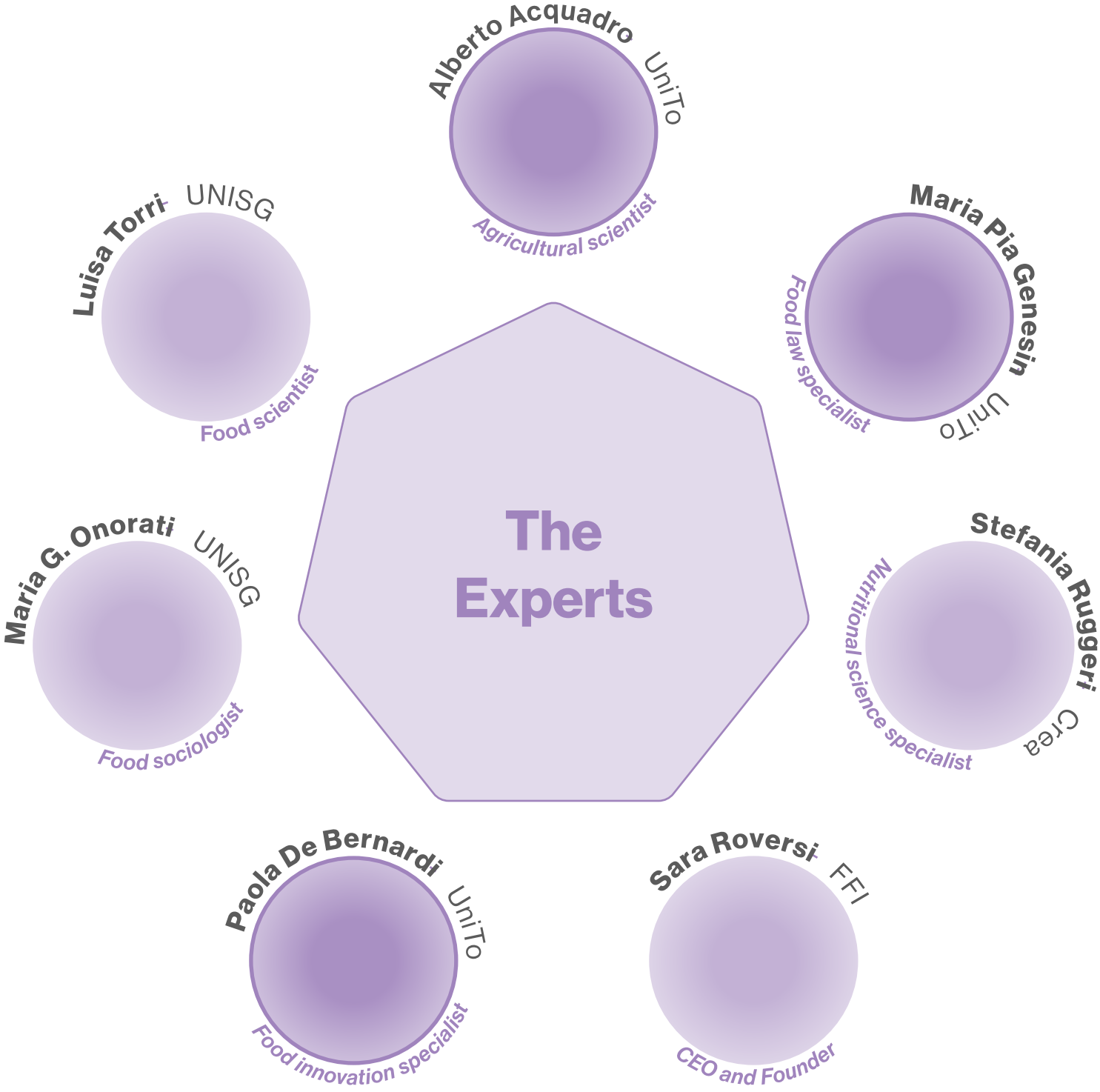


Fig. 3.82 Experts consulted.

Maria Pia Genesin

Expertise: Food law
Position: Associate Professor of Food Law and Regulation (UniTo)
Date of the interview: 11/12/2025

The aim of this interview is to analyse the agro-industrial system from a **legislative and policy perspective**, focusing in particular on **understanding the current regulatory framework** and its main challenges. We will then examine how this influences innovation and its uptake, such as the adoption of genetic engineering practices in plants or the spread of so-called "Novel Foods". Finally, the last section will focus on the topic of **food labelling**, which is a key and particularly topical issue, given the advent of digital technologies such as blockchain and new consumer sensibilities and lifestyles.

INTRO: Food Law and Regulatory Scenarios between Governance and Innovation

The following reflections stem from a discussion with Professor Maria Pia Genesin, Associate Professor of Food Law and Regulation at the University of Turin. The discussion centred on the crucial role of the regulatory framework as a mediator between technological progress and consumer protection, analysing in particular the **differences between the European and US regulatory models**. Another significant issue that emerged concerns the impact of policy on the speed of adoption of new technologies and the transformation of regulations, which can evolve from mere compliance requirements into strategic tools for competitiveness and food safety on a global scale.

Regulatory architecture and global geopolitical structures

The framework for global trade is defined by the **Marrakesh Agreement**, signed on **15 April 1994** and which came into force in 1995, establishing the **World Trade Organisation** (WTO), which now comprises 164 member states. At the international level, there is no single decision-maker, as the system relies instead on the policies of individual states. Unlike other states, the European Union presents an additional layer of complexity, as EU regulations overlap with those

of member states, effectively creating three regulatory levels. In this context, agri-food production has reached such critical environmental levels that the objectives of the **2030 Agenda** (SDGs 2 and 12) have become fragile instruments, as their implementation depends on individual national decision-makers. In recent years, the pandemic and geopolitical instabilities, mainly due to conflicts in **Ukraine** and the **Middle East**, have caused a rise in raw material costs and the imposition of strategic tariffs, leading many governments to put the Paris Agreement on the back burner in order to address emergency priorities.

Keywords: Multi-level governance, WTO, 2030 Agenda, Geopolitical instability

European strategies and the sustainability of supply chains

The EU has strict regulations governing the agri-food sector, covering hygiene, quality, animal welfare and the use of pesticides and additives. At the heart of this system is the **European Green Deal**, the action plan to achieve all the UN's 2030 Agenda and Paris Agreement targets (not only concerning the agri-food sector, but also other sectors), through strategies such as **"Farm to Fork"**.
A growing regulatory challenge concerns **European companies importing raw materials**, requiring them to **ensure social and environmental sustainability standards** throughout the supply chain, especially for critical products such as soya and palm oil often linked to **deforestation**. Alongside sustainability, the system must manage constant health threats, particularly those arising from the livestock sector, such as avian influenza or African swine fever, phenomena that highlight the risk of **zoonoses** (the transmission of diseases from animals to humans). Furthermore, another issue concerns **global warming**, which is limiting agricultural yields and forcing the relocation of crops. Notable examples of this phenomenon include **Piedmont hazelnut** crops suffering from rising temperatures, vines being planted at ever-higher altitudes, and Sicily now growing avocados. The products most affected by these changes are **PDO, DOCG and PGI products**, which are subject to extremely strict regulations and are closely tied to their territory of origin.

Keywords: Green Deal, Farm to Fork, Deforestation, Zoonoses, Certifications (PDO/PGI)

Global market, Italian-sounding products and novel foods

Unfair competition is a significant global issue, manifesting itself in practices such as **"Italian Sounding"**, primarily in countries with a strong historical Italian immigrant population (USA, Argentina, ecc..), where products that evoke an Italian aesthetic take market share away from authentic products. When it comes to innovation, the EU takes a radically different approach from the rest of the world regarding, for example, **Novel Foods** (products not present on the market before 1997). While more liberal countries prioritise economic considerations, Europe focuses on food safety and protects the end consumer. In Italy, even Novel Foods such as insect-based products must be clearly labelled to warn of allergy risks (similar to those of shellfish). However, these products have not yet gained a foothold in large-scale retail and remain confined to niche markets. **GMOs**, whilst technically classified as Novel Foods, are now subject to specific, separate legislation due to their complexity and legislative history.

Keywords: Italian-sounding products, novel foods, food safety, GMOs, allergen traceability

NGTs and the regulatory divergence between EU and US

Advances in biotechnology and the discovery of **CRISPR-Cas9** have led to the emergence of NGTs, sparking debate over how they differ from GMOs. In 2025, the political agreement in the EU outlined a two-tier structure: **Type 1 NGT**s, considered equivalent to conventional varieties and marketable without product labelling (but with a requirement for seed labelling), and **Type 2 NGTs**, which remain subject to the restrictive GMO regime. The European approach, supported by scientific advice from **EFSA**, remains focused on controlling the production process to prevent unintended errors. In contrast, in the United States, the **FDA** adopts a model **based on the final result**: if the product is molecularly identical, the process used to obtain it is irrelevant. This makes the **American process faster** and more conducive to innovation, with the US prioritising risk management against deliberate terrorist attacks (a legacy of 9/11) whilst the **EU focuses on preventing accidental contamination**. Finally, supply chain vulnerabilities are becoming increasingly evident,

with the US's vertical structure being more prone to disruption than Europe's branched model, despite Europe's continued reliance on external markets for essential resources like wheat.

Keywords: NGT1 vs NGT2, EFSA vs FDA, Process vs Outcome, Supply Chain Vulnerability, Intellectual Property

Alberto Acquadro

Expertise: Agricultural sciences
Position: Ordinary Professor of Agricultural Genetics (UniTo)
Date of the interview: 14/01/2026

The aim of this interview is to discuss the **main challenges facing primary production**, particularly in **agriculture**, whilst also exploring the most **relevant and promising solutions** in terms of technology as well as holistic approaches, etc. The second part will focus more on the **application of biotechnology** to plant species, which is one of Alberto Acquadro's key areas of expertise. Finally, to conclude, there will also be a focus on **consumer acceptance** of these future foods derived from "genetically modified" plants and on how they are communicated.

INTRO: Agricultural Genetics and Resilience in the Breeding of "Domesticated Species"

The following content summarises the discussion with Professor Alberto Acquadro, Professor of Agricultural Genetics at the University of Turin. The analysis traces the **evolutionary history of domesticated species** to address the challenges posed by climate change, outlining **the role of New Genomic Technologies (NGTs)** as tools for accelerated adaptation. The discussion focused on the mismatch between genotype and environment and on the need for a **new social narrative of biotechnological innovation**, incorporating the contributions of Professor Vera Ventura (University of Brescia) regarding the paradoxes of public perception and sustainability.

Human settlement and the birth of the agricultural system

Farming and livestock breeding began **around 10.000 years ago** with the settlement of human populations. This shift brought an end to the hunting and gathering of wild species, marking the start of a **process of domestication** that has continued for millennia. The plants we consume today are the result of 5.000 to 10.000 years of guided evolution, with different timescales and rates depending on the species. Biologically, agricultural plants have become **"gentle" organisms** that have lost their wild hardiness, making them **unable to survive without constant human intervention**. A case that best illustrates the dependence of domesticated species on humans is the **grapevine**, which for around 200 years, due to **soil pests (phylloxera)**, has been unable to grow on its own roots. The survival of the viticulture system now depends on grafting onto **American rootstocks**, a technique necessary for a specific genotype to express its phenotype in environmental contexts that would otherwise be lethal.

Keywords: Sedentarisation, Domestication, Wild-type vs domesticated species, Genotype and Phenotype, American grafting

Climate crisis and genotype-environment mismatch

Global warming, a phenomenon that has been monitored since the 1980s, acts as a destabilising factor for crop distribution. One of the most serious consequences of changing temperatures in agriculture is that it forces a **shift in production centres towards northern latitudes** (the migration of crops from the global south to the global north), gradually rendering historically suitable areas uncultivated, as is currently happening in the wine-growing regions of southern France. The main critical issue lies in the problem of **genotype-phenotype mismatch**: if the plant's genetic makeup remains unchanged but the climatic context changes dramatically, the phenotypic response (yield and quality) is no longer guaranteed. Basically, the **phenotype collapses because the genotype is no longer aligned with the environment**. To mitigate the impacts of these **abiotic stress conditions** (water scarcity and extreme temperatures) on plants, the **PNRR** research plans and **EU-funded projects** follow two approaches: identifying naturally resilient varieties already pre-

sent in nature or the use of gene editing (CRISPR technology). The aim is to intervene in a targeted manner on the genotype to **accelerate adaptation times** that natural **evolution would be unable to match** at the same pace as climate change.

Keywords: Global warming, Crop migration, Abiotic stress, Genotype-environment mismatch, Accelerated adaptation

The potential of NGTs

Genetic improvement is nothing new, it has been practised ever since the dawn of agriculture. Farmers have, in fact, always **selected and crossbred the best specimens to increase yield and quality**, but it is an extremely slow process. Today, thanks to modern biotechnology, these timescales have been drastically reduced, particularly since **2012**, the year in which Jennifer Doudna and Emmanuelle Charpentier developed the **CRISPR-Cas9 technology** (a discovery that earned them the Nobel Prize in Chemistry in 2020). NGTs (New Genomic Techniques) are plants obtained through these **assisted evolution techniques**. The key difference from GMOs lies in the genetic content: whilst GMOs are transgenic organisms containing DNA from different species, **NGTs work on the specific genome of the plant itself**, modifying it in a targeted manner without inserting foreign material. Internationally, many countries already use NGTs because they assess the final product, whereas the European Union has so far focused on the production process, creating a bureaucratic obstacle to their adoption. However, the **regulatory framework is evolving**, as between 2024 and early 2025 the EU worked on new regulations distinguishing NGTs into two categories:

- ***Type 1 NGTs***: plants **considered equivalent** to those obtained by conventional means (with minimal modifications). For these, the regulations provide for a simplified procedure and mandatory **labelling only on seed bags**, whilst it is not required on finished consumer products.

- ***Type 2 NGTs***: plants with more **complex modifications**, which remain subject to **stricter regulations**, similar to those for GMOs.

The potential of NGTs is vast and varies depending on the ultimate goal being pursued. They can be used to **improve aesthetic** or **nu-**

tritional characteristics (more protein, more vitamins), to **eliminate specific allergenic genes**, or to **make plants more resistant to abiotic stresses** caused by global warming, for example by reducing their water requirements. A concrete example of this application is the **PROSPEcT project** (Disabling S-genes in Solanaceae species, 2020–2023), coordinated by Professor Alberto Acquadro, which aims to make certain fruit and vegetable species, such as **tomatoes** and **aubergines**, more resilient to environmental challenges. Using the CRISPR/Cas9 technique, the research team is working to **deactivate so-called susceptibility genes (S-GENES)**, such as MLO, PRM4 and DMR6. By deactivating these specific genetic factors, it is possible to **develop varieties** that are naturally **resistant to or tolerant of devastating pathogens** such as downy mildew and powdery mildew, drastically reducing the need for chemical interventions. In addition to crop protection, there are significant applications in the **health and nutraceutical sectors**, such as the production of foods with **higher levels of antioxidants** or **vitamin D**. This last point is crucial: over a billion people worldwide suffer from vitamin D deficiency (found mainly in meat and dairy products), particularly in poorer countries. NGTs can therefore represent a solution to this type of global nutritional problem. A prime example of such an application is that in **Japan**, where, to address high levels of stress among the population, **tomatoes with a high GABA content** have been produced and marketed; GABA is an amino acid that helps alleviate stress and reduce blood pressure. Finally, it is important to emphasise that modifications made using **NGTs do not affect the organoleptic characteristics of the products**. The flavours and tastes we are familiar with remain unchanged, making the innovation almost "invisible" to the palate, yet crucial for the sustainability and health of the food system.

Keywords: CRISPR-Cas9, Assisted evolution, NGT type 1 and type 2, S-GENES (Susceptibility genes), Biofortification

Social perception and the sustainability paradox

*With contributions from **Vera Ventura**, Associate Professor at the University of Brescia (UNIBS), during the event* **"Nuove frontiere biotecnologiche per il futuro dell'agricoltura"** *2025 in Novara.*

A key challenge to the effective implementation of these technolo-

gies is public acceptance, which is often hindered by alarmist reporting and cognitive biases. Socio-economic research highlights a **paradox**: consumers who are most concerned about sustainability are often the most **skeptical about biotechnological innovation**. There is a discrepancy between the desire for low-impact agriculture and the rejection of the tools that could make it possible (such as resistant plants that do not require pesticides). The imagery used by the media, which often associates biotechnology with notions of danger or **"monstrosity"**, influences perceptions of insecurity more than scientific reality. For genuine systemic progress, trust must be rebuilt through **transparent storytelling**, presenting NGTs not as a threat to nature, but as an indispensable ally for environmental sustainability and the protection of the land.

Keywords: Public acceptance, Cognitive biases, Sustainability paradox, Transparent storytelling, Systemic trust

Paola De Bernardi

Expertise: Food Business Innovation
Position: Ordinary Professor of Management Control Systems and Circular Economy Management (UniTo)
Date of the interview: 15/01/2026

The interview aims to identify the most promising **areas of innovation** that **will shape the future of the sector**, adopting an economic, strategic and market analysis perspective. The approach will focus on understanding the systemic drivers and catalysts that are shaping its development, assessing the scalability and operational sustainability of new models, as well as analysing the political and management control barriers that are hindering their adoption.

INTRO: Innovation and Agri-Food Management between Sustainability and Systemic Thinking

This article summarises the discussion held with Professor Paola De Bernardi, lecturer in Circular Economy Management and Cli-

mate Change Management at the University of Turin. The interview explored the complexities of the **ecological and digital transition** in the **agri-food sector**, drawing on her decade-long experience within **EIT Food**, Europe's leading public-private partnership for food innovation. The discussion focused on the need for a **systemic approach** that integrates impact measurement (ESG KPIs), data management and the new frontiers of conscious consumption, charting a course that combines **technological innovation** with **resource regeneration**.

Innovation management and the role of data

In today's landscape, technological innovation should not be seen as the adoption of digital tools such as AI, robotics or satellite mapping for their own sake, but rather as the ability to **manage the resulting data in a systematic way**. The real leap forward lies in data management, because simply installing sensors is not enough if the information remains fragmented. The critical issue is the **interoperability of systems**; without a robust information platform capable of **supporting decision-making processes**, the entrepreneur risks abandoning costly technologies precisely because they are unable to identify the correlations and scale the costs. The objective must be to improve process efficiency from a managerial perspective, moving beyond the old management approach based on day-to-day improvisation and simple visual observation of the field.

Keywords: Public acceptance, Cognitive biases, The sustainability paradox, Transparent storytelling, Systemic trust

Institutional drivers and supply chain dynamics

Change in the sector is driven by institutional factors and the capacity for cross-company collaboration. **Public funding** and **targeted calls for proposals** (such as those for controlling the hazelnut bug in the Cuneo area) act as key catalysts for the adoption of new technologies. Alongside these, the **leadership of large companies** such as Mutti in the tomato sector plays a key role, as these organisations act as a driving force for their suppliers, **spreading best practices throughout the value chain**. However, a **cultural obstacle** persists, linked to a feudal mindset and resistance to change, which can only

be overcome by adopting a **medium- to long-term vision**, supported by an appropriate appetite for financial risk and the sharing of common objectives, thereby transforming the initial investment into a lasting competitive advantage for the entire system.

Keywords: Institutional incentives, Industry leadership, Cultural barriers, Long-term vision

European policies, waste and business models

European policies, from the CAP to the EU Biodiversity Recovery Act, are often perceived by businesses as a bureaucratic burden. However, true innovation stems from the ability to turn regulatory compliance into a **strategic opportunity**. Reducing the use of chemicals is not merely an obligation but a **way to attract consumers willing to pay a higher price for quality** (the "green premium"). In this context, the fight against waste emerges as a priority, accounting for 30% of consumption. This impact stems largely from the food service sector (canteens and catering) as well as from household consumption. New regulations prohibit the disposal of edible food nearing its expiry date, encouraging **upcycling processes** or redistribution via food banks to transform waste into a resource.

Keywords: PAC, Upcycling, Food Service, Premium Price, EIT Food

Paradoxes of the future between regenerative agriculture and nutrition

The future of the agri-food system will continue to be marked by stark contradictions. Whilst technologies such as **vertical farming** and **hydroponics** address the need to **produce food in urban areas** or on land that has become barren and polluted, questions remain regarding the **energy efficiency** and **scalability** of these technologies. On the other hand, we are witnessing a necessary **return to the past** through **Regenerative Agriculture** and other similar practices that aim to restore soil fertility in order to recover the density of micronutrients lost through intensive farming methods. The most serious systemic risk, however, remains the **over-reliance on highly processed foods**. Hyper-processed food distances food

from its role in supporting health and creates a form of silent inflammation known as **"inflammaging"**, which deteriorates the body over time and ultimately places a heavy burden on national healthcare systems, which find themselves treating conditions that could be prevented through diet. From a systemic perspective, **poor nutrition creates a social paradox** where the poorest sections of the population are often **obese** because they eat cheap **junk food that lacks real nutrients**. Instead, we should rediscover food as medicine, favouring **natural foods that allow the metabolism to regenerate** rather than forcing it to constantly process additives and complex sugars.

Keywords: Vertical farming, Regenerative agriculture, Ultra-processed foods, Inflammaging, Food Inequity

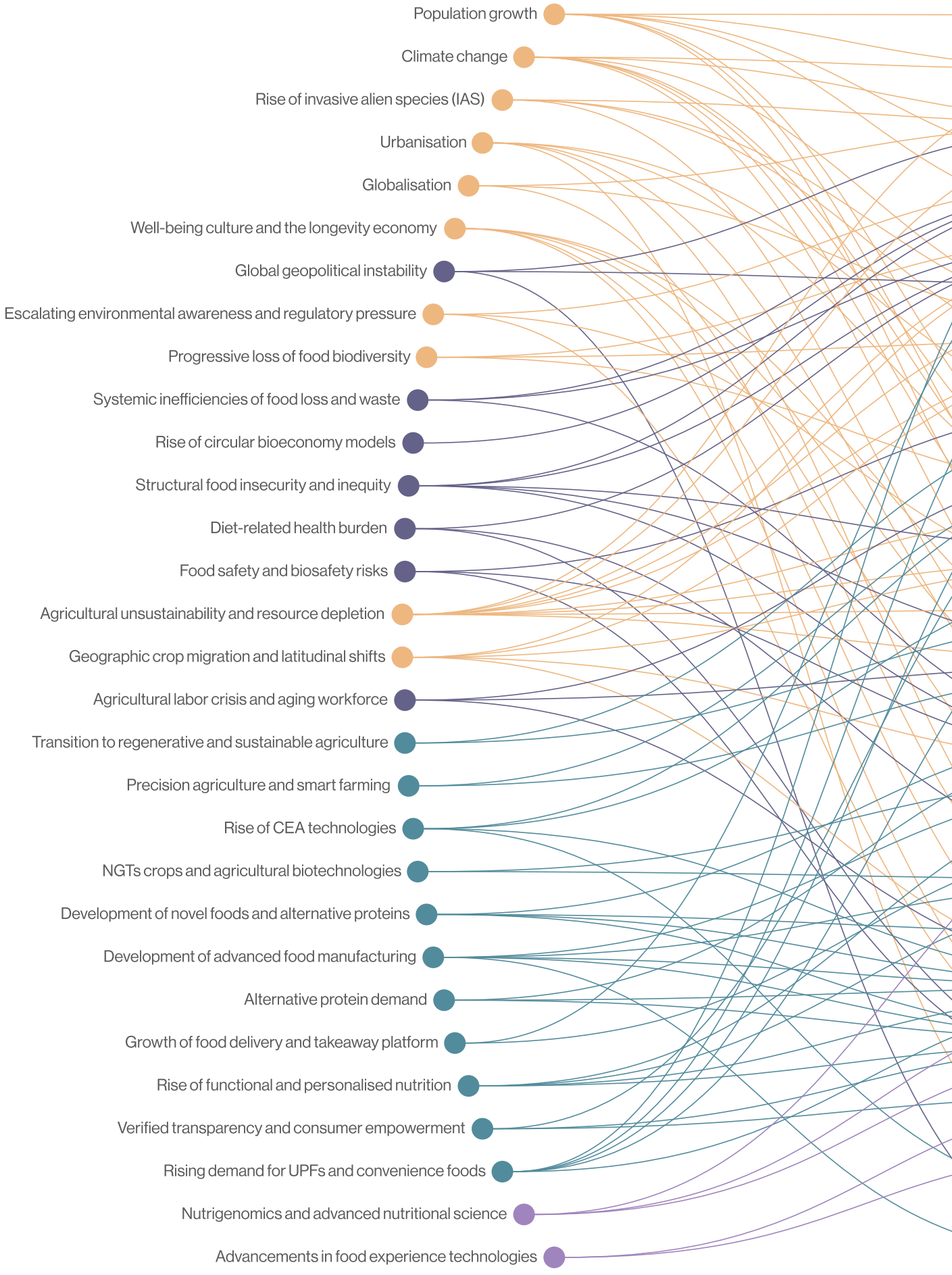
Novel foods, Longevity economy and the paradigm of sufficiency

Novel foods such as insect proteins, algae or fermented foods represent necessary experiments to ensure the protein requirements of ten billion people are met, but their viability depends on **overcoming technical** and **institutional barriers**. Against a backdrop of demographic decline, food is becoming part of the **Longevity Economy**, where the aim is to ensure health through sufficiency. This trend points towards the concept of Sufficiency, theorised by researchers such as **Nancy Bocken** (Maastricht University), who argues that we must optimise resource consumption by moving away from unnecessary market diversification and the complexity of ingredients. The future will see the success of **transparent products containing just two or three ingredients**, capable of activating self-healing mechanisms such as autophagy, transforming nutrition into a form of **preventive medicine**.

Keywords: Novel Food, Longevity Economy, Nancy Bocken, Sufficiency, Autophagy

3.8 Final Considerations and Assumptions

The mapping work carried out so far, through the analysis of various drivers of change, finds its final convergence in this section. The entire research process has brought to light a series of **final considerations** and **assumptions**, designed to bring order to the complexity of the factors examined and to summarise the main themes that will influence the agri-food sector going forward ***(Fig. 3.83)***. This is not merely a conclusion, but a reorganisation of the concepts that have emerged, necessary to understand the direction in which the entire system is moving and the pillars upon which contemporary innovation rests. These concluding considerations have been developed to serve as a **strategic bridge** to the next phase of the work, where these assumptions will become the tool for entering into the **analytical phase**. It is precisely at this stage that the findings derived from the analysis of all the factors identified during the research will be critically evaluated, testing their relevance and unpredictability. Clearly defining these assumptions makes it possible to filter the data collected and **highlight the key concepts** that characterise the current system and will characterise the future one. This approach ensures a smooth and coherent transition to the next section of the thesis, guaranteeing that every analytical assessment is firmly grounded in the evidence gathered throughout the process of mapping the agri-food sector.


Population growth
Climate change
Rise of invasive alien species (IAS)
Urbanisation
Globalisation
Well-being culture and the longevity economy
Global geopolitical instability
Escalating environmental awareness and regulatory pressure
Progressive loss of food biodiversity
Systemic inefficiencies of food loss and waste
Rise of circular bioeconomy models
Structural food insecurity and inequity
Diet-related health burden
Food safety and biosafety risks
Agricultural unsustainability and resource depletion
Geographic crop migration and latitudinal shifts
Agricultural labor crisis and aging workforce
Transition to regenerative and sustainable agriculture
Precision agriculture and smart farming
Rise of CEA technologies
NGTs crops and agricultural biotechnologies
Development of novel foods and alternative proteins
Development of advanced food manufacturing
Alternative protein demand
Growth of food delivery and takeaway platform
Rise of functional and personalised nutrition
Verified transparency and consumer empowerment
Rising demand for UPFs and convenience foods
Nutrigenomics and advanced nutritional science
Advancements in food experience technologies

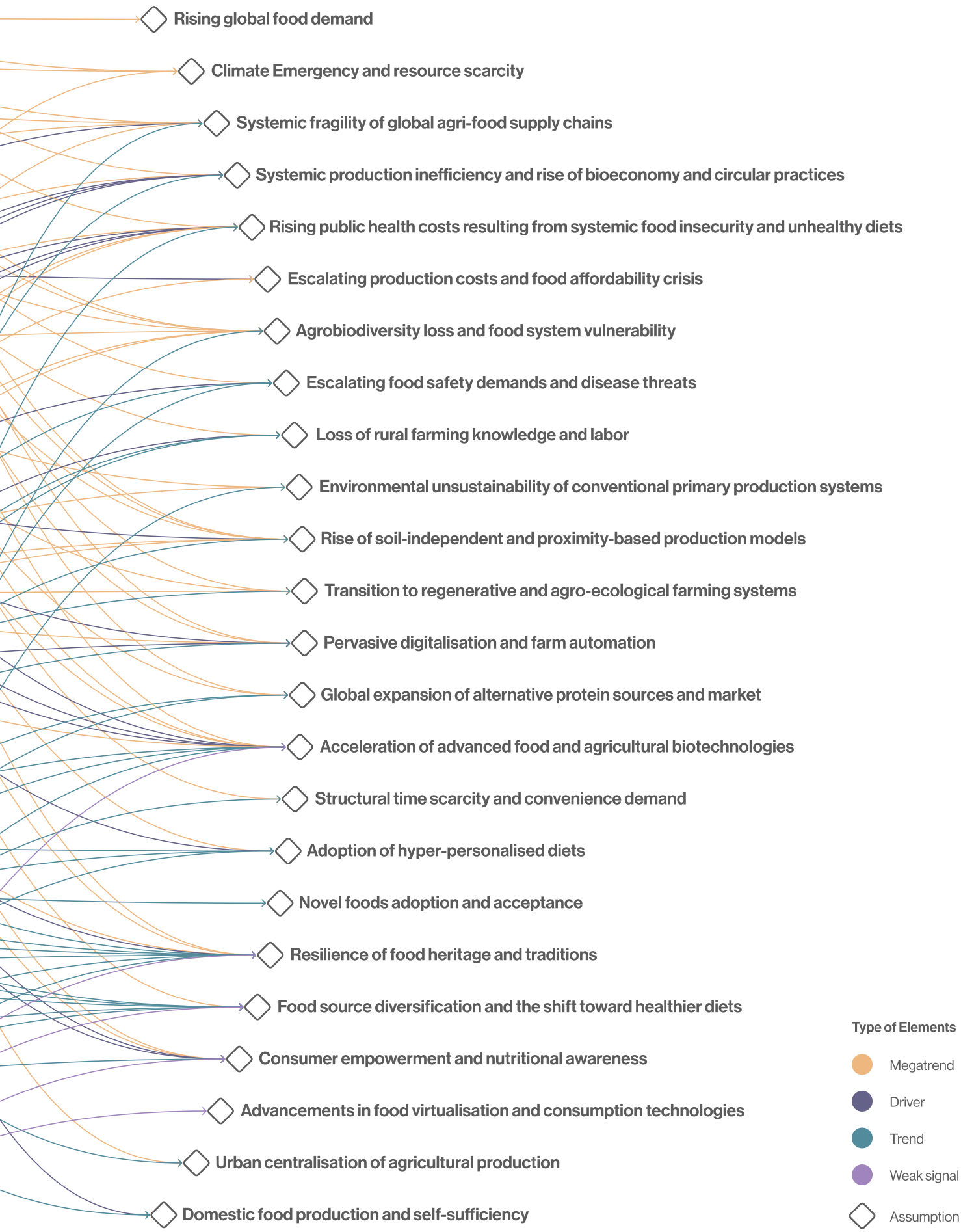
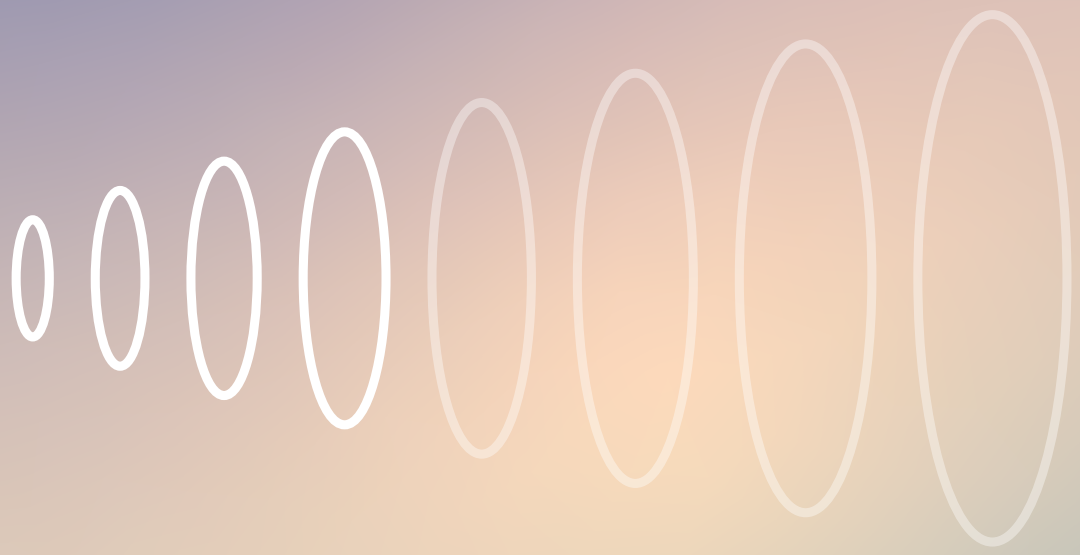


Fig. 3.83 Systemic Research Synthesis map.



04

Analysis

Analysis

The analysis phase follows the research phase and, as mentioned earlier, builds on the assumptions and final considerations identified at the conclusion of the previous phase. In particular, this activity is characterised by a single main phase known, according to the Copenhagen Strategic Foresight methodology, as the Dynamics of Change phase. In this step, the aim is to **classify and evaluate the various factors** that have emerged based on their **potential impact** and their **uncertainty**. This is a fundamental step for long-term strategic planning, as it allows the signals and drivers identified during the scanning phase to be transformed into a hierarchical framework. Through this evaluation, it is possible to distinguish between what is predictable and what is uncertain, providing a solid basis for interpreting the future trajectories of the agro-industrial system and guiding planning decisions in a systematic way.

4.1 Analysis Flow

DYNAMICS OF CHANGE

The Dynamics of Change phase is essential for **critically evaluating the factors** previously identified, with the aim of prioritising those that are most crucial for the future evolution of the system. This step makes it possible to distinguish between elements of greater strategic importance and those of secondary importance, focusing the analysis on the **dynamics that will truly shape the agro-industrial sector**. To put this classification into practice, the **Impact/Uncertainty Matrix** is used, a tool that allows each driver to be mapped according to its potential impact and the degree of uncertainty associated with it.

IMPACT/UNCERTAINTY MATRIX

The Impact/Uncertainty Matrix is the **analytical tool** chosen to evaluate and **visualise all the factors analysed** on a matrix composed of two perpendicular axes. The vertical axis measures the ***degree of potential impact*** these factors have on the system, while the horizontal axis represents the **level of uncertainty** regarding the likelihood that the analysed elements will actually occur in the future. To better understand how this tool works, the matrix is divided into **three main areas** or quadrants that allow drivers to be classified based on their strategic relevance:

- ***THE LOWER QUADRANTS (Low-impact):*** these contain factors with a low potential impact. These are **secondary drivers** which, for the time being, can be disregarded for the purposes of strategic foresight. However, they require constant monitoring, as over time they may evolve and come to have a greater impact within the system.

- ***THE TOP-LEFT QUADRANT (High-impact/low-uncertainty):*** contains factors characterised by high impact and low uncertainty. These represent relatively certain elements, genuine established trends that **must be closely monitored** and on which immediate action should be taken in current strategic planning.

- ***THE TOP-RIGHT QUADRANT (High-impact/high-uncertainty):*** identifies critical uncertainties. These are the drivers that possess both high impact and high uncertainty, acting as the **main drivers of change** for the various possible futures. It is precisely on these elements that long-term planning focuses in order to anticipate and **prepare for alternative scenarios**.

4.2 Assessment of Factors Driving Change

The assessment of the identified factors is carried out by analysing their scope of impact and the associated degree of uncertainty. To ensure this assessment is as robust as possible, **three specific criteria** have been defined for each of the two reference parameters. The final score determining the **position of each driver on the matrix** is therefore derived from the average of the three selected criteria. This method allows each element to be weighted with greater accuracy, transforming the qualitative analysis into a numerical value used for graphical positioning on the matrix.

Impact Assessment

Impact scope defines the extent of change that a factor can trigger within the system. In an effort to measure this more objectively, three criteria have been identified that **analyse the influence of each**

driver from different perspectives, enabling us to understand how significantly the current balance might be altered.

1. *SYSTEMIC SCOPE:* This criterion indicates the **potential scale of the impact** on the system. An assessment is made as to whether the effect of the driver is confined to a single stage or extends to the entire agro-industrial system, or whether, given its strength, it is capable of spreading beyond it, thereby affecting other systems as well.

2. *SURVIVAL CENTRALITY:* This criterion reflects **the extent to which the impact is decisive on a scale** related to the **survival of the population**. A factor that poses a direct threat to the survival of humanity is awarded the maximum score, considering the vital significance of the challenge it creates.

3. *DISRUPTIVE POTENTIAL:* This criterion refers to an element's ability to radically change the rules of the system. The assessment focuses on the extent to which **the impact can break with existing models**, profoundly **transforming the way the system operates**.

Uncertainty Assessment

The assessment of the degree of uncertainty aims to measure the predictability of the factors analysed, i.e. the probability that they will actually materialise over time. Here too, **three specific criteria** have been identified to quantify this aspect, making it possible to assess the robustness of each driver and the nature of its future developments using the following parameters:

1. *DIRECTIONAL VOLATILITY:* This criterion analyses the **volatility of a factor's trajectory** to assess the extent to which the driver is focused and certain in its course, or whether, on the contrary, its future development is unpredictable and characterised by a volatile trajectory.

2. *SIGNAL IMMATURITY:* This criterion assesses the **consolidation of the evidence over time**. It examines whether the driver has now been established and is supported by **collective knowledge** and a body of **scientific literature**, or whether it is a

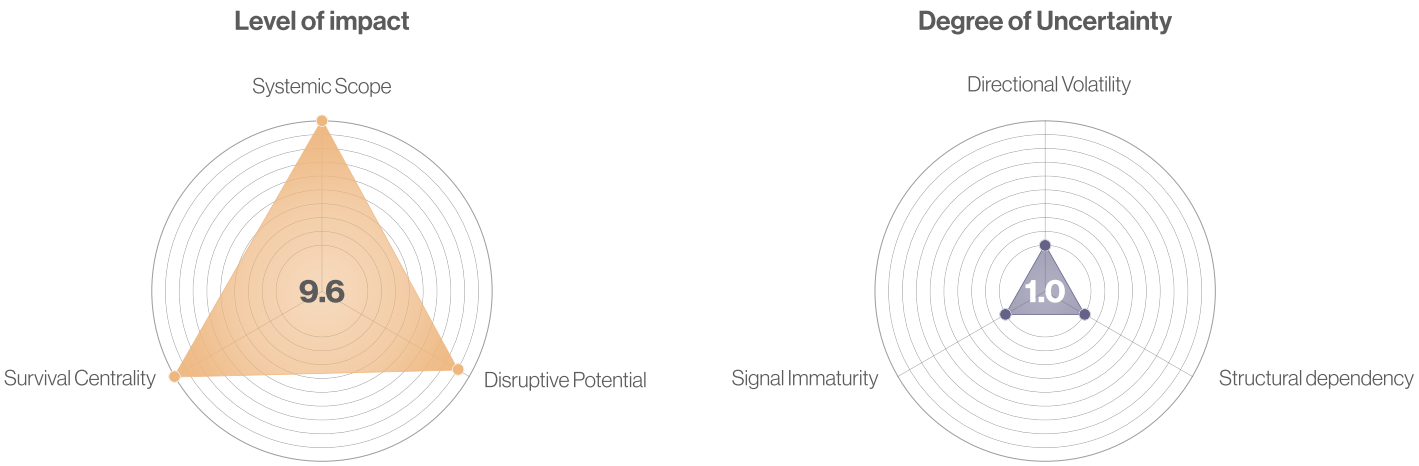
relatively new factor, with little information or in-depth analysis available.

3. ***STRUCTURAL DEPENDENCY:*** This criterion represents the degree to which the signal's trajectory depends on other structural aspects of the system. It assesses whether the factor can manifest itself independently or whether its occurrence is contingent upon the alignment of various external variables, making it less likely to occur due to structural and systemic constraints.

Factors Under Assessment

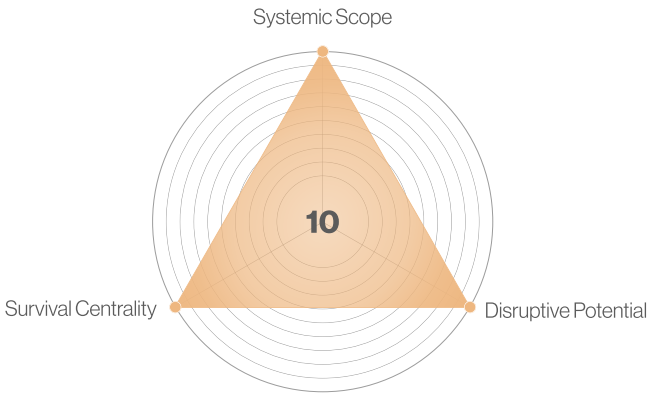
The factors selected for assessment on the impact and uncertainty scale reflect the final assumptions identified during the research phase. Each of these elements is assigned a **specific score** based on the criteria identified, thereby enabling the concluding reflections of the scan to be re-examined from a strategic perspective. Listed below are the drivers that will be analysed in detail to determine their position on the matrix and understand their actual influence on the future of the agri-food system.

1 - Rising global food demand

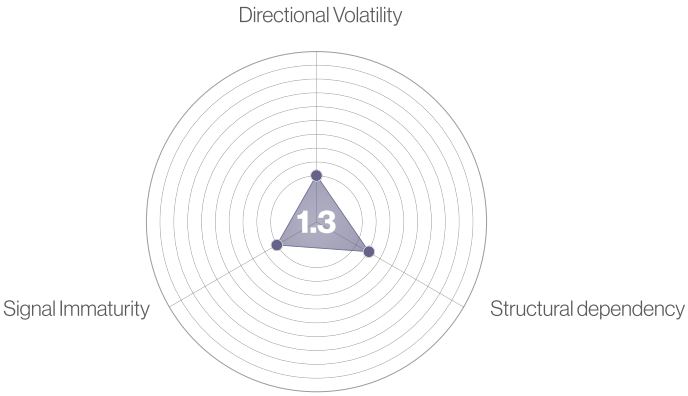


2 - Climate emergency and resource scarcity

Level of impact

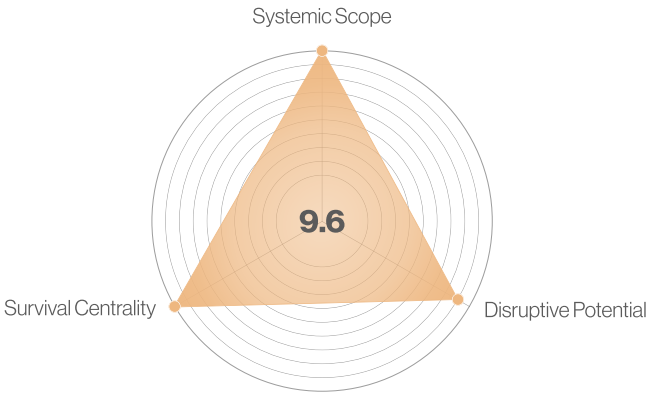


Degree of Uncertainty

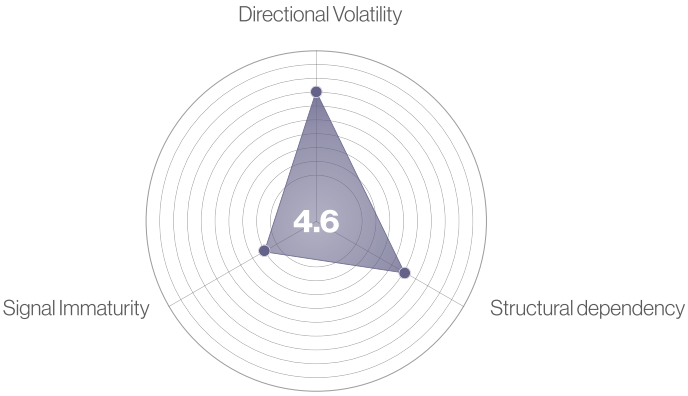


3 - Systemic fragility of global agri-food supply chains to shocks

Level of impact

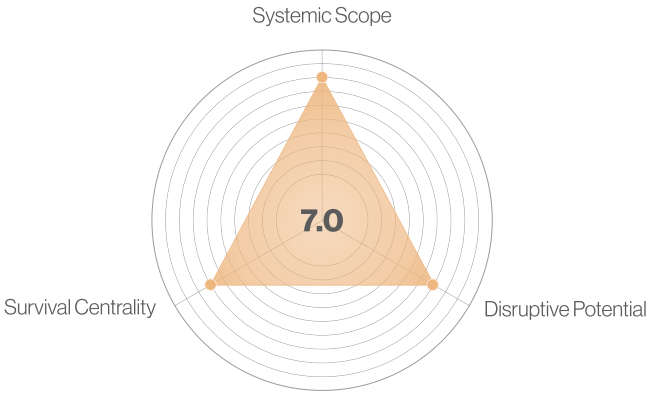


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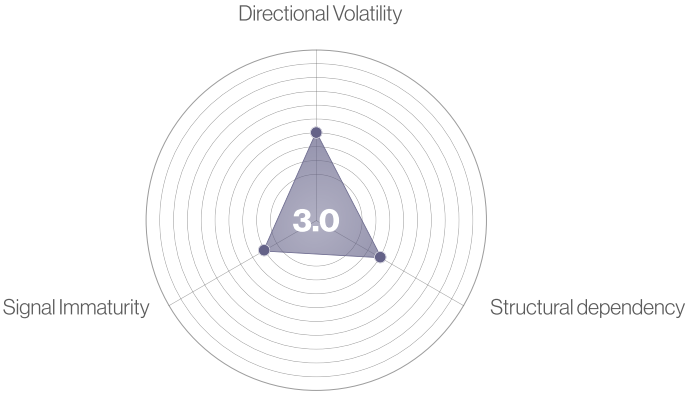


4 - Systemic production inefficiency and rise of bioeconomy and circular practices

Level of impact

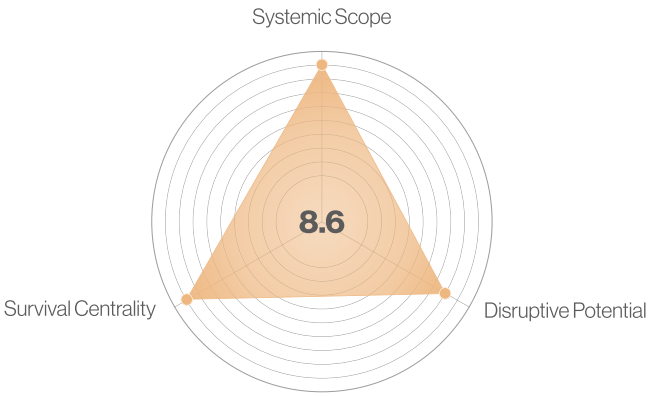


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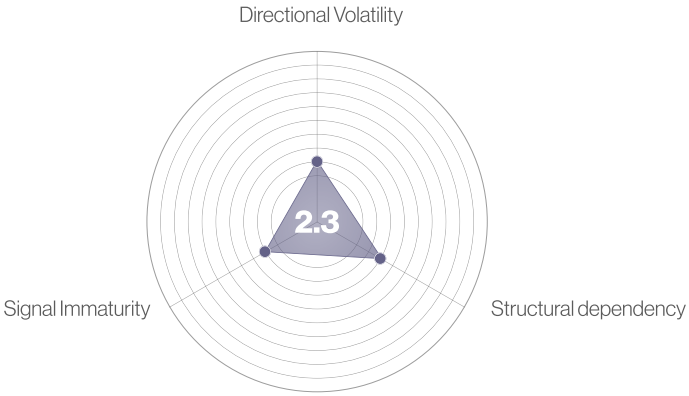


5 - Rising public health costs resulting from systemic food insecurity and unhealthy diets

Level of impact

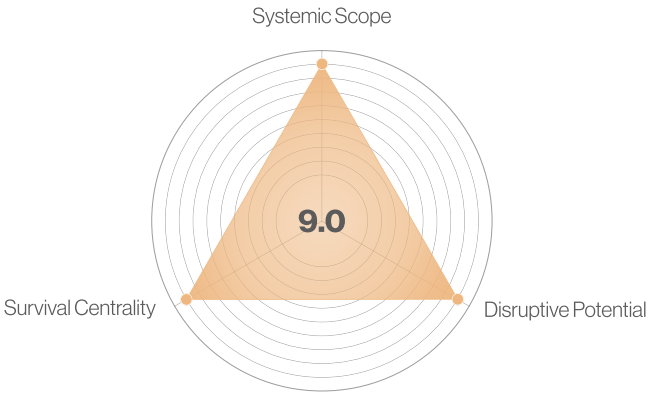


Degree of Uncertainty

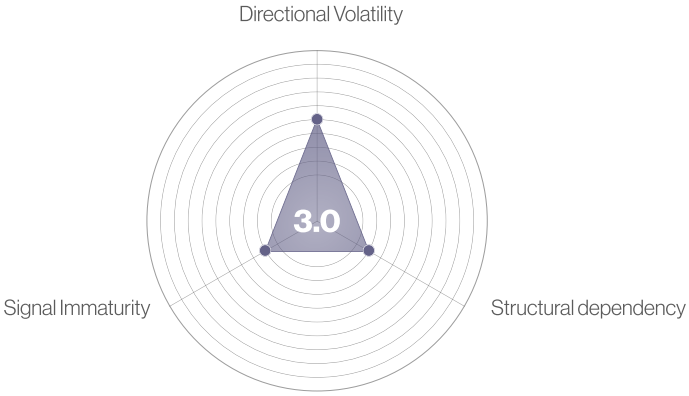


6 - Escalating production costs and food affordability crisis

Level of impact

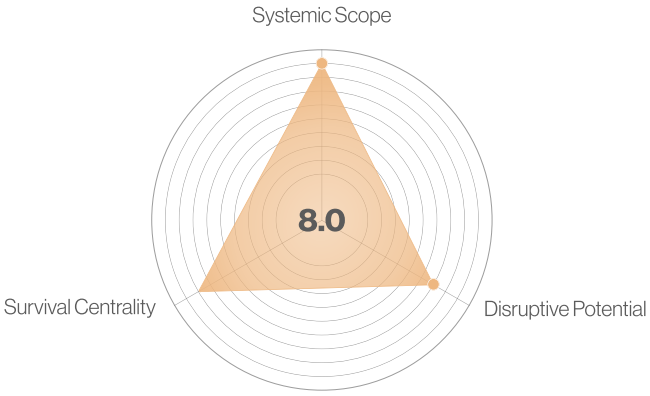


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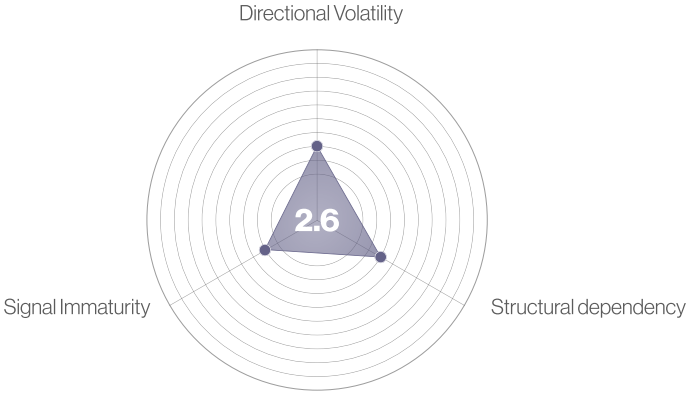


7 - Agrobiodiversity loss and food system vulnerability

Level of impact

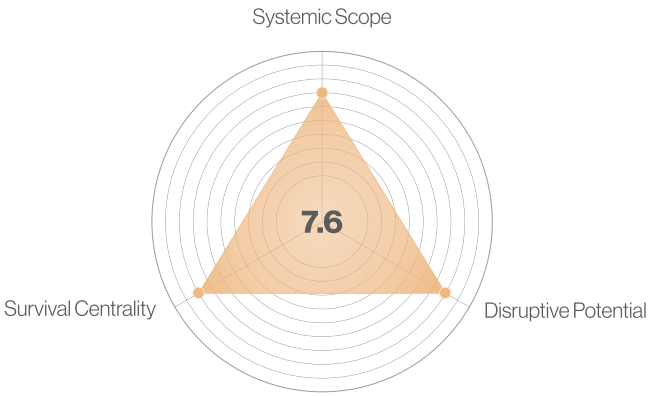


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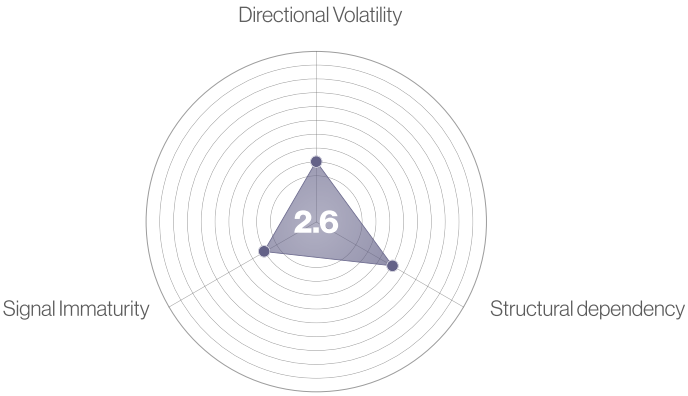


8 - Escalating food safety demands and disease threats

Level of impact

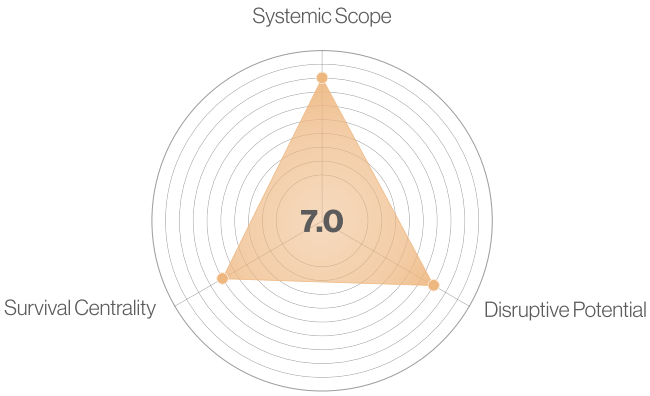


Degree of Uncertainty

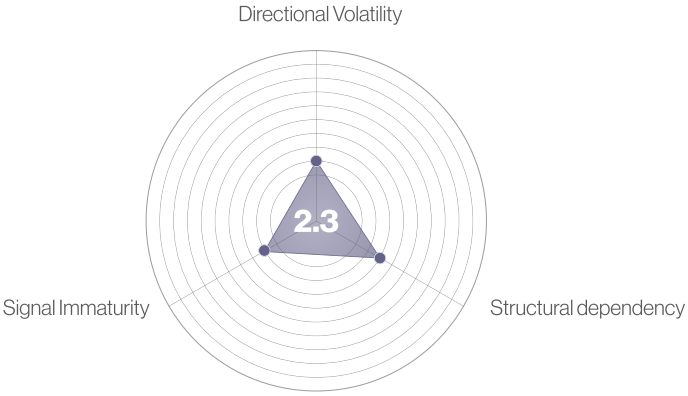


9 - Loss of rural farming knowledge and labor

Level of impact

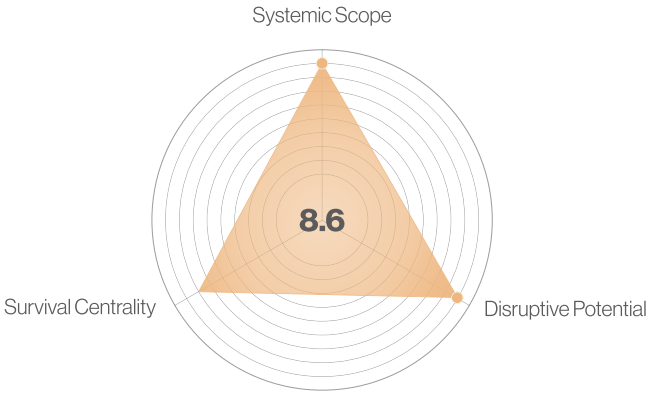


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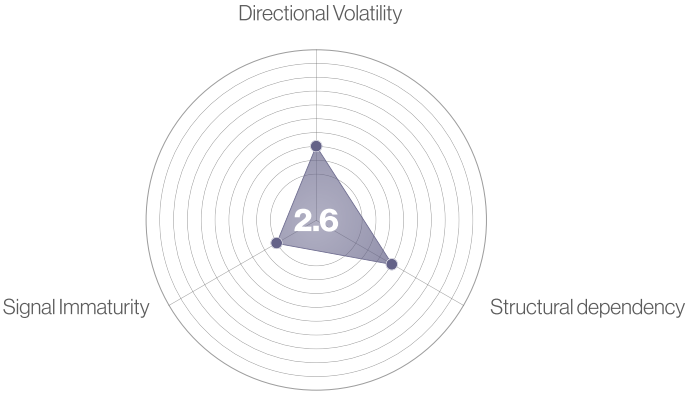


10 - Environmental unsustainability of conventional primary production systems

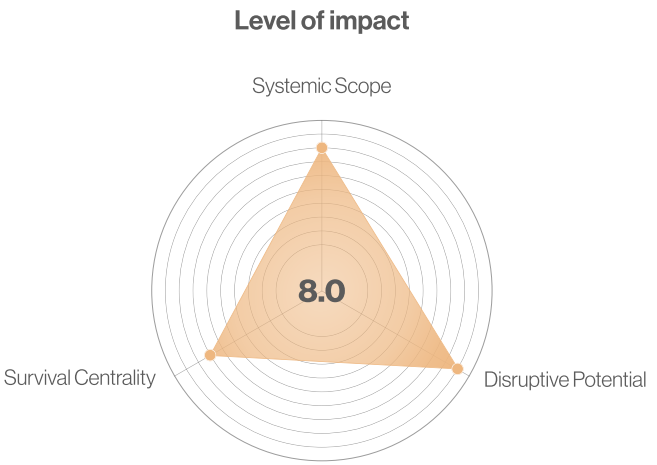
Level of impact

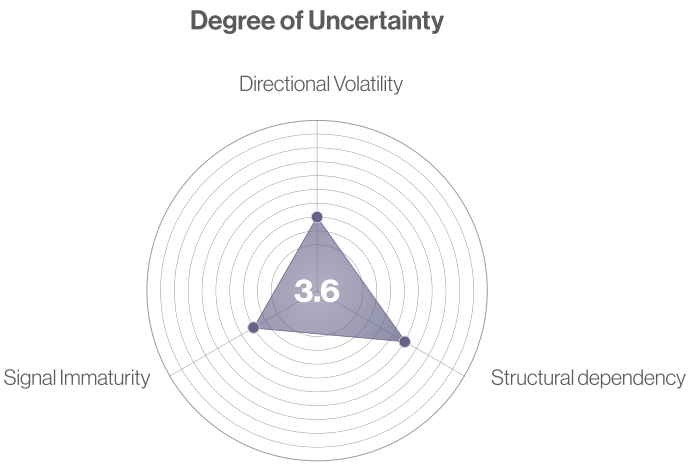


Degree of Uncertainty

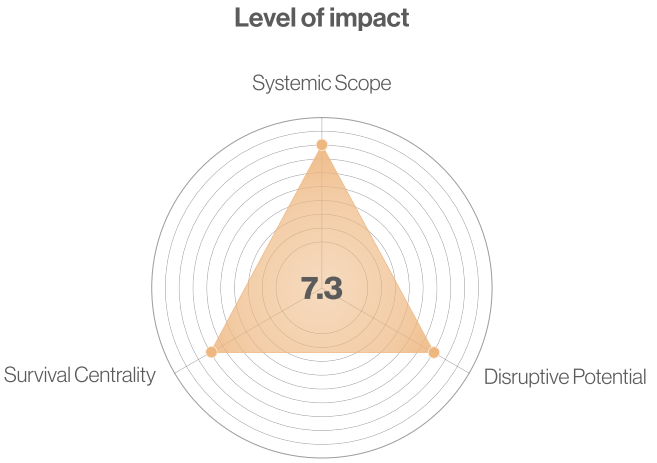


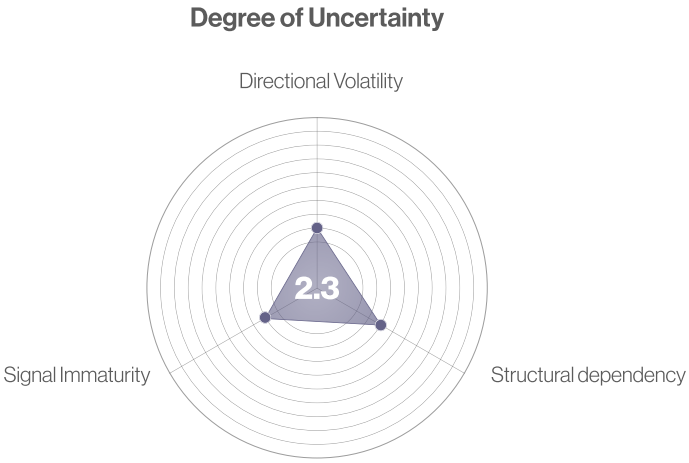
11 - Rise of soil-independent and proximity-based production models



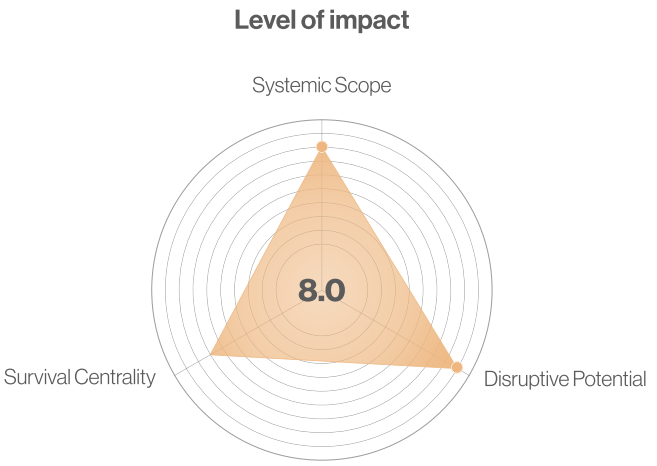


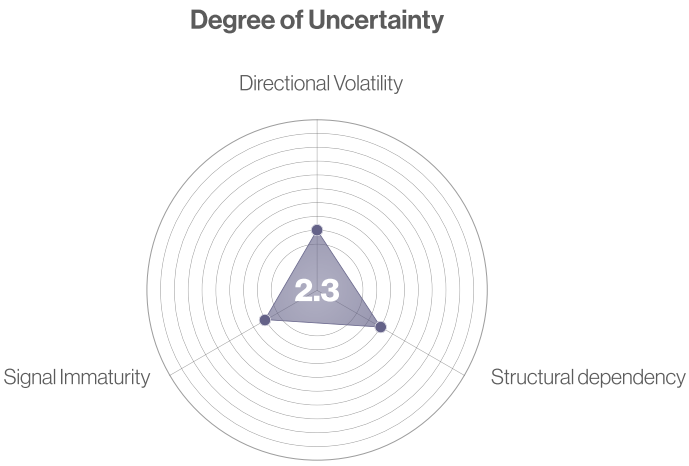
12 - Transition to regenerative and agro-ecological farming systems



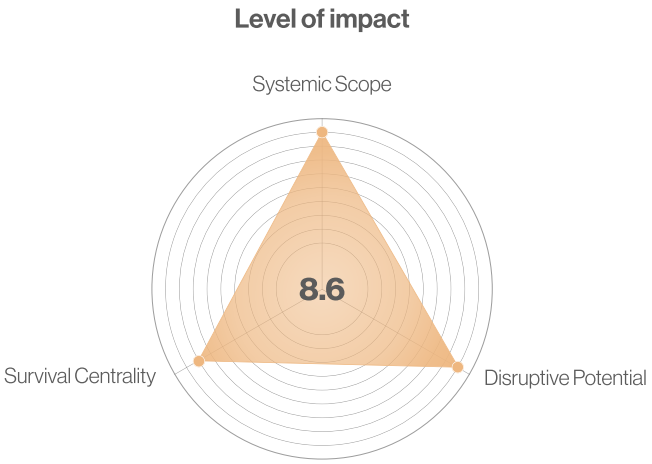


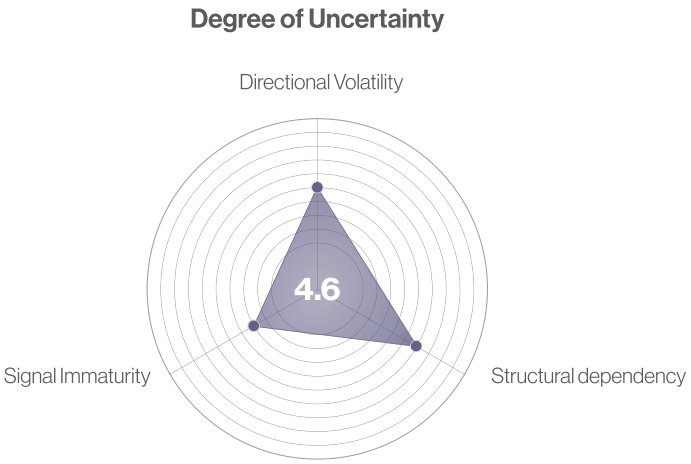
13 - Pervasive digitalisation and farm automation



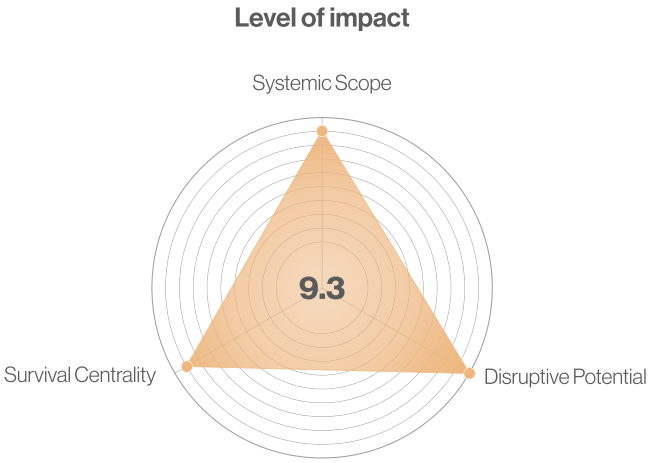


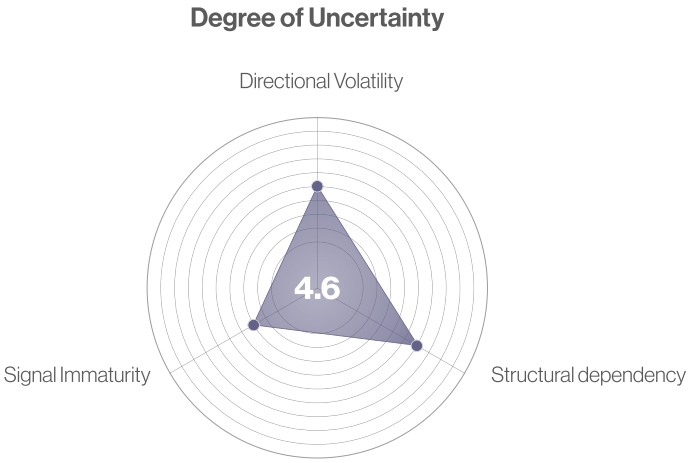
14 - Global expansion of alternative protein sources and market



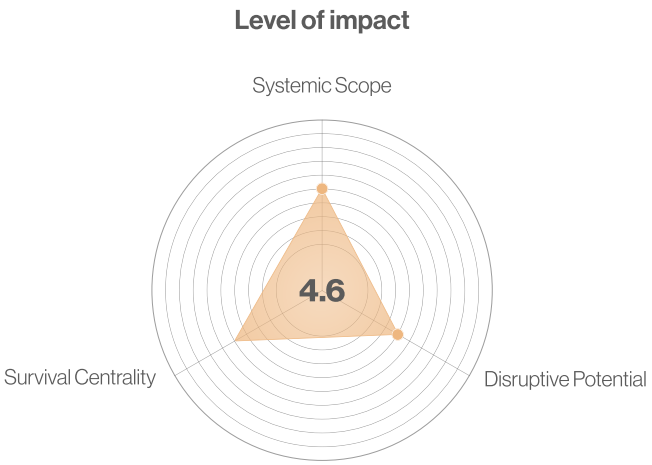


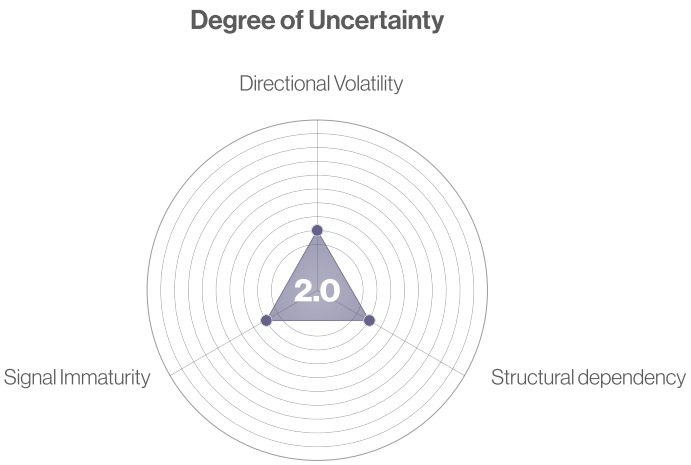
15 - Acceleration of advanced food and agricultural biotechnologies





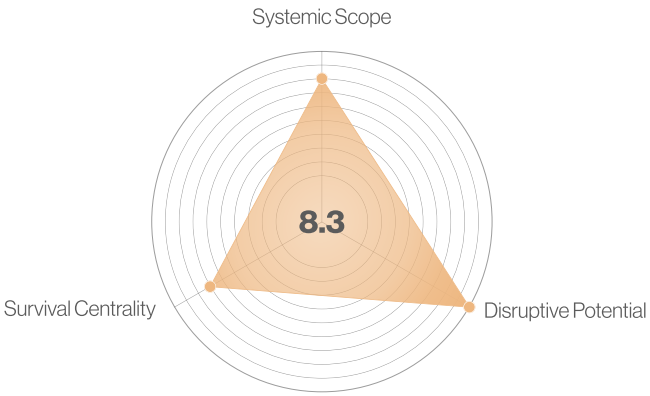
16 - Structural time scarcity and convenience demand



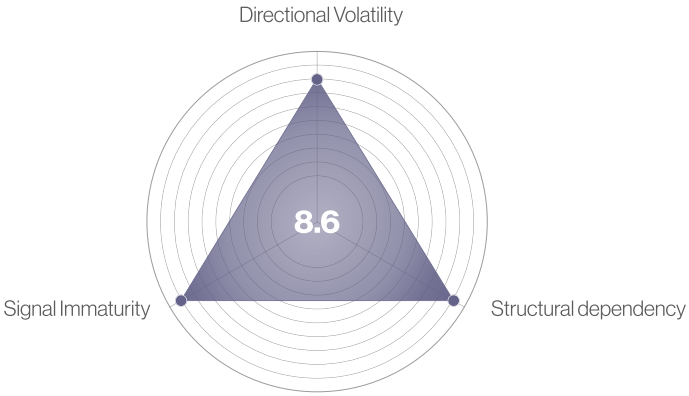


17 - Adoption of hyper-personalised diets

Level of impact

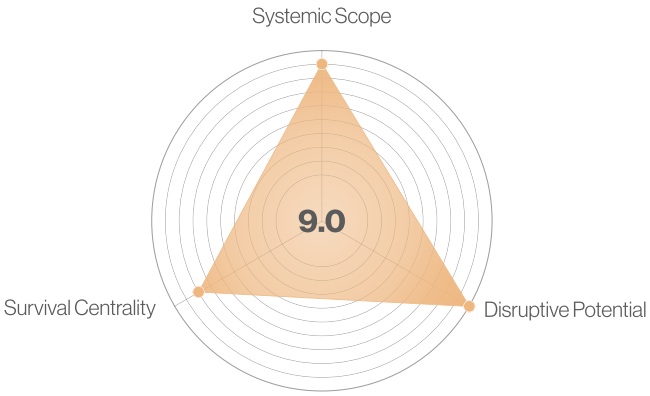


Degree of Uncertainty

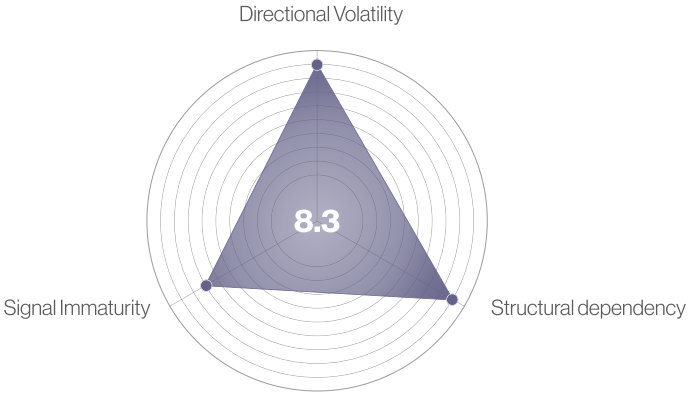


18 - Novel foods adoption and acceptance

Level of impact

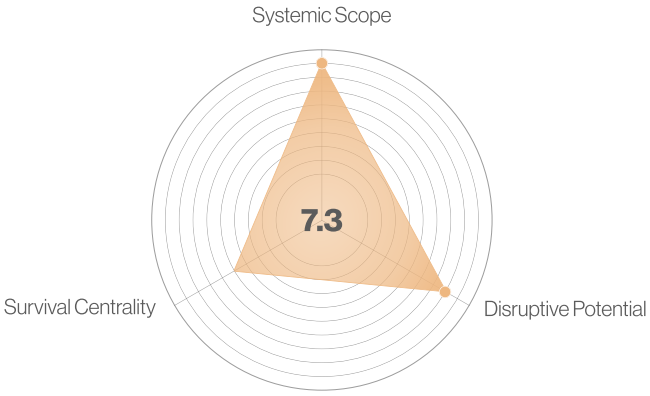


Degree of Uncertainty

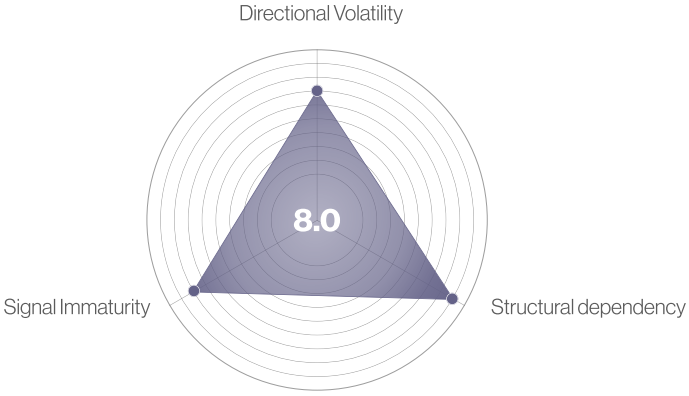


19 - Resilience of food heritage and traditions

Level of impact

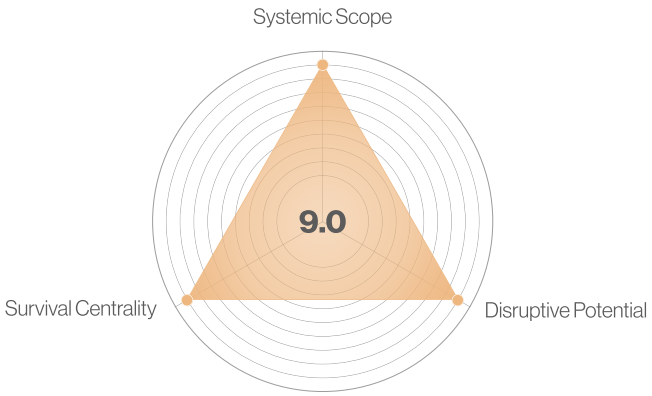


Degree of Uncertainty

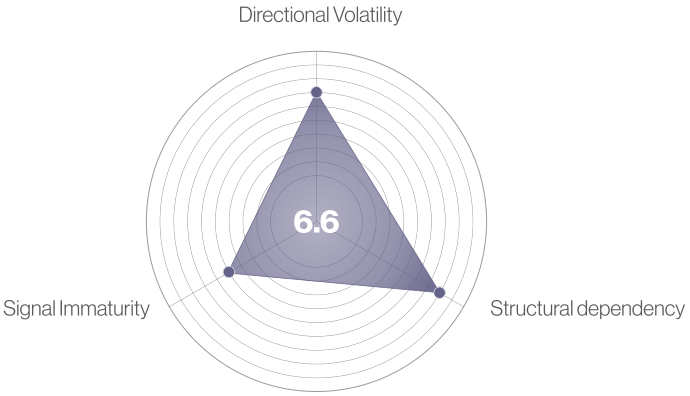


20 - Food source diversification and the shift toward healthier diets

Level of impact

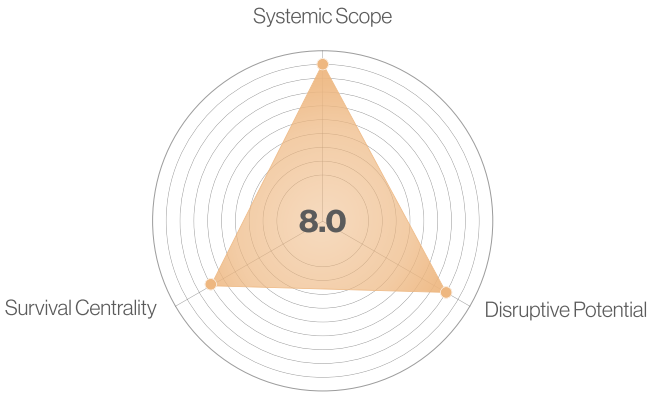


Degree of Uncertainty

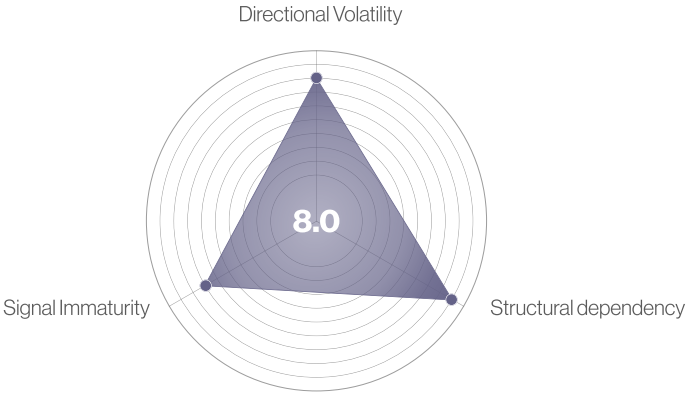


21 - Consumer empowerment and nutritional awareness

Level of impact

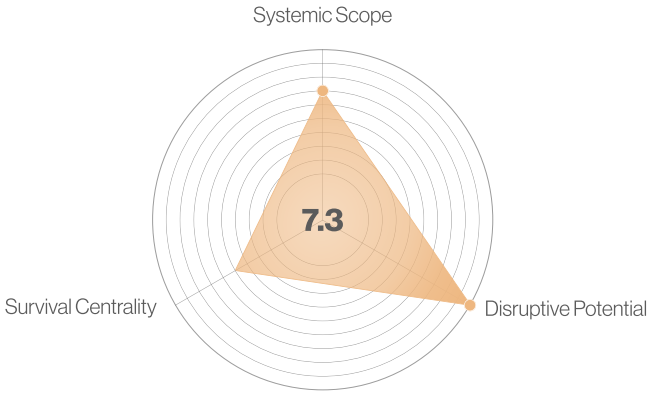


Degree of Uncertainty

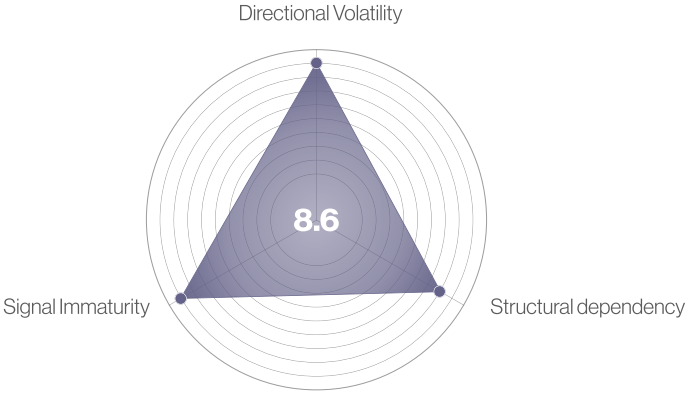


22 - Advancements in food virtualisation and consumption technologies

Level of impact

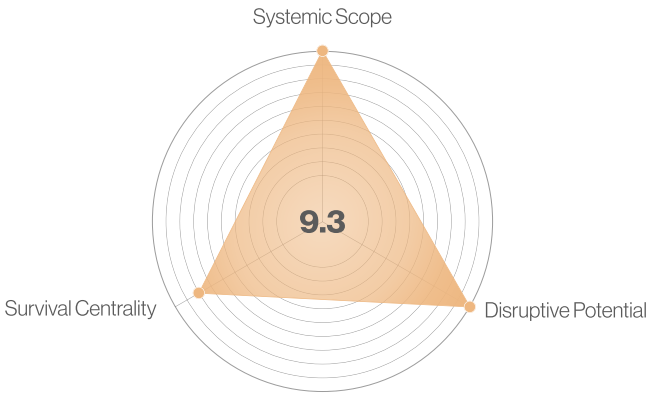


Degree of Uncertainty

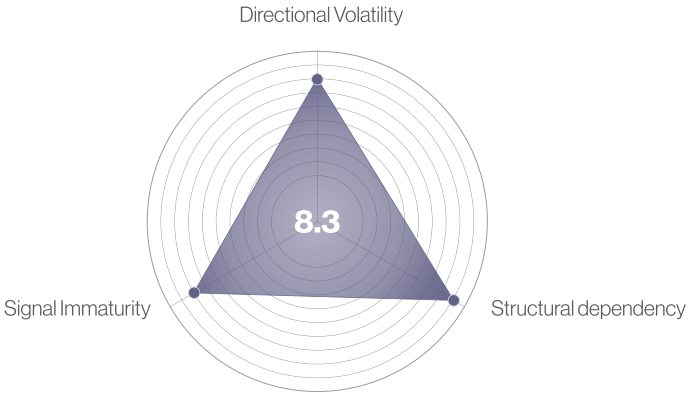


23 - Urban centralisation of agricultural production

Level of impact

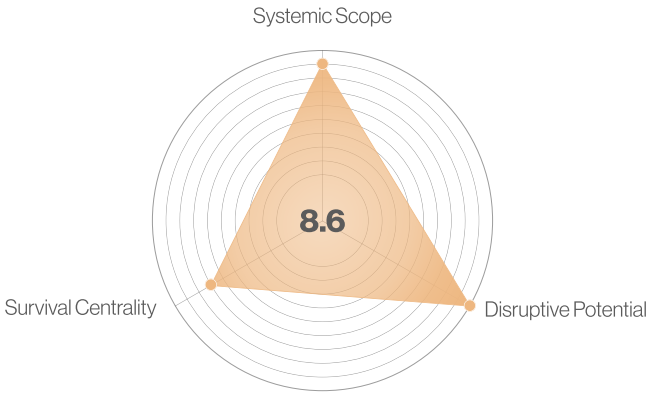


Degree of Uncertainty

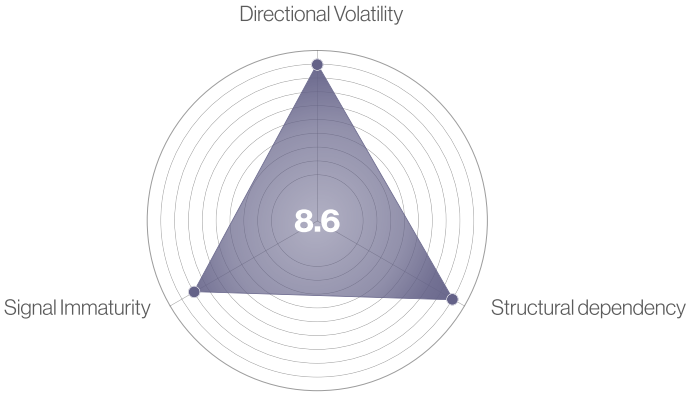


24 - Domestic food production and self-sufficiency

Level of impact



Degree of Uncertainty



4.3 Impact-Uncertainty Matrix

To build the Impact/Uncertainty Matrix ***(Fig. 4.1)***, the scores assigned to each factor were used, both in terms of the level of potential impact and the degree of uncertainty, in order to determine their exact position. Within this matrix, **three main categories of drivers** can be distinguished. In the lower part of the matrix, from left to right, there are the **secondary drivers**. These are factors that are not particularly relevant in the construction of scenarios, as they do not have the potential to profoundly define the system. Although they may be more or less certain, their impact is considered marginal and, for this reason, they are generally not included in the formulation of future scenarios. In the top left-hand corner are the so-called **high-impact drivers**: those certain and obvious elements that will undoubtedly shape the future of the system over time. These factors must necessarily be taken into account and are fundamental to the construction of any future scenario precisely because of their significant influence and certainty. Finally, in the top right-hand corner are the **critical uncertainties**. These are the elements of high impact and high uncertainty, the critical factors whose trajectory is more difficult to predict, but which have the potential to radically change the rules of the game within the system. These elements are crucial for **constructing future scenarios**, as they represent the most useful tools for imagining non-mainstream and less common scenarios, capable o**f provoking reflection and raising greater awareness within society**. The analysis carried out, and in particular the identification of critical uncertainties, forms the fundamental basis for the subsequent envisioning phase. Using what has been learnt and analysed so far, it will be possible to envision and construct **coherent future scenarios** for the agri-food system, anticipating the development of these factors and their possible trajectories over time.

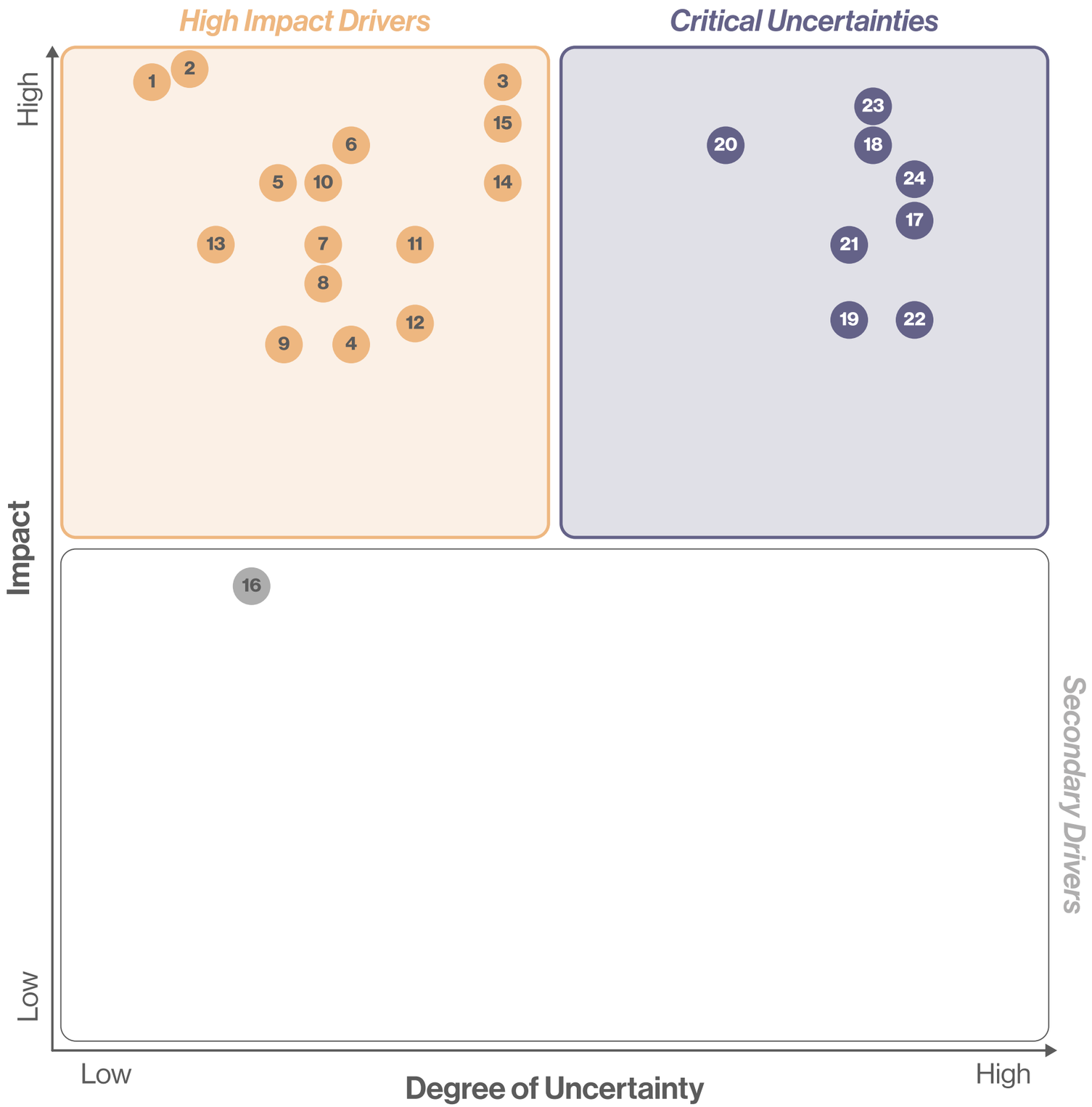
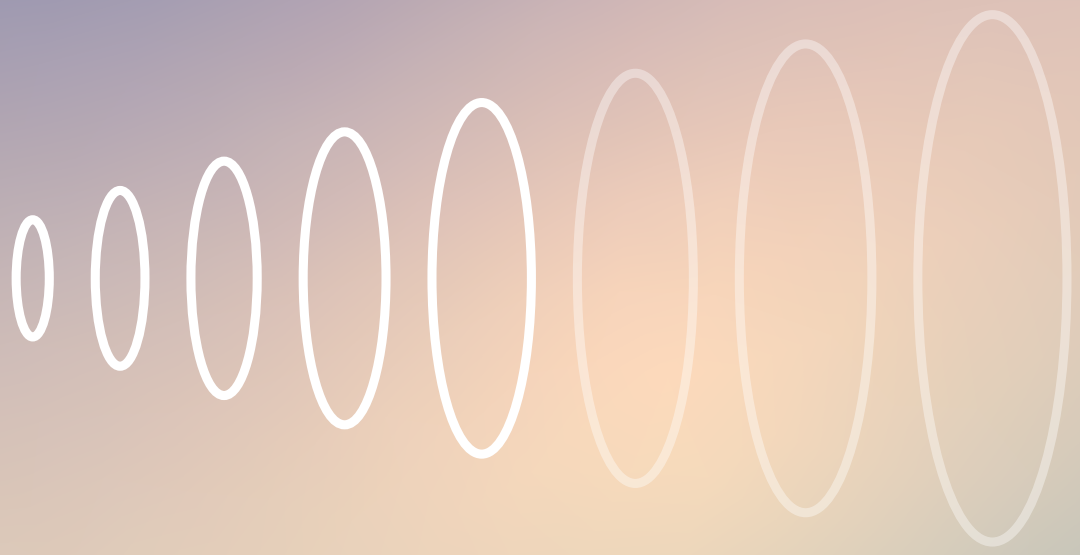


Fig. 4.1 Impact/Uncertainty Matrix.



05

Envisioning

Envisioning

The Envisioning phase continues the work of the two previous phases, starting from the **Critical Uncertainties** identified in the Impact/Uncertainty matrix. The aim of this activity is to **develop future scenarios**, using the information gathered during the research and analysis stages. According to the Copenhagen Strategic Foresight methodology, this phase is defined as **Alternative Futures** and is divided into **two complementary stages**. Initially, the process involves an analytical phase in which **strategic combinations of critical uncertainties** are sought to develop potential scenarios. This is subsequently followed by a **narrative phase** which, through the use of the **What if Scenarios tool**, allowed for the development of **narrative storyconcepts** capable of giving substance to the identified scenarios, making them more comprehensible and tangible. The chapter concludes with the application of the **Futures Cone**, a fundamental tool for critically examining the manifestation of these visions and classifying them according to their nature: probable, plausible or simply possible.

5.1 Envisioning Flow

ALTERNATIVE FUTURES

In the alternative futures phase, creativity comes into play, enabling participants to **imagine possible future trajectories for the agri-food sector** based on the various insights gained previously. The aim, as mentioned, is to construct and describe possible alternative scenarios for the agri-food system that are consistent with the research and analysis carried out. To put this exploration into practice, **three main tools** are used:

2x2 SCENARIOS MATRIX

This method, which is also drawn from the CIFS methodology, is one of the key tools for **stimulating creativity** and **developing future scenarios**. The tool begins with critical uncertainties, using them as two independent axes at the ends of which the respective polarities are placed. The intersection of these axes generates four distinct quadrants, defined as **"scenario spaces"**. This structure serves to stimulate creative associations, allowing us to imagine possible developments of the agro-industrial system based on the specific combinations that emerge from each quadrant. The aim is to ensure

that the visions produced are structurally distinct from one another and logically consistent, providing a solid basis for exploring alternative futures.

WHAT IF SCENARIOS

The second tool used is that of "What-if Scenarios", which is essential for giving voice and form to the essence of the concepts that emerged from the 2x2 matrix. Through brief speculative narratives, the aim is to create a sense of the essence of each scenario. Starting with the question **"What if...?"**, narratives are developed that help to make the implications of critical uncertainties tangible, transforming analytical data into **immersive and comprehensible visions**. This approach serves not only to describe a possible future, but to evoke it, allowing us to understand its impact and the potential change it might generates.

THE FUTURE CONE

The final tool used in this fifth phase is the Futures Cone, which is essential for visually representing the variety of alternative futures. Introduced in 1994 by futurists **Trevor Hancock** and **Clement Bezold**, the cone draws on the taxonomy developed by Norman Henchey in 1978 to distinguish between **possible**, **plausible** and **probable futures** (Boldrini, 2023). Thanks to this classification, it is possible to graphically map the scope of potential futures and critically examine their nature and the likelihood of such scenarios actually materialising.

5.2 Development of 2x2 Matrices and Storyconcepts

Starting from the eight critical uncertainties identified in the previous Impact/Uncertainty matrix analysis, five 2x2 matrices were developed. This process enabled the **systematic intersection of pairs of critical uncertainties** with the aim of generating various trajectories and future scenarios for the agri-food system. The relevant **storyconcepts** were included in each matrix, ensuring that at least one was present in every scheme. The positioning of each concept within the quadrants follows a logical assessment of its relevance to the polarities expressed by the reference axes. The spatial placement therefore reflects the degree of influence of the analysed variables on the proposed narrative, validating the consistency

between the identified uncertainty and the imagined scenario. At the end of the presentation of each matrix, detailed sheets on the individual storyconcepts are provided to offer a detailed overview of the dynamics of each emerging vision.

Matrix 1

The first matrix ***(Fig. 5.1)*** emerges from the intersection of Consumer empowerment and nutritional awareness and Food source diversification and the shift towards healthier diets. The aim of this analysis is to explore the tension between **individual awareness** and the actual availability of **dietary biodiversity** and **access to healthier diets**, seeking to understand whether the transition towards healthier diets is driven by an active consumer choice or by a necessity imposed by the system. Relating these two variables allows us to visualise scenarios in which human health and the health of the planet converge through knowledge. From this reflection emerged the storyconcept **"The Regenerative Menu"**, strategically positioned in the top-right quadrant. In this space, characterised by high levels of empowerment and nutritional awareness, there is a strong diversification of food sources, where the consumer does not merely suffer change but governs it, transforming the act of eating into a conscious gesture of care for the environment.

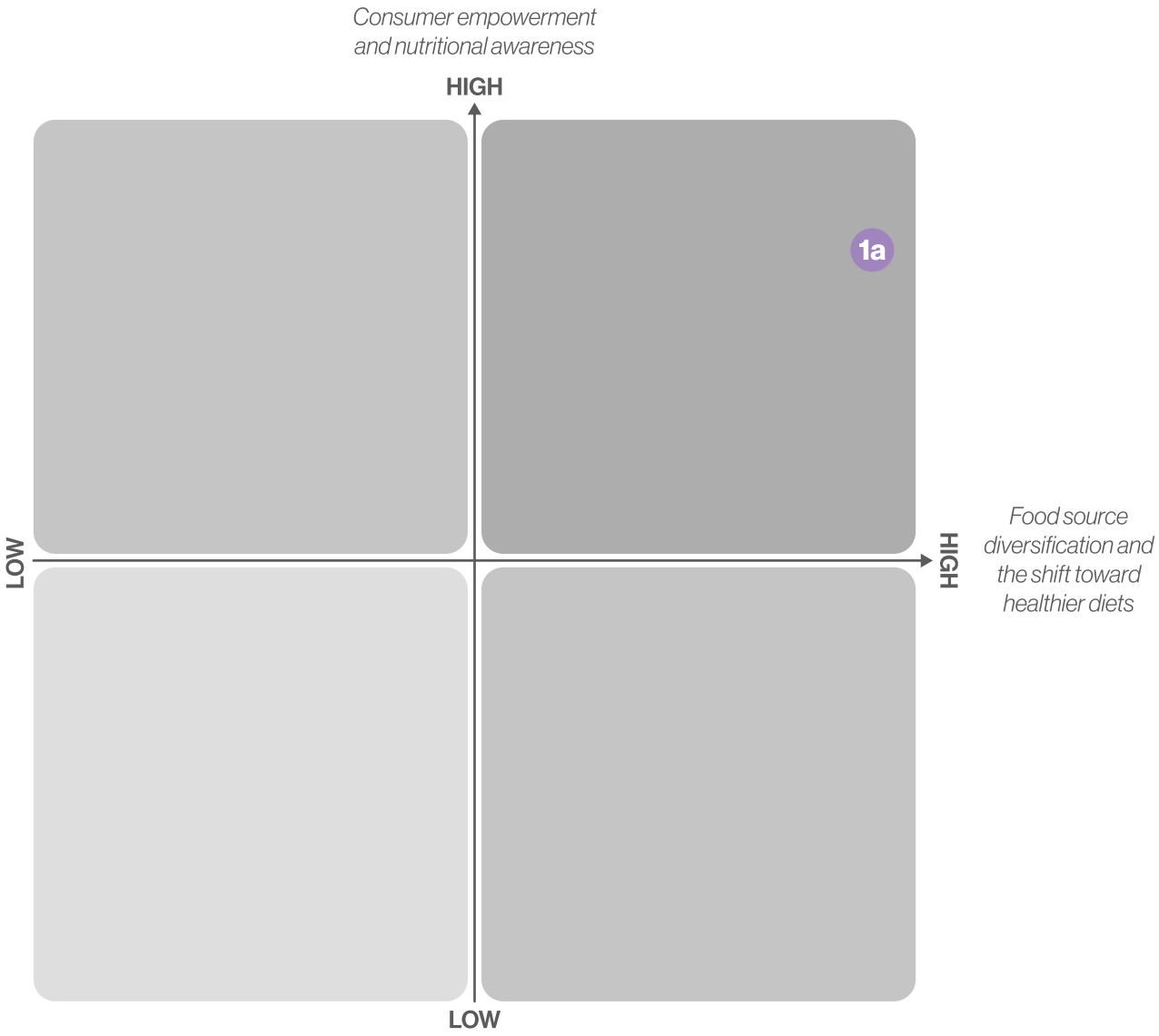


Fig. 5.1 Matrix 1.

/Storyconcept 1a

The Regenerative Menu

What if the solution to saving our food system wasn't in new labs, but in those species we currently fight against or discard?

Storyconcept:
With industrial monocultures causing progressive environmental degradation and the loss of biodiversity, we may find ourselves forced to seek a solution by embracing what we have previously discarded or fought against. Imagine if a company decided to map and make the most of **invasive and underutilised species**, transforming them from ecological problems into **valuable ingredients for our tables**. This service would make everyday consumption an act of dual care, allowing ecosystems to be restored through the targeted removal of harmful species while ensuring a radically more **varied and healthy diet** for anyone wishing to embrace this change.

Keywords:
#Invasive species valorisation
#Ecosystem restoration
#Dietary diversification


Scopri Specie Selvatiche!
Crisalide di Punteruolo
Rovo Invasivo
Erba Azolla
Trova Vicino a te!
Ricetta Consigliata
Frittelle di Azolla
Facile e Gustosa!
Azolla Selvatica
Farina & Uova
Erbe Aromatiche
RICETTA DEL GIORNO
Pasta con Canapa d'Acqua
Zuppa di Cardo Selvatico
Riscopri Il Gusto Selvatico!

Matrix 2

The second matrix ***(Fig. 5.2)*** is based on the intersection of domestic production and self-sufficiency with the urban centralisation of agricultural production, aiming to explore possible scenarios for **decentralisation** capable of enhancing the **resilience of the agri-food system** in the face of climate shocks and **geopolitical instability**. This analytical framework allows us to reflect on the **tension between rural heritage and mass urbanisation**, outlining models of food independence that provide a concrete response to the fragility of global supply chains. Within this framework, the **"The Prosumer Biolabs"** scenario is situated in the top right quadrant, representing the highest degree of urban integration in which domestic self-sufficiency transforms every home into an autonomous and resilient production unit. In parallel, **"The Tamagotchi Farms"** is positioned in the third quadrant, describing a model which, whilst guaranteeing medium-to-high decision-making autonomy, keeps physical production detached from the urban context, utilising remote automation technologies to monitor and cultivate now depopulated rural areas.

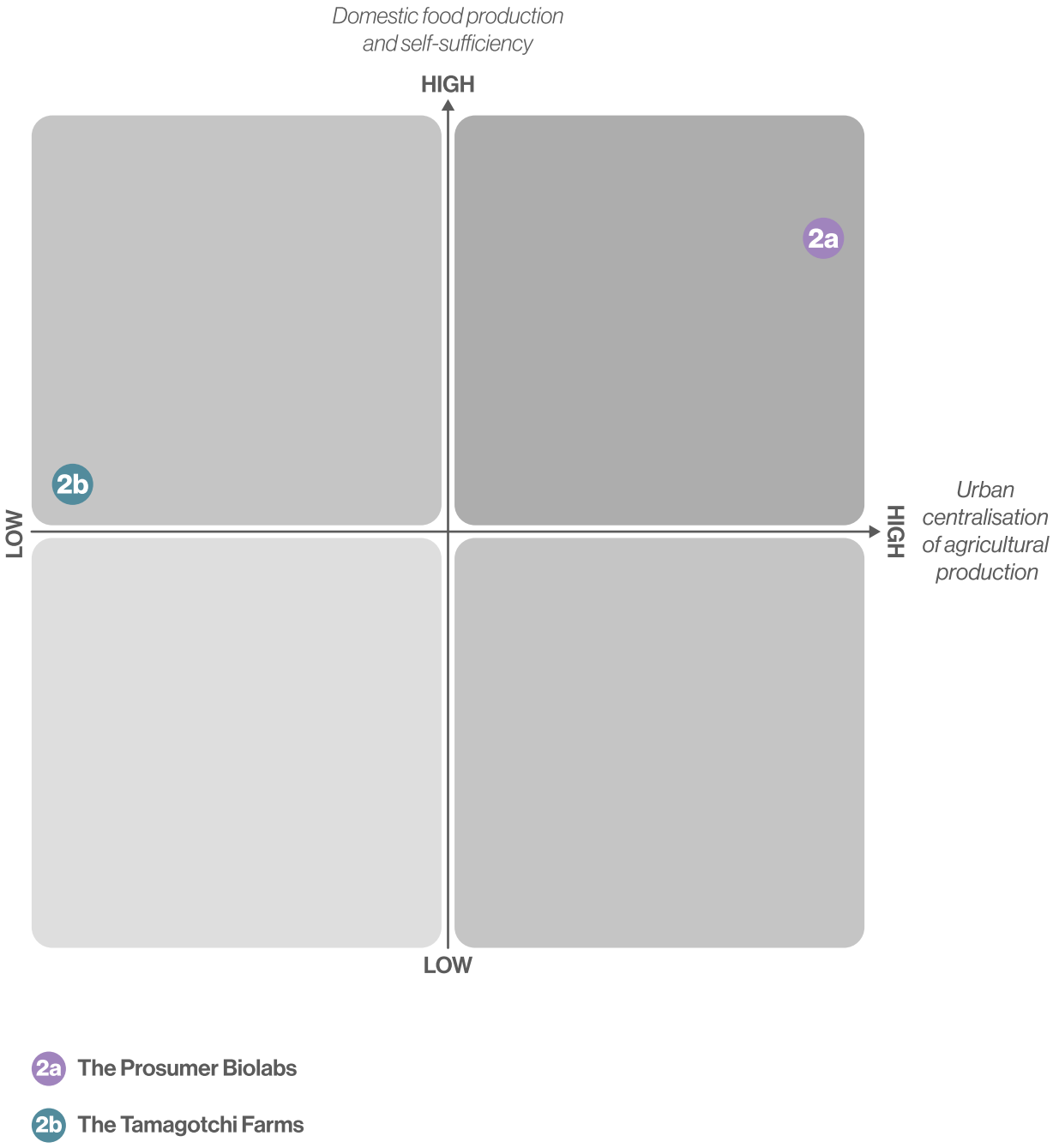


Fig. 5.2 Matrix 2.

/Storyconcept 2a

The Prosumer Biolabs

What if, in the face of a total collapse of trust in industrial supply chains, home-grown food were to become the most reliable form of currency in a decentralised, peer-to-peer economy?

Storyconcept:
The convergence of **global market instability** and growing **mistrust of industrial supply chains**, perceived as unreliable and saturated with ultra-processed products, has driven people to seek complete food and logistical independence. In this landscape of widespread self-sufficiency, access to food variety is managed by a new digital infrastructure that acts as a portfolio of **"biological assets"**. This is not traditional e-commerce, but a value management system that certifies, quotas and **trades domestic surpluses as a secure currency**. This platform enables a horizontal distribution network, allowing users to convert their organic output into purchasing power and ensuring subsistence through a **peer-to-peer market** free from the logic of large-scale distribution.

Keywords:
#Peer-to-Peer trading
#Biological assets
#Decentralised distribution


Organic Eggs & Veggies
Raccolto: 15/04/24
ID: 73284566

/Storyconcept 2b

The Tamagotchi Farms

What if we could achieve food self-sufficiency through a digital interface, managing remote robotic farms from our urban living rooms as if they were a strategic survival game?

Storyconcept:
In order to escape from the opaque logic of the food industry, what if we decided to become farmers without ever getting our hands dirty? Let's imagine that the now-deserted countryside is converted into a **grid of remotely managed micro-plots**, where **hordes of robots** faithfully carry out the commands sent from our **smartphones in the city**. A service would allow us to **"remotely control"** our survival, transforming agriculture into a sort of vital **strategy video game**. We would be able to decide on irrigation, nutrients and harvest times via an app, tending to the plants through a screen. We would then find ourselves receiving the actual fruits of a purely virtual labour delivered to our door, enjoying the total security of **self-production** whilst remaining **comfortably seated on the sofa** in our living room.

Keywords:
#Remote farming
#Farming gamification
#Smart farming technologies


2,500
1,200
IRRIGA
NUTRI
RACCOLTA
DRONE
Semina
Cura
Raccogli

Matrix 3

The third matrix ***(Fig.5.3)*** analyses the intersection between the Diversification of food sources and Advances in technologies for virtualising consumption. This framework explores how the **digital dimension** can act as either a catalyst or a barrier to the **transition towards healthier and more sustainable diets**. The focus shifts to the capacity of **immersive technologies** to facilitate the **acceptance of new dietary paradigms**, making accessible sources which, whilst fundamental to ecosystem balance, are aesthetically or culturally distant from common sensibilities. The sole story concept developed for this matrix is **"Augmented Appetite"**, which is positioned in the top-right quadrant to highlight high value in both variables. The scenario assumes a massive integration of mixed reality to encourage the adoption of food biodiversity, but does so through systematic **"neuro-deception"**. While this technology enables the achievement of systemic health goals that would otherwise be difficult to accept, it also raises critical questions regarding the **ethics** and legitimacy of an approach that bases its effectiveness on the **manipulation of sensory** perception and **aesthetic illusion**.

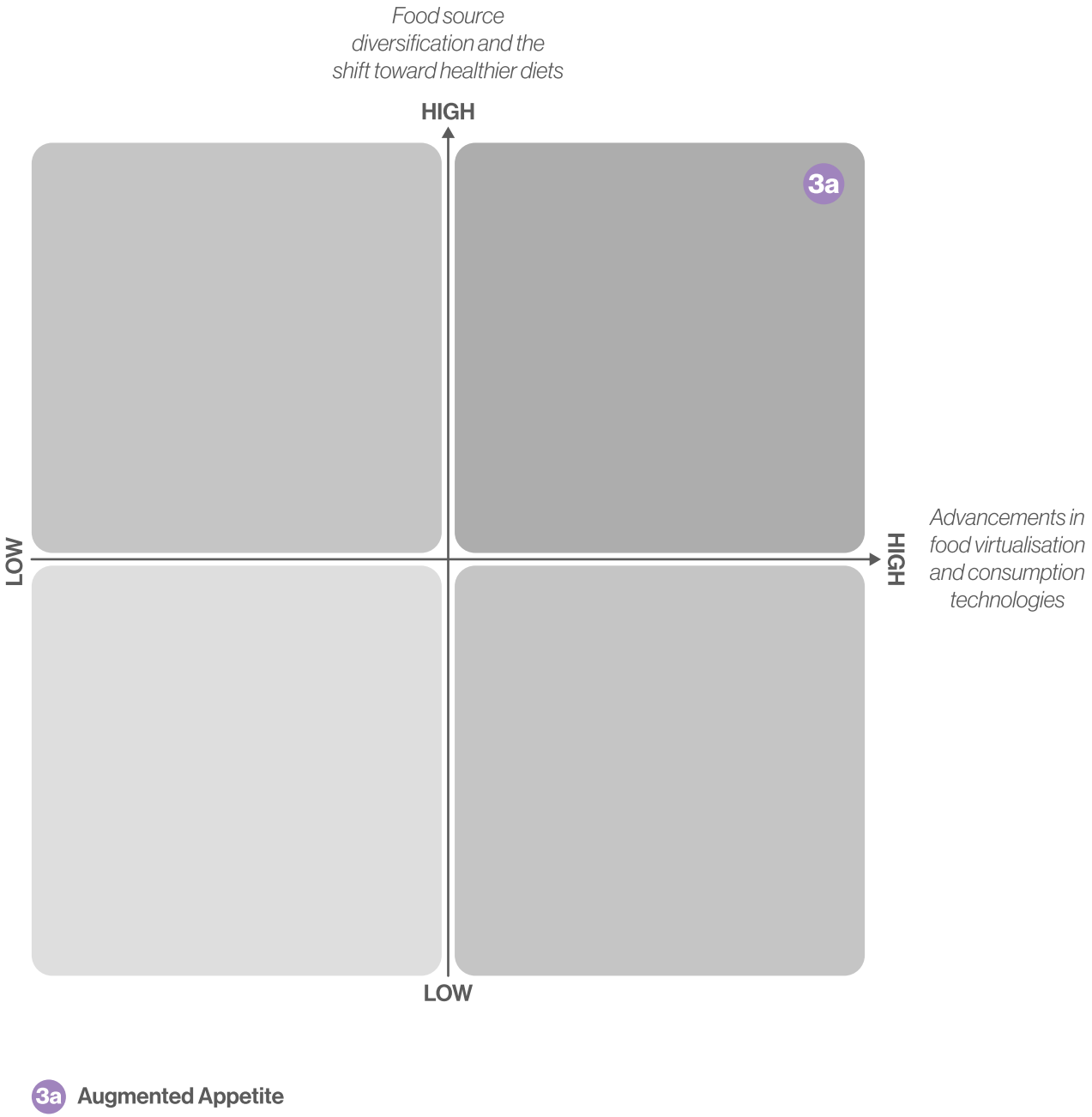


Fig. 5.3 Matrix 3.

/Storyconcept 3a

Augmented Apetite

What if a daily “neuro-deception” through AR visors was the only way to bridge the gap between ecological necessity and our sensory rejection of sustainable and healthy food?

Storyconcept:
In a future where ecological survival demands a shift towards more sustainable, yet aesthetically unappealing, food sources, the **act of eating** becomes an experience entirely **mediated by Mixed Reality**. As we consume these new food sources, **smart visors overlay holograms** of familiar, comforting dishes over the raw ingredients, creating a veritable **“neuro-deception”** in the food we eat. The digital illusion **masks** the **food’s actual sensory appearance**, allowing the brain to accept with pleasure what the eye would otherwise reject.

Keywords:
#Digital appeal
#Sensory neuro-deception
#Mixed Reality



Matrix 4

The fourth matrix ***(Fig. 5.4)*** analyses the relationship between the adoption of hyper-personalised diets and Advances in biometric monitoring and precision health technologies. The aim of this analysis is to investigate how the constant **availability of data** on our physiological state might redefine the concept of **dietary choice**, transforming it from a personal decision into a tool for the **technical management** of **individual biology**. This explores the boundary between self-care and the automation of health, where technology does not merely suggest, but ultimately governs **nutritional behaviour**. It is within this context that the storyconcept **"Nutrition as a Service"** develops, situated in the top-right quadrant. This scenario represents the ultimate expression of this convergence, where hyper-personalisation is no longer an option, but a system tied to **individual biological performance targets** ensured by constant **biometric monitoring**.

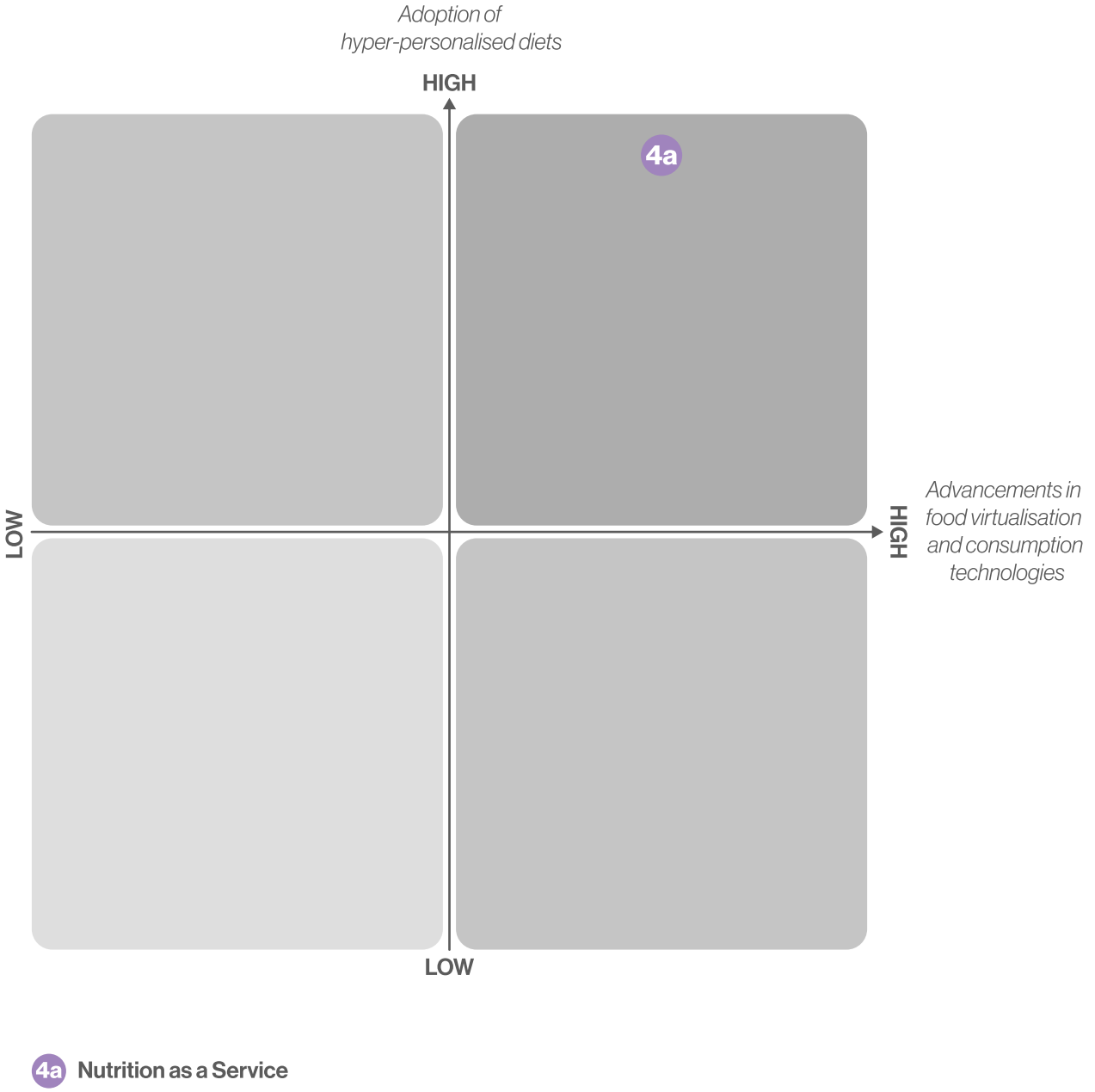


Fig. 5.4 Matrix 4.

/Storyconcept 4a

Nutrition as a Service

What if the pursuit of perfect health led us to sacrifice the joy of eating, transforming our homes into clinical labs where AI dictates every nutrient based on real-time biometric data?

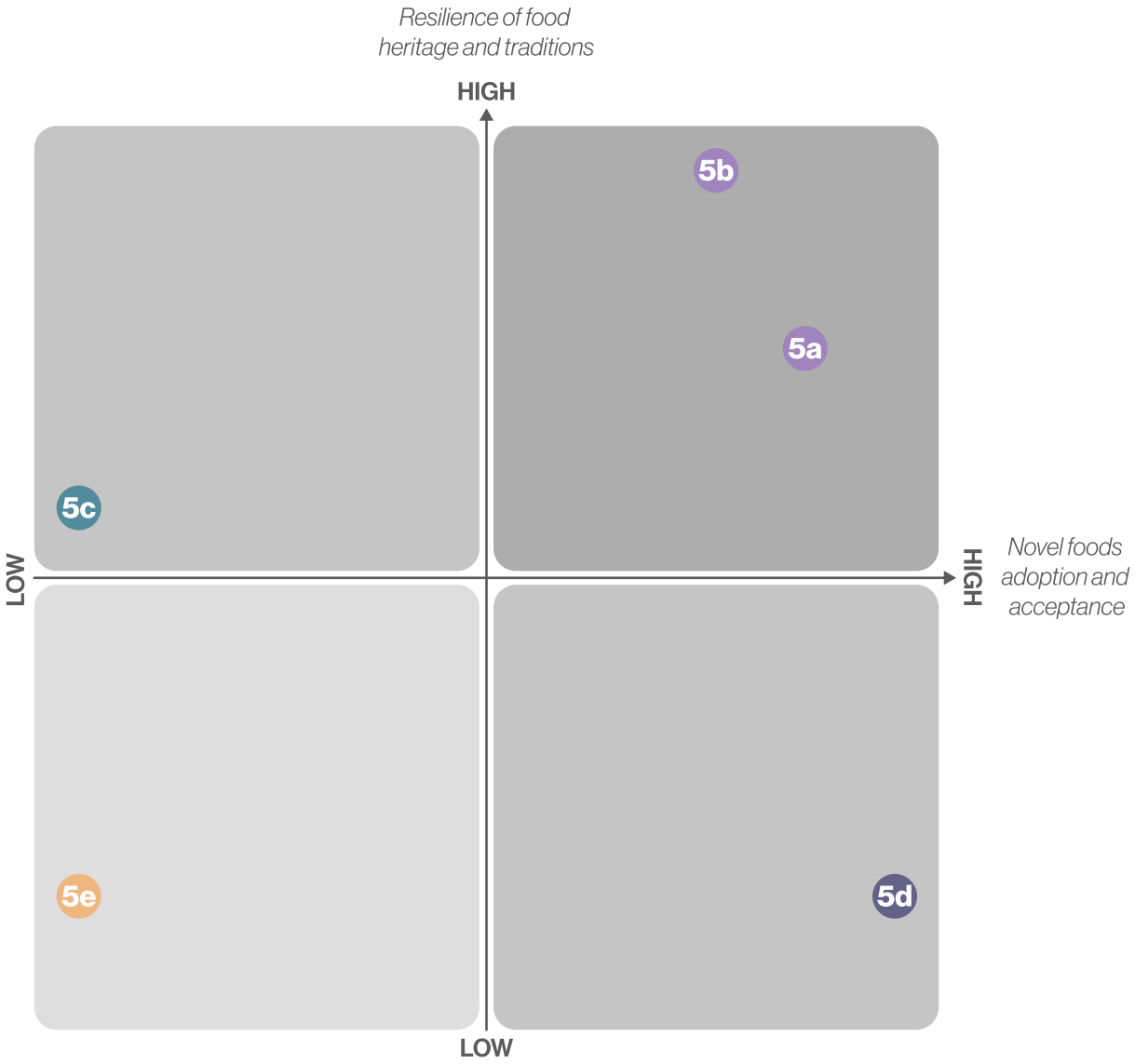
Storyconcept:
In a **society** obsessed with **biological performance and longevity**, the pleasure of eating is sacrificed for the sake of measurable well-being. In this scenario, food loses all sensory connotations, reduced to a purely **functional tool**, managed through **clinical goal-based subscriptions**, where one no longer chooses what to eat based on desire, but subscribes to plans such as the Zero-Cholesterol Membership or the Longevity Plan, where the physiological outcome is the only valuable parameter. The **home** is transformed into an automated, **interconnected laboratory**, with **biometric sensors** and home analysis systems constantly monitoring health status, communicating directly with smart appliances that meticulously ration nutrients. The **act of eating** thus becomes a **precise intake of biochemical components** calculated by artificial intelligence, rendering appetite and the joy of sharing obsolete concepts in the face of the pursuit of biological perfection.

Keywords:
#Algorithmic nutrition
#Biometric environmental integration
#Performance-based subscription


ANALYSIS IN PROGRESS
URINE
GLUCOSE
HYDRATION
ALLY TARGET
NUTRIENT DISPENSING
PROTEIN
VITAMINS
CALORIES
TARGET
ACHIEVEMENT
3D FOOD PRINTING
OPTIMIZING MEAL

Matrix 5

The fifth matrix ***(Fig. 5.5)*** represents the most dense and productive analytical space in this research, originating from the intersection between the acceptance of Novel Foods and the resilience of gastronomic heritage. The aim is to explore the complex negotiation between **new production models** and the **preservation of a cultural heritage** that is forced to change its nature in order not to disappear. This dimension has generated **five different scenarios**, capable of mapping the food system's responses to the biological and technological transition. In the top right quadrant, where innovation converges with the desire to preserve identity, we find **"Gastronomic Heritage Remastered"** and **"The Alchemical Renaissance"**. Both concepts investigate how the past persists through the integration, at times forced, of alternative food sources into historical rituals, **elevating novel raw materials** through **artisanal technique** and collective memory. Moving into the quadrant characterised by strong resistance to change in the face of low acceptance of new sources, we find **"Zoopolis"**. In this scenario, the cultural rejection of novel foods drives the system towards an **extreme adaptation of traditional protein sources**, forcing livestock within the architectural constraints of urban density to meet contemporary food needs. On the contrary, the **"Metropolitan Terroir"** scenario is situated in the lower right quadrant. Here, the **adoption of new sources** is total, but there is a definitive break from rural tradition, with production shifting entirely **into the urban fabric**, where the architecture itself generates a new urban terroir, creating a novel gastronomic identity detached from classic agricultural contexts. Finally, the lower left quadrant hosts **"The Ghost Franchise"**, which represents the scenario of total loss, with **low adoption of food innovations** combined with the **collapse of gastronomic heritage**. Food is reduced to simple, neutral and standardised assembly bases, devoid of any connection to nature or culture, subservient solely to the logistical efficiency of frenetic urban rhythms.



5a Gastronomic Heritage Remastered

5b The Alchemical Renaissance

5c Zoopolis

5d Metropolitan Terroir

5e The Ghost Franchise

Fig. 5.5 Matrix 5.

/Storyconcept 5a

Gastronomic Heritage Remastered

What if, to preserve our culinary soul in a world of vanishing resources, we learned to re-create our most beloved traditional recipes using exclusively sustainable novel foods?

Storyconcept:
In an age when traditional ingredients have become unsustainable and unavailable, culinary heritage finds a way to survive through the **incorporation of novel foods**. In this context, the essence of traditional dishes, characterised by their flavour profiles, textures and convivial value, is preserved, even though these **new versions of traditional dishes** are entirely reconstructed **using alternative food sources**. In this context, the adoption of new ingredients is not seen as a compromise but as an **act of resilience necessary to preserve the identity of the cuisine**.

Keywords:
#Resilience of gastronomic identity
#Evolution of tradition
#Sustainable food transition


CRICKET
FLOUR
SPIRULINA
POWDER

/Storyconcept 5b

The Alchemical Renaissance

What if we granted sustainable novel foods the same legal and artisanal prestige as our most cherished traditional culinary delights?

Storyconcept:
New global regulations and sustainability subsidies have increasingly restricted traditional agricultural production, turning historical products into rarities. To preserve its identity, Italy has responded by creating the **DOT**, or Denominazione di Origine Tecnologica **(Technological Designation of Origin)**. This new system certifies that **modern foods**, such as alternative food sources, are processed with the **same artisanal care and lengthy maturation periods** of the past. In this way, it is possible to elevate sustainable ingredients, transforming them into products of excellence with a traditional flavour, thereby **preserving cultural heritage** and **adapting it to the needs of the present**.

Keywords:
#Approval of novel foods
 # DOT certification
#Sustainable food transition


Prosciutto di Cultivar
DOT
Denominzzione di Orgieirie Techoologica

/Storyconcept 5c

Zoopolis

What if, to satisfy the urban demand for meat, we integrated vertical “animal satellite cities” directly into our metropolitan landscapes?

Storyconcept:
With rapid population growth and the phenomenon of mass urbanisation, **global demand for animal protein has exploded**. Faced with **consumers’ clear rejection of novel foods**, which are culturally unacceptable, cities have had to bring the production of real meat in-house. This has led to the emergence of **“Animal Satellite Cities”** on the outskirts, built as high-density **vertical districts specifically designed for livestock**. These structures function as efficient **urban “meat factories”**, with architecture specifically designed to ensure high standards of **animal welfare** in confined spaces, which is essential for maintaining social acceptance and productivity in the absence of pastures.

Keywords:
#Vertical livestock
#Peri-urban production
#Animal welfare engineering


EcoBarn
Animal Care Hub
VITALS
STABLE

/Storyconcept 5d

Metropolitan Terroir

What if the “terroir” of our food shifted from rural soil to urban landscape, where a building’s specific environment defines the unique flavor and identity of what we eat?

Storyconcept:
The widespread adoption of novel foods and new food technologies has released food production from traditional geographical constraints, as these foods can be produced entirely in **controlled environments**. In this new context, the **concept of terroir shifts from the countryside to the city**, shaped by the interaction between the neighbourhood’s identity and the “metabolism” of the building itself. Factors such as **urban location**, sun exposure and **architectural materials define the organoleptic characteristics of the product**. Each urban structure is transformed into a unique production ecosystem, generating a **new map of taste** where quality is no longer certified by the agricultural region, but by the city’s coordinates and the technical characteristics of the individual building.

Keywords:
#Urban terroir
#Geography of urban taste
#Sustainable food transition



/Storyconcept 5e

The Ghost Franchise

What if the kitchen became an outdated luxury, replaced by urban gathering places that use sensory engineering to mask the total standardisation of our diet?

Storyconcept:
Urban density and a **high-paced lifestyle** have made **ready-to-eat meals a structural necessity**, while inflation and resource scarcity have turned fresh ingredients into luxury goods accessible to only a few. To ensure affordable prices without resorting to new protein sources, the system has reorganised itself around **Ghost Assembly Hubs**, assembly centres that have replaced traditional kitchens. These labs work with **neutral nutritional bases** derived from intensive monocultures, modifying them only in the final stage through the **industrial application of flavours and textures**. Delivery platforms distribute a semblance of gastronomic variety that **masks total production standardisation**, offering an **efficient logistical solution** capable of bridging the gap between consumer desire and actual purchasing power.

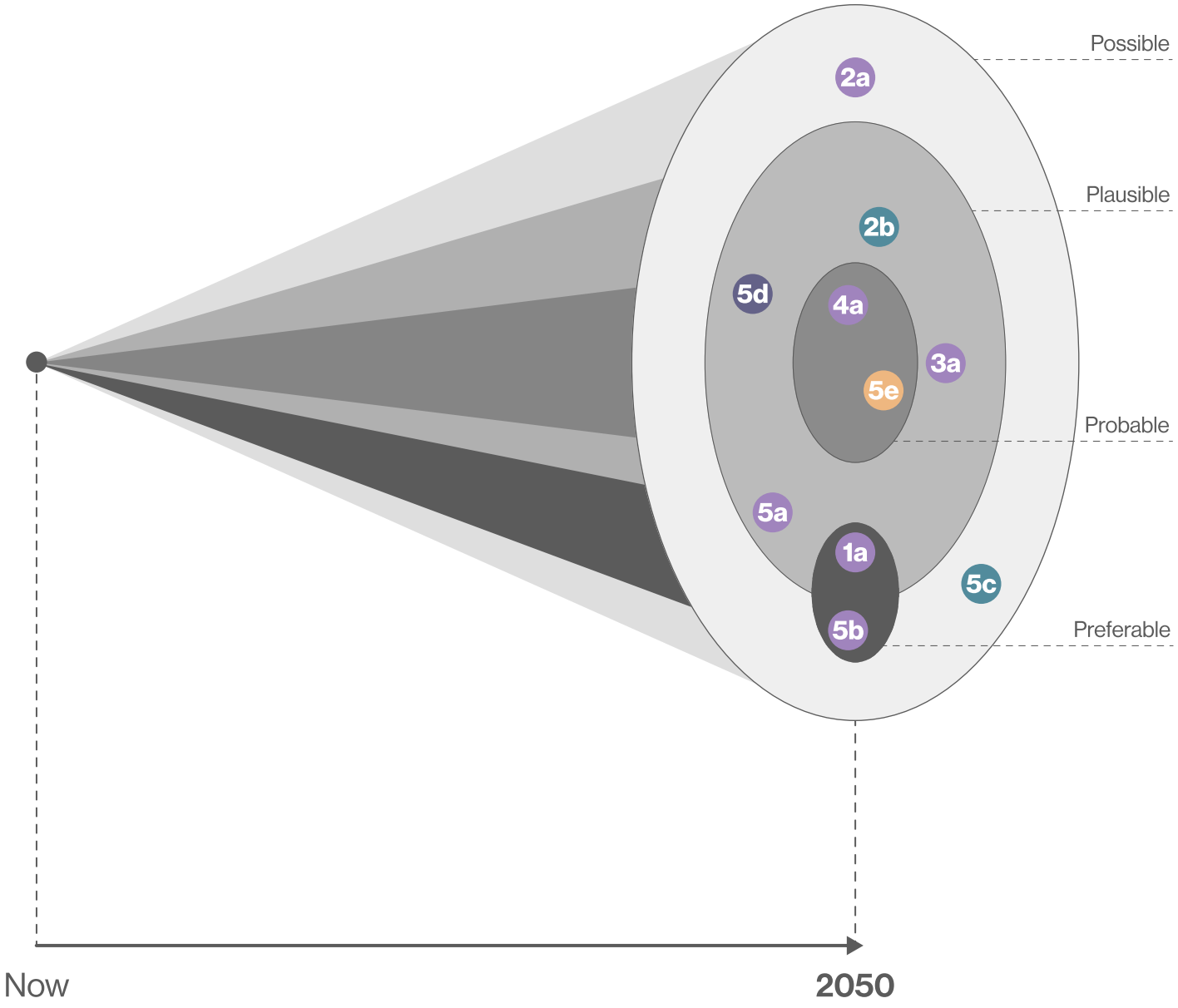
Keywords:
#Ghost kitchen
#Modular food assembly
#Sensory engineering


GHOST ASSEMBLY HUB
FLAVORSPRAY:
NONNA'S SUNDAY

5.3 Futures Cone

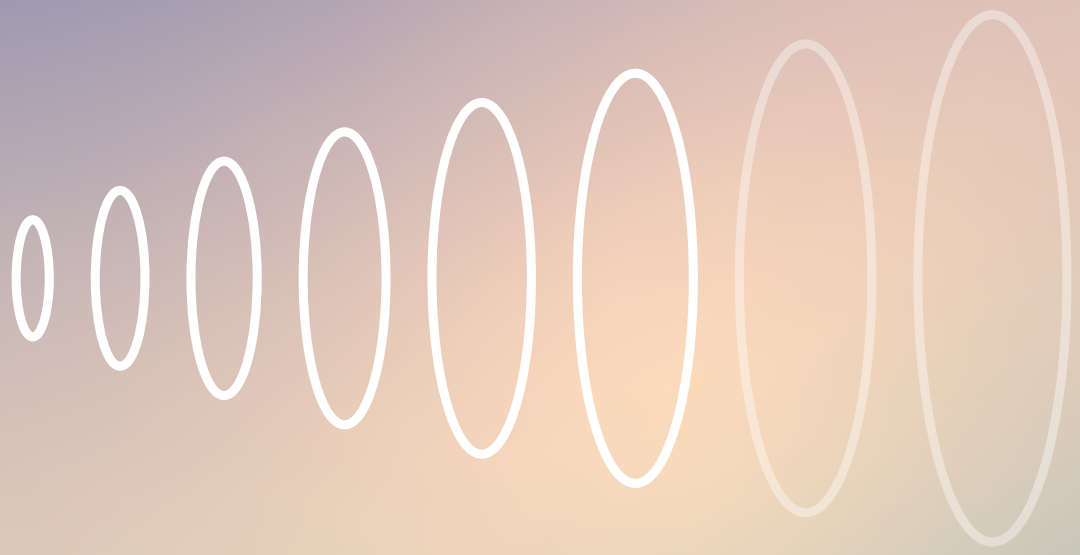
The positioning of the storyconcepts within the **Futures Cone** ***(Fig. 5.6)*** enables us to map the various evolutionary trajectories of the food system towards the 2050 horizon. This tool for classifying futures categorises scenarios according to their likelihood and the feasibility of their actualisation, offering a critical overview of the proposals developed. **Probable futures** represent those scenarios rooted in current trends, although Joseph Voros warns that such trends are not necessarily continuous and may undergo discontinuities or disappear suddenly (Boldrini, 2023). This category includes **"The Ghost Franchise"** and **"Nutrition As A Service"**, which emerge as logical extensions of the current dynamics of food digitalisation and servitisation. Moving towards the **plausible future**, the analysis encompasses what we believe may occur based on our current understanding of the world, from the laws of physics to existing technologies. In this space, we find scenarios such as **"The Tamagotchi Farms"**, **"Metropolitan Terroir"**, **"Augmented Appetite"** and **"Gastronomic Heritage Remastered"** visions that challenge the status quo whilst remaining anchored to processes and dynamics that are scientifically comprehensible today. **Possible futures**, on the other hand, encompass everything we can imagine, however unlikely or improbable, provided that we acquire knowledge in the future that we do not yet possess. This more speculative quadrant includes **"The Prosumer Biolabs"** and **"Zoopolis"**, scenarios that explore radical frontiers requiring not only new scientific paradigms but, above all, specific cultural and social events. Finally, the **preferable futures** outlines the intentional dimension, that is, what we would like to see happen as opposed to undesirable futures (such as those linked to climate collapse). In this value area lie **"The Regenerative Menu"** and **"The Alchemical Renaissance"**, scenarios identified as desirable trajectories due to their ability to combine human well-being and ecosystem health, steering innovation towards a positive systemic impact.

Due to its relevance to the research carried out and out of personal interest, the storyconcept **"Metropolitan Terroir"** was **selected for the development** of the subsequent phases of the project.



1a The Regenerative Menu
2a The Prosumer Biolabs
2b The Tamagotchi Farms
3a Augmented Appetite
4a Nutrition as a Service
5a Gastronomic Heritage Remastered
5b The Alchemical Renaissance
5c Zoopolis
5d Metropolitan Terroir
5e The Ghost Franchise

Fig. 5.6 Futures Cone.



06

Strategy

Strategy

The Strategy phase builds on the work of the three previous phases, marking the culmination of the Strategic Foresight process according to the methodology of the Copenhagen Institute for Futures Studies (CIFS), which names this final phase **"Strategic Insights & Action"**. The aim of this stage is to give concrete form to what has emerged previously, using backcasting as a tool to trace backwards the strategies necessary for the selected scenario, **"Metropolitan Terroir"**, to actually materialise. The analysis was structured into **two complementary sections**; initially, a series of **landscape events** were identified, namely external and not directly controllable conditions that must occur to **create the ideal context** for the development of the vision. Subsequently, a series of **practical and technical strategies** were defined, focusing on operational feasibility and the models of action necessary for the construction of the scenario in everyday life. The chapter concludes with the development of an **action roadmap**, a fundamental tool for transforming the design hypothesis into a plausible and implementable **operational plan for the effective realisation of the scenario**.

6.1 Strategy Flow

STRATEGIC INSIGHTS & ACTION

The Strategic Insights & Action phase moves into a more operational dimension, enabling us to outline the pathways and actions required to bring the previously developed visions to reality. The aim, as mentioned, is to make the path towards achieving and fostering the formation of that specific imagined future more tangible by **defining a series of hypothetical actions** and **events** consistent with the analysis carried out. To put this exploration into practice, backcasting was used as the main tool, enabling us to **retrace the timeline** and identify the **strategic milestones** necessary for the selected scenario to actually materialise.

BACKCASTING

The backcasting method has been fundamental in connecting the vision set out in the "Metropolitan Terroir" story concept to the present, enabling us to develop a **strategy of events and actions that logically link the speculative vision to the current reality**. Unlike traditional planning, this method works backwards, starting from the

characteristics of the final scenario to identify the key steps needed to bring them to fruition, thus overcoming the so-called **"present bias"** that often confines our planning capacity to the limitations of the present. The analysis focused on distinguishing between factors that fall under the organisation's direct control, which can therefore be managed and transformed into active strategies, and events belonging to the **external landscape**, which are beyond direct control and are determined by the evolution of the context. To make the scenario more tangible, we have hypothesised both the macro-level contextual conditions necessary for the system's development and the operational and structural characteristics of a hypothetical company capable of initiating this transition within the current context. The final outcome of this process is a strategic roadmap setting out a sequence of hypothetical events and actions over a **25-year timeframe,** projecting the full realisation of the Metropolitan Terroir scenario by **2050**. This roadmap is supported by a selection of real-world case studies, which are used to contextualise and validate the practical feasibility of the new urban food paradigm by establishing a logical connection between the drivers of the present and the vision for the future.

6.2 Development of the Strategic Landscape

The development of the **Contextual Landscape** was structured using the backcasting methodology, initially defining the final features of the scenario for 2050 and then working backwards to reconstruct the logical steps linking it to the **key drivers** analysed during the research phase and selected for the construction of this scenario. This approach allows the narrative to be presented not as a mere abstraction, but as a coherent evolution of current forces. The map's architecture is based on the integration of **Data Points**, i.e. real elements supported by statistical and scientific evidence, and **Scenario Projections**, narrative projections that hypothesise the future development of such data should the system continue in the direction outlined. The destination of this journey is defined by **five key features** that outline the new paradigm of the Metropolitan Terroir:

- ***Increased Agrifood Resilience through Local Autonomy:*** greater resilience of the food system achieved through local

production independence.

- ***Urban-Centric Production Consolidation:*** the consolidation of food production within the urban centre.

- ***Consumer Awareness and Food Reconnection:*** a renewed consumer awareness and an emotional and physical reconnection with food.

- ***Consolidation of Urban Gastronomic Heritage:*** the emergence and consolidation of a specifically urban gastronomic heritage.

- ***Cultural Acceptance of Novel Foods:*** the full cultural acceptance of novel foods and alternative proteins.

The flow of information, as can be seen in the roadmap on the right ***(Fig. 6.1)***, aims to highlight how the **drivers of change** identified at the beginning and supported by the data collected (such as the shift in crop patterns or the growth of vertical farming) act as a **catalyst for deeper systemic transformations**, such as the collapse of traditional agricultural systems or the definitive **decoupling of our gastronomic heritage from the rural landscape**. In this sense, the development described represents a projection rooted in current real-world events, and through this logical connection, the roadmap seeks to demonstrate the plausibility of the transition towards the final scenario, making the evolution towards a **new urban production paradigm** tangible and credible.

Stages of Landscape Evolution

To clarify the progression towards the 2050 horizon, the evolution of the landscape has been divided into **three key phases**. These phases represent not merely a chronological sequence, but three distinct **stages of evolution** in which the drivers of change and current data progressively transform the existing agri-food system. Each phase defines a step in the transition towards the proposed Metropolitan Terroir scenario, allowing us to observe how today's weak signals evolve into profound and irreversible systemic transformations.

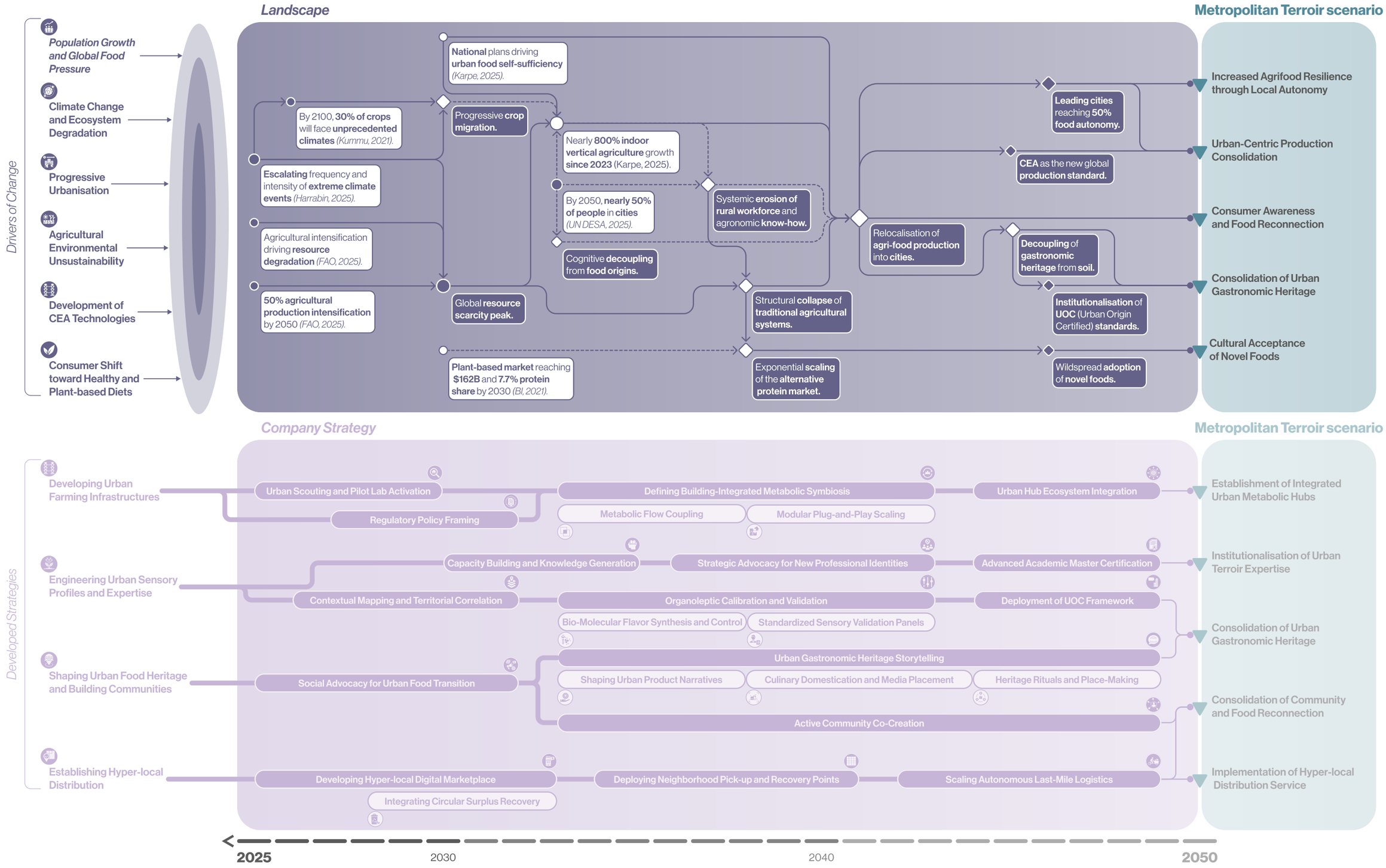


Fig. 6.1 Roadmap (Landscape framework).

S1 - Systemic Limits and Social Alienation

The first stage of the strategic landscape, entitled "Systemic Limits and Social Alienation", outlines the current scenario of profound crisis within the global agri-food system. This phase brings together the main critical issues of the dominant agro-industrial production model, characterised by poor systemic efficiency and ecological unsustainability, which is leading to the progressive degradation of ecosystems. The combination of agricultural intensification, the massive use of chemical inputs and the escalation of climate change is seriously threatening the resilience of production. This situation, combined with global demographic pressure that will require a **50% increase in food production** by 2050 (FAO, 2025), unequivocally highlights the structural limits of a system that cannot persist on a planet with finite resources. At the same time, the ongoing **mass urbanisation** is acting as a powerful catalyst for the standardisation of consumption patterns. In urban settings, characterised by a frenetic pace of life, we are witnessing an **explosion in the market for ultra-processed foods** and **convenience foods**. Although these habits show signs of growing awareness of plant-based diets in certain segments of the population, they are unsustainable both for the environment and for public health. The integration of these lifestyles generates widespread **social alienation** from the value of food, with consumers, increasingly distant from places of production, losing the cultural ability to recognise fresh and healthy raw ingredients, preferring purely functional or convenient alternatives. Together, these elements reveal the fractures in an **increasingly unsustainable model**, laying the foundations for the need for a radical paradigm shift.
















Save with
Bashas' BRANDS!
Cheetos
Chobani





S2 - From Rural Erosion to Urban Symbiosis

Building directly on the challenges identified in the previous phase, the second stage, entitled “From Rural Erosion to Urban Symbiosis”, describes the moment when the fragility of the traditional rural system triggers the emergence of new production models that can be integrated into the urban fabric and offer a potential alternative to the traditional production model. This transition is fuelled by a progressive **“rural erosion”**, with the exodus from agricultural areas and the loss of skilled labour, due to the lack of interest among younger generations in conventional agricultural work, compounded by systemic vulnerability exacerbated by **geopolitical and climatic shocks**. In a world where global supply chains are increasingly unstable, the need to ensure food resilience is driving the system towards a radical relocation of production. The major opportunity emerging at this stage is represented by the **rise of CEA** (Controlled Environment Agriculture) technologies and **indoor farming**. This sector has seen **exponential growth of 800% since 2023** (Karpe, 2025), offering a practical solution to make agriculture less vulnerable to extreme weather events. Through new production models such as vertical farming and the integration of hydroponic, aeroponic and aquaponic systems, it becomes possible to **decouple production from land use**, which represents another of the most critical limitations of the traditional agricultural model, whilst **optimising the use of critical resources** such as water and nutrients. These models represent not only a technical innovation but a strategic necessity for nations with high urban density and limited arable land. A prime example is **Singapore**, where national plans such as **“30 by 30**” aim to **increase food self-sufficiency by 2030** (Karpe, 2025). In geopolitically complex contexts marked by **volatile commodity prices**, the ability to produce food within one’s own urban boundaries becomes a fundamental pillar of national security, reducing dependence on external sources and transforming the city from a mere centre of consumption into a resilient production hub.

















S3 - Metropolitan Terroir and New Food Sources

The final stage of this evolution, "Metropolitan Terroir and New Food Sources", marks the completion of the systemic transition and the definitive move beyond the traditional agro-industrial model. At this stage, the **decline of conventional rural practices** and the pressure of urbanisation, which will see over **50% of the world's population living permanently in cities by 2050** (DESA, 2025), make **CEA technologies** the dominant production standard. In this context, the need to shorten supply chains to increase urban resilience transforms cities from centers of pure consumption into self-sufficient production hubs, capable in some cases of **covering up to 50% of their own food needs**. This physical shift in production is accompanied by a profound evolution in consumption, driven by **growing awareness of the health risks** associated with ultra-processed foods, which is pushing citizens toward **healthier and more sustainable diets**, fueling a market for **plant-based and alternative proteins** estimated to reach USD 162 billion by 2030 (BI, 2021). Since livestock farming is more complicated in urban contexts, production is shifting toward **new food sources such as algae, mushrooms, and insects**, whose biology is perfectly suited to the controlled environments of indoor farming technologies. Novel Foods, supported by new legislative initiatives and growing cultural acceptance, are becoming the cornerstone of a new urban food system. However, the rise of CEAs is leading to a gradual **decoupling of food from the soil** and traditional terroir, severing that historic connection between product and territory which has defined national gastronomic identities for centuries. To fill this void of belonging and rebuild a value-based connection with what we eat, the system is evolving towards the **institutionalisation of UOC** (Urban Origin Certified) **standards**. This new certification formalises the emergence of the **"urban terroir"** and a new paradigm in which product excellence is no longer defined by the agricultural region of origin, but is shaped by the characteristics of the referring urban context.



















MIXED
BASKET
12 00
BASKET


6.3 Development of the Company Strategy

The development of the company strategy was structured using the **backcasting** tool, initially defining the **organisation's target features** for 2050 and then working backwards to identify the **strategic actions** and key milestones required to achieve them. In contrast to the la analysis, which focuses on external and often uncontrollable changes, this **roadmap** ***(Fig. 6.2)*** explores the deliberate levers that an organisation can activate to **catalyse the transition** towards the "Metropolitan Terroir" scenario. The architecture of this map incorporates specific **Main Phases** and **Sub-phases** of the strategy, identifying the technical, social and infrastructural aspects required to transform a visionary concept into a viable business model. The direction of this initiative is defined by **five key features** that outline the strategic objectives the company must actively pursue to ensure that the scenario created is developed:

- ***Establishment of Integrated Urban Metabolic Hubs:*** creation of production centres that integrate food systems with urban cycles.

- ***Institutionalisation of UrbanTerroir Expertise:*** formalisation of specific roles and specialist knowledge for this new form of urban agriculture.

- ***Consolidation of Urban Gastronomic Heritage:*** establishment of a culinary culture rooted in the unique identity of the metropolitan context.

- ***Consolidation of Community and Food Reconnection:*** consolidation of social ties through the direct involvement of citizens in the new urban food system.

- ***Implementation of Hyper-local Distribution Service:*** Implementation of a hyper-local distribution service: establishment of autonomous last-mile logistics to bridge the gap between production and the consumer.

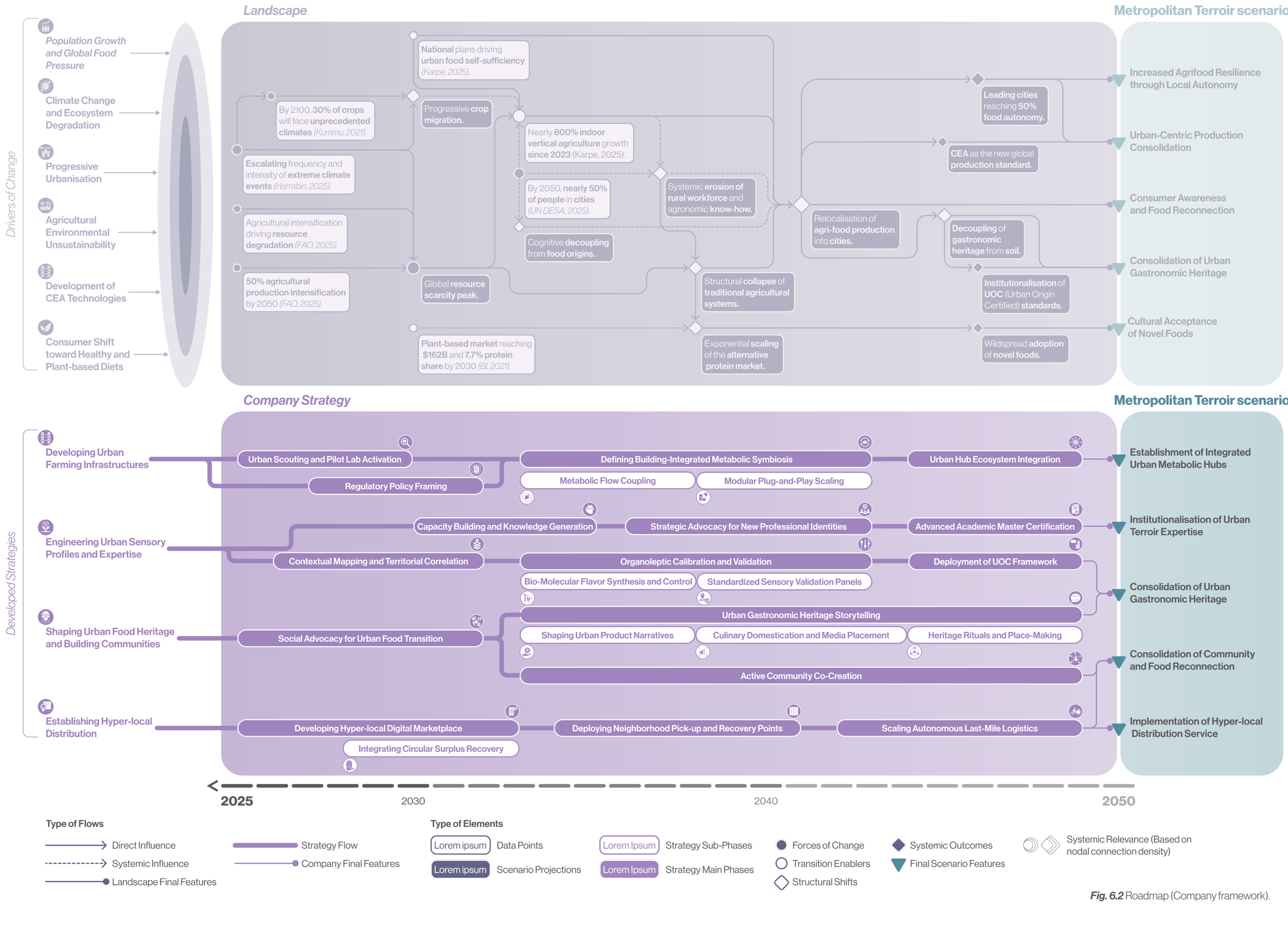


Fig. 6.2 Roadmap (Company framework).

Key Company Strategies

In order to realise the features that define the envisioned scenario, the business strategies have been structured around four main pillars. The first two, **Developing Urban Farming Infrastructures (S1)** and **Engineering Urban Sensory Profiles and Expertise (S2)**, focus on building the technical infrastructure and developing the expertise required to create this new urban flavour. This constitutes the operational and scientific core of the project, aimed at ensuring that urban production is not only efficient but also of excellent quality. The third strategy, **Shaping Urban Food Heritage and Building Communities (S3)**, addresses the socio-cultural aspect, with the aim of creating the optimal context for acceptance by raising awareness of the benefits provided by this new model and its products, thus deeply embedding it within the socio-cultural fabric. Finally, the fourth strategy, **Establishing Hyper-local Distribution (S4)**, defines the physical and digital infrastructure needed to make the service tangible and accessible, optimising the logistical link between the production site and the end consumer.

Developing Urban Farming Infrastructures (S1)

This macro-strategy has been developed with the primary aim of addressing Key Future No. 1, i.e. Establishment of Integrated Urban Metabolic Hubs. The strategy is structured around a series of sub-strategies which, between now and 2050, will seek to ensure that this specific objective is achieved, focusing specifically on the **creation of urban food production labs** that are deeply integrated into the urban landscape. The aim is to transform the existing urban fabric into a productive organism, where technology is not a foreign element but a function in symbiosis with the architecture itself.

S1.1 Urban Scouting and Pilot Lab Activation (2025 – 2030)

This phase involves an initial **scouting exercise** aimed at identifying and mapping the unused **potential of the urban environment**, such as rooftops, derelict spaces, or other types of buildings, in order to select the most suitable locations for **launching pilot experiments**. The main objective is to **obtain technical and scientific validation**

of the idea's practical feasibility. These pilot projects serve to demonstrate that production is safe and feasible in the specific urban site, providing tangible evidence that will form the basis for the development of subsequent phases. The research focuses on identifying contexts where it is, first and foremost, **feasible to launch the project** in terms of permits, but which are also technically interesting for the construction of the future urban flavour. A tangible example of the enhancement of an urban context for food production is the case study **The Plant** in Chicago. This project has transformed a former meat-packing plant into an incubator for circular food production, demonstrating how the regeneration of a derelict industrial space can become a pilot laboratory with a new purpose.

S1.2 Regulatory Policy Framing (2027 – 2032)

This second sub-strategy represents a phase of institutional legitimisation that runs parallel to the pilot trials, with the aim of transforming the results obtained in the field into **actual legal permissions**. The core of the initiative lies in pushing the regulatory framework towards the **acceptance of these new urban production models**, seeking to obtain official authorisation for cultivation within **civil buildings**. Through this process, the aim is facilitate changes in the intended use of buildings and to define specific safety standards for the integration of agriculture into urban architecture. In this sense, **Singapore's 30 by 30 plan** serves as a clear reference point moving in this direction, with the initiative demonstrating how a clear political will can **make cities more resilient** by aiming to meet **30% of food requirements by 2030**, acting as a first institutional step towards the development of innovations of this kind.

S1.3 Building-Integrated Metabolic Symbiosis (2033 – 2043)

This phase marks the transition to operational implementation and technical-economic feasibility, with the primary objective being to **reduce the high costs typically associated with CEA technologies** by integrating the production hub into the building itself. This is the most practical phase of the design and construction of the laboratories that will be **incorporated into urban production buildings**. This sub-phase is composed of **two key steps:**

- ***Metabolic Flow Coupling (2033 – 2038):*** This step is crucial because one of the main challenges facing CEA technologies is the **high energy costs** involved in maintaining **controlled environments**. The aim of this phase is to integrate the production unit with the building's systems by applying the principles of **Building Integrated Agriculture (BIA)**, in order to optimise the use of the resources required for production, primarily energy and water. Rather than operating as isolated systems, the aim is to create a **symbiosis of flows** in which the hub utilises the building's waste and specific characteristics, with the aim of significantly **reducing operating costs (OPEX)**. In this way, the building's efficiency translates directly into savings for the hub, making urban production economically sustainable and competitive. A concrete example of this synergy is the model proposed by **EcoData-Center** in collaboration with **WA3RM**, which recovers the waste heat generated by data processing within data centres to power large-scale food production, effectively transforming industrial waste heat into a primary resource for agricultural activity.

Building Integrated Agriculture
Building-integrated agriculture (BIA) is a sub-type of Urban Agriculture (UA) and Zero Acreage Farming (ZFarming). This practice involves installing high-performance soilless greenhouse systems such as hydroponics, aeroponics and aquaponics on and in mixed-use buildings to exploit the synergies between the building environment and the production system. (D'Ostuni et al., 2022)

- ***Modular Plug-and-Play Scaling (2038 – 2043):*** The central objective of this phase is to **standardise production systems** to ensure maximum **flexibility and adaptability**. It is essential that these units are designed to be **easily scaled and to integrate** flexibly into highly **diverse urban contexts**. In this sense, the modularity of the structures becomes an essential requirement for ensuring the versatility needed for large-scale deployment. Through this approach, technological complexity is translated into the ability to adapt to the specific needs of the urban fabric in which they are situated. An illustrative case study of this logic is **Urban Crop Solutions**, which develops modular and scalable indoor cultivation systems. In particular, their **ModuleX system** is specifically designed to offer a flexible technical solution to diverse infrastructural needs, facilitating the adoption of the technology and its scalability.

S1.4 Urban Hub Ecosystem Integration (2044 – 2049)

The final sub-strategy of the first macro-strategy represents the concluding phase, coinciding with the transition from individual buildings to the **urban network**. The aim is to create an **integrated system** between buildings, connecting the various hubs within an interconnected ecosystem via grids capable of sharing flows of information

and resources. This approach increases the neighbourhood's resilience and transforms the city into an organism where each hub retains its own identity and distinct character (Micro-Terroir), whilst benefiting from the security and efficiency of an integrated network. A key case study in this regard is **Fab City with its DIDO (Data In, Data Out) model** ***(Fig. 6.3)***. This project promotes the idea of a city capable of producing locally what it needs, whilst remaining globally connected through the **exchange of data and knowledge**, ensuring local and regenerative production.

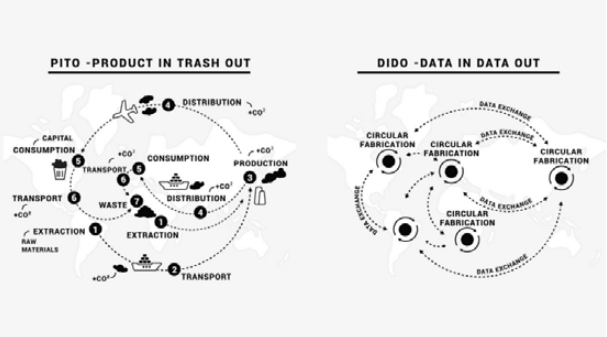


Fig. 6.3 A Comparison of the PITO and DIDO Models.

Engineering Urban Sensory Profiles and Expertise (S2)

The second macro-strategy, Engineering Urban Sensory Profiles and Expertise, has been developed to pursue two of the key futures central to the 2050 scenario: the **Institutionalisation of Urban Terroir Expertise** and the **Consolidation of Urban Food Heritage**. This strategy follows two main lines of action, focusing on the one hand on the **development of specific skills** within the company and the creation of social capital made up of new, highly **specialised professional roles**. On the other hand, it focuses on the creation of **novel organoleptic and nutritional profiles** that are intimately **linked to the urban context** in which they are produced. In summary, the aim is to build both the technical expertise required to manage these complex systems and the sensory identity of the various products, laying the foundations for a **new metropolitan food heritage**.

S2.1 Contextual Mapping and Territorial Correlation (2026-2032)

This sub-strategy takes the form of a detailed analysis of the production context, aimed at identifying and defining the parameters that will shape the **urban flavour** profile of these new products. By mapping local peculiarities, the system analyses how the specific **features of the location** can be extracted and transformed into a defined aromatic profile. The aim is to establish a direct correlation between the environment and the organoleptic and nutritional qualities of the food, identifying how contextual factors influence the character of the crops. A concrete example of this approach is **Audric de Campeau's Miel de Paris** project ***(Fig. 6.4)***, which, through his practice of urban apiculture in Paris, relies precisely on **honey**'s ability to **reflect the flavours of the city**, capturing the different botanical nuances of the various districts. This case study confirms that the urban environment is not merely a neutral space, but an ecosystem capable of generating products with a unique sensory identity.



Fig. 6.4 Le Miel de Paris, Audric de Campeau.

S2.2 Capacity Building and Knowledge Generation (2030-2035)

This sub-strategy focuses on the investment required to build the s**ocial and cultural capital** that defines the company's core identity. The aim is to generate proprietary knowledge by directly **training its own pioneers** and **building a solid base of knowledge**, philosophy and culture to transmit to **future professionals**. This set of skills, in which technical expertise is intertwined with **cultural vision**, constitutes the company's true heritage and transforms internal knowledge into a unique competitive advantage. A key case study is

Apple University, founded by Jobs in 2008 to teach what it means to be an Apple employee. The programme **educates staff on the company's culture and history**, offering a clear **explanation of the brand's philosophy** and what it means to work for Apple. Through this approach, the company ensures that its identity and methods are preserved and consistently passed on over time.

S2.3 Organoleptic Calibration and Validation (2033-2043)

This phase involves working on the technical formulation and subsequent validation of the flavour of the various products developed. Here, chemistry and sensory design are central to defining the profile of the new products, operating with precision at both the organoleptic and nutritional levels. The purpose of this step is precisely the **development and validation of taste**, seeking to **translate the environmental parameters** mapped in phase 2.1 of Contextual Mapping and Territorial Correlation into a defined **sensory profile**, ensuring that the final product is consistent with the established nutritional and organoleptic objectives. This sub-phase is composed of **two key steps:**

- ***Bio-Molecular Flavor Synthesis and Control (2033 – 2038):*** This initial stage focuses on controlling specific parameters to ensure that specific biological reactions take place, with the aim of developing the desired **nutritional and organoleptic properties**. Essentially, it involves stimulating natural processes to achieve precise and controllable results, with the aim of guiding and steering the sensory and nutritional composition of crops. A case study in this area is the **Noma Projects**, where research focuses specifically on the use of **biochemical processes** to create and **control new flavour profiles**. Through the study of fermentation, the laboratory demonstrates how it is possible to intervene in biological processes to explore and define complex flavours, validating the idea of a technically guided synthesis of taste to achieve specific sensory results.

- ***Standardised Sensory Validation Panels (2038 – 2043):*** This phase focuses on validating the organoleptic and nutritional profiles developed in the previous stages. The objective is to convene **panels** comprising **experts** and leading figures from the culinary and gastronomic sectors, who are responsible for certifying

the quality and innovation of these new products. By confirming their value from a taste perspective, this stage acts as a **formal validation** designed to endorse and, in a sense, authorise these new foods within the wider food landscape. An illustrative case study of this dynamic is the **illy Chef Ambassador** programme, where the company collaborates with **Michelin-starred chefs** to create bespoke coffee profiles specifically designed to complement their menus. This partnership demonstrates how the involvement of haute cuisine professionals is fundamental to **validating sensory quality**, ensuring that technical innovation translates into gastronomic excellence recognised and certified by the sector's leading experts.

S2.4 Strategic Advocacy for New Professional Identities (2036-2043)

This phase focuses on creating and promoting the new professional roles needed to manage the urban food systems of the future. Through the organisation of **public events** and **masterclasses**, the aim is to raise public awareness of these roles, seeking to make them appealing and highlighting their strategic importance. This is a real communication and storytelling exercise, where these professions must step out of the laboratories and into the collective imagination, demonstrating that they are interesting and fundamental roles for the food landscape of the future. A key case study for this activity is the **Food Innovation Bootcamps** ***(Fig. 6.5)*** organised by the **Future Food Institute (FFI)**. These programmes are not merely training courses, but immersive experiences that highlight the role of the "food innovator" and the skills needed to transform the food system. Through masterclasses and real-world challenges, the FFI effectively communicates the existence and relevance of these **new careers**, making them attractive to younger generations and validating their social and professional necessity on a global scale.



Fig. 6.5 Food Innovation Bootcamps, FFI.

S2.5 Advanced Academic Master Certification (2044-2049)

This phase involves the formalisation and **institutionalisation of the knowledge** developed by the company, incorporating it into an official academic programme that leads to legally **recognised qualifications** and professional certifications. At this stage, the new roles created by this model receive formal recognition, supported by structured professional courses that facilitate a dedicated academic pathway. A key case study is the **Dyson Institute of Engineering and Technology**, which aims to train the world's best engineers for its own business, guaranteeing them a **fast-track career** at **Dyson**. At this institute, academic rigour is directly combined with the design of the brand's future products; students are entrusted with corporate responsibilities, allowing them to learn and work at the same time. This approach ensures that technical education is inextricably linked to real-world innovation, shaping the next generation of experts within the company's own ecosystem.

S2.6 Deployment of UOC Framework (2044-2049)

The final element of this overarching strategy concerns the formal certification of the entire production process. The aim is to draw up a production specification capable of transforming the internal technical protocol into a **recognised legal label**. This is a crucial step in establishing a legislative framework for the new products of the urban model, ensuring transparency and safety through a **clear regulatory framework** that defines their quality standards and origin. The main reference in this area is the **Participatory Guarantee Systems (PGS)** model promoted by **IFOAM**. These systems represent an alternative and complementary certification tool to **third-party certification**, based on the active participation of the stakeholders involved and on **shared trust**. By promoting government recognition of PGS, it is demonstrated that it is possible to create rigorous yet flexible standards, suited to innovative production models that do not fit within traditional agricultural frameworks.

Shaping Urban Food Heritage and Building Communities (S3)

The third macro-strategy is designed to bring to fruition two fundamental aspects of the Metropolitan Terroir 2050 vision: the **consolidation of urban food heritage** and the **reconnection between communities and food**. Following an initial phase of public awareness-raising, the strategy follows two distinct yet complementary paths. On one hand, it **develops a narrative** around this emerging gastronomic heritage, using storytelling and strategic communication to ensure its recognition and promotion. On the other, it focuses on **promoting community building** within productive urban environments, directly involving citizens to encourage **active participation** and **local resilience**. Basically, the strategy aims to reintegrate food production into the social fabric of the city, transforming this new model into a common pillar of urban identity.

S3.1 Social Advocacy for Urban Food Transition (2025-2032)

This phase aims to raise public awareness of novel foods, which represent the dietary foundations upon which the new urban gastronomic heritage is built. The central objective is to **foster acceptance of the idea of the city as a new centre of production**, laying the cultural groundwork for the introduction of these foods. To **overcome food neophobia**, which often hinders innovation in such a sensitive and delicate sector, the campaign must encourage consumers to try these foods for themselves. It is vital to **highlight the advantages of these models**, presenting them as a concrete solution to the environmental and health related unsustainability of the traditional system. The key case study is **Veganuary** ***(Fig. 6.6)***, an initiative that has supported millions of people in **trying a plant based diet for a month**. By raising public awareness and offering guided support, the project **helps consumers test new dietary habits** and **overcome the initial barriers** that often block the act of change. This challenge clearly demonstrates that it is often the fear of abandoning established habits that holds back the adoption of new practices; once the path is made more accessible, the transition to new products becomes a natural and less daunting process.



Fig. 6.6 Veganuary campaign.

S3.2 Urban Gastronomic Heritage Storytelling (2033-2049)

This phase focuses on building and **promoting** the intangible value of the **city's gastronomic heritage**, with the aim of making it tangible for citizens. By engaging the **media** and **experts**, the intention is to help consumers understand these new products and to foster a true gastronomic culture dedicated to them. This involves demonstrating **how to integrate them into people's diets**, by **providing recipes** and **promoting co-creation activities** that can also be replicated in domestic contexts. All of this serves to create a cultural dimension for these products, defining a food cultura that allows people to get to know them better and to understand how to use and make the most of them in their daily lives. This sub-phase consists of t**hree key steps:**

- ***Shaping Urban Product Narratives (2033 – 2038):*** This phase concerns the choice of **narrative for each product**, which must reflect and be **linked to its specific production context**. The aim is to create a narrative that captures the features of the site where production took place, **using metaphors** to convey the connection formed with the context and how this influences the product's properties. In essence, the narrative of each food product must capture its essence and **reflect the history of the place** where it was produced. The case study in question here is the **Biova Project**, which has created a range of **beers** made **using repurposed materials** sourced from certain **neighbourhoods in Turin**. As well as communicating aspects related to the circular economy, the project effectively highlights the **link between the product and the neighbourhood**, ensuring that

the beer becomes an **expression of local identity**.

- ***Culinary Domestication and Media Placement (2038-2043):*** This phase focuses on introducing new foods into people's diets, raising awareness to encourage their daily adoption. As these are products for which there is not yet an established food culture, it is essential to **leverage the role of the media, experts and influencers** to help people understand their properties. The aim is to demonstrate in practical terms **how these ingredients can be integrated into everyday life**, by proposing dishes and recipes that make their regular use easier. The case study in question is **MasterChef 13**, specifically the episode featuring chef **Chiara Pavan** ***(Fig. 6.7)*** dedicated to the **Blue Crab** and the **Rapana Venosa**. In this context, through the chef's expertise, the programme raised public awareness by presenting dishes that showcased these new and invasive products. By transforming an environmental problem into a **food opportunity**, practical solutions were offered to integrate these nutritional sources into consumers' diets, shifting the perception of the product from "foreign" to a potentially valuable culinary ingredient.



Fig. 6.7 Chiara Pavan, Masterchef 13.

- ***Heritage Rituals and Place-Making (2044-2049):*** This phase marks a shift in the narrative from the screen to the physical space of the production hubs. Virtual communication is integrated with a tangible dimension through the **organisation of neighbourhood events**, **cookery workshops** and awareness-raising sessions led by experts. These gatherings allow **people to experience the new products first-hand**, bridging the gap created by media coverage to build, through direct experience, the cultural heritage and value behind these foods. The aim is to

transform the place of production into a gathering space where the community can discover and integrate these innovations into their daily lives. A prime example of this is **Lufa Farms' Open House Days**, which organises open days and **guided tours of its urban greenhouses**, allowing the public to **visit the production sites** in person, see how food is grown and interact with the growers. This direct contact **breaks down the barriers between producer and consumer**, fostering a genuine reconnection between people and food and making the production site a focal point for the **local community**.

S3.3 Active Community Co-Creation (2033-2049)

The final phase of this strategy focuses on directly **engaging citizens through practical activities** and **co-creation workshops**. By taking part in the preparation of these new ingredients, people develop a greater awareness that encourages their acceptance and incorporation into daily diets. The aim is to **build an active community** capable of learning skills and recipes that can then be replicated at home, transforming the new dietary model into a shared and familiar practice. The key case study is the **Refettorio model** ***(Fig. 6.8)*** proposed by **Food for Soul**, the initiative led by chef **Massimo Bottura** and **Lara Gilmore**. The Refettori are excellent examples of how the systematic organisation of community events can **redefine the value of food**, as they are not simply dining halls, but spaces designed for hospitality where sharing a meal becomes a **social ritual**. This model is fundamental because it demonstrates how the activation of a physical space through collective events can **transform the perception of overlooked ingredients** into valuable resources, building a sense of belonging and a new shared food culture.



Fig. 6.8 Refettorio model, Food for Soul.

Establishing Hyper-local Distribution (S4)

The fourth macro-strategy, Establishing Hyper-local Distribution, has been developed to address two key aspects of the Metropolitan Terroir 2050 vision: the **Consolidation of Community and Food Reconnection** and the **Implementation of Hyper-local Distribution Services**.This strategy aims to establish an **integrated urban micro-logistics** system that enables the widespread distribution of products produced in local hubs directly **into the urban fabric**. Through a **hyper-local service**, food travels from the neighbourhood production centre to the consumer's home, drastically **reducing the supply chain and distance** compared to traditional models. The system represents a fundamental step towards **bridging the gap between production and consumption**, strengthening the local economy and reducing food transport. In this way, it is possible to **make cities more resilient and self-sufficient**, as well as r**e-connecting citizens** with the origin of what they eat thanks to the physical proximity of production.

S4.1 Developing Hyper-local Digital Marketplace (2025-2033)

This first sub-strategy concerns the development of a service model designed to connect citizens with local production hubs and the food they produce. The fundamental starting point is the creation of a **digital marketplace**, a platform that enables not only the purchase of products, but also the discovery of these urban hubs themselves. The system aims to put metropolitan production centres in direct contact with consumers, **eliminating the intermediary stages** of large-scale distribution and allowing citizens to learn more about what is produced in their own neighbourhood. The reference case study is **Cortilia**, a service model that **connects local farmers and producers with citizens**, operating outside traditional distribution channels and offering its customers healthier, **higher-quality products**. Following this logic, the proposed platform acts as a digital bridge to help people discover urban hubs and their products, facilitating a direct purchasing process that promotes local production and drastically reduces the distance between producers and consumers. This strategy also incorporates an additional service feature, detailed in a **dedicated sub-step**, known as:

- ***Integrating Circular Surplus Recovery (2028-2033):*** This phase

focuses on integrating a specific feature into the sales platform to **reduce food waste**, with the aim of enabling consumers to purchase, at reduced prices, products that would otherwise be discarded or remain unsold. By incorporating this **circular logic** into the marketplace, the aim is to **reduce overall waste** from production hubs, whilst offering a financial benefit to the user and **improving the systemic efficiency** of the entire urban supply chain. The reference case study is **Too Good To Go**, a model that has long enabled the **recovery of unsold goods** through the sale of **"bags" at reduced prices** at the end of the day. The idea is to transpose this same functionality within the urban hub platform, providing a practical tool for managing surpluses and **raising consumer awareness** towards more conscious, waste-free consumption.

S4.2 Deploying Neighborhood Pick-up and Recovery Points (2034-2041)

This phase involves setting up physical pick-up points strategically located within the neighbourhood. The aim is to **turn logistics into an opportunity for people to meet**, by creating spaces that are not merely holding areas for goods, but genuine **meeting places** that **encourage interaction** among residents and strengthen social relations. By focusing on proximity, this sub-strategy directly contributes to **reconnecting communities with food**, making citizens active participants in a local system. From an economic perspective, the model also helps to **reduce the final price** of the product by eliminating home delivery costs, making quality food more accessible to everyone. The case study in question is the **Lufa Farms Pick-up Points** system ***(Fig. 6.9)***, which utilises an extensive network of **collection points** located within existing local businesses, enabling the company to distribute fresh produce whilst **minimising logistical impact**. This approach demonstrates how the moment of pick-up can become a daily ritual that supports the local economy and strengthens the **community's sense of belonging** to its own production system.



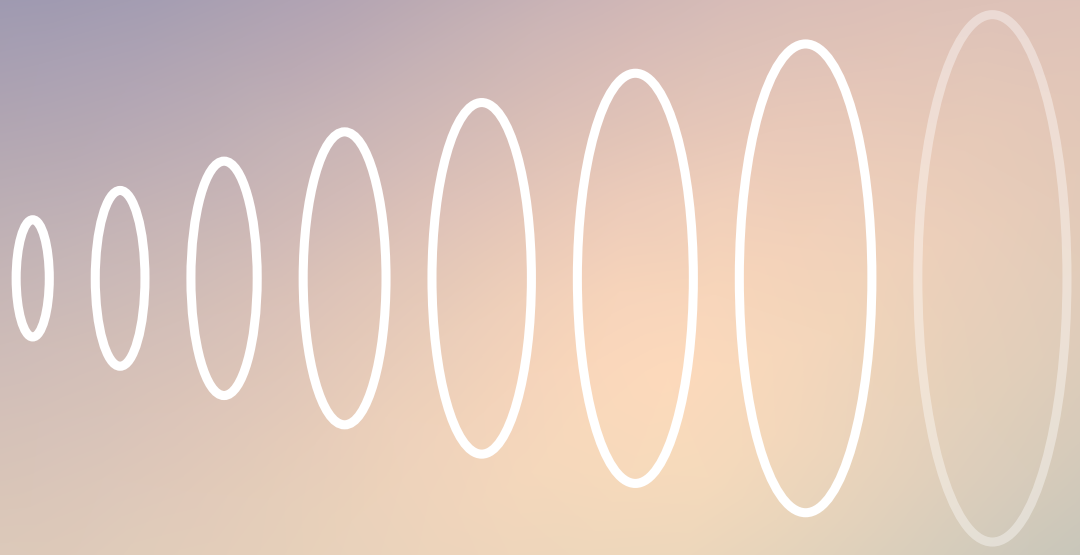
Fig. 6.9 Neighboorhood Pick-up Points, Lufa Farms.

S4.3 Scaling Autonomous Last-Mile Logistics (2042-2049)

This phase involves **organising the logistics infrastructure** required to manage the delivery of products from hubs to consumers' homes. The service is based on **hyper-local micro-logistics** that uses **low-impact transport**, such as **electric or pedal-powered vehicles**, with the aim of **minimising delivery costs** and the **environmental footprint** within the urban fabric. The integration of this system with the digital platform completes the service model, ensuring efficient, cost-effective distribution that is consistent with the city's resilience objectives. The case study in question is **Robin Food** (Florence), a company that has structured its **delivery service** around **360-degree sustainability**. Their approach demonstrates how it is possible to manage the last mile by reducing emissions and logistics costs, providing a local service that respects the urban environment and effectively meets the needs of the local community.



Fig. 6.10 Robin Food, Florence.



07

Artifact Design

Artifact Design

The main objective of this phase is to **visualise the future scenario** and make it more tangible through the creation of specific **"artifacts of the future"**, namely physical or digital components that **support the narrative** and understanding of the imagined world. At this stage, design becomes the key tool for making the scenario not only clearer and more relatable to people's experiences but also perceived as feasible and plausible. Through these artifacts, the project aims to **stimulate deep reflection** on the dynamics of the system, allowing for an immediate **perception of potential transformations** in the agri-food sector and making future hypotheses an integral part of a possible and imaginable reality.

7.1 Development of the artifact ecosystem

Starting from the chosen story concept, **"Metropolitan Terroir"**, this phase attempted to imagine a new production ecosystem focused on food production directly within urban settings. To give concrete form to this scenario, the work centred on developing an **ecosystem of artifacts capable** of demonstrating how this model would function in everyday life, making the dynamics of the proposed system tangible. At the heart of this narrative lies **Alchemetry**, the fictional company that conceived the project with the aim of moving food production into cities, followed by the definition of the **new Integrated Urban Food System** that illustrates the blueprint of the entire process, from start to finish. Finally, the picture is completed by the **Urban Sommelier**, a new professional role that emerges and is shaped precisely within this new model of food production in urban contexts.

7.2 ALCHEMETRY

Alchemetry fits into the Metropolitan Terroir landscape as a player aiming to **bridge the gap** between production and consumption by shifting the focus of the agri-food system directly into cities. Through the use of **Integrated Building Agriculture** and **CEA technologies**, the company cultivates healthy and sustainable food sources, focusing on **novel foods** such as algae, insects and fungi within controlled environments capable of reflecting the characteristics of urban contexts in distinctive organoleptic and nutritional qualities. In addition to the production phase, Alchemetry operates as an integrated system that interfaces with consumers through an urban ordering and **distribution service**. Drawing inspiration from food delivery models, this platform delivers products directly to citizens, thereby closing the loop of the metropolitan agri-food system. By offering new food sources, the company enhances the city's resilience to climatic and geopolitical shocks, increasing production **self-sufficiency** and promoting a **healthier, more sustainable diet** integrated into the urban fabric.

Identity and Strategic Purpose

NAMING

The name Alchemetry is derived from the combination of the concepts of **Alchemy** and **Metrics**, which together perfectly encapsulate the company's objective and approach to the production of its food sources. The inspiration for the first part of the term comes directly from the world of the Japanese anime **Fullmetal Alchemist**, in which alchemy and **transmutation** represent the technique of radically transforming matter into something different. This concept was adopted because it faithfully reflects the company's aim to transform the characteristics of a building or an urban setting into the organoleptic and nutritional qualities of a specific food, making alchemy the conceptual cornerstone for defining the new Urban Terroir. The term "Alchemy" was then paired with the word "Metrics" to emphasise the **scientific** and **data-driven approach** that guides the creation of these products. The method is based on the use of advanced technologies capable of translating environmental parameters of the production context into precise commands and prompts to scientifically develop the profile of the new foods, making the process of transforming urban data into nourishment tangible and replicable.

MISSION

Alchemetry aims to **shape a new urban identity for food**, transforming the environmental and cultural parameters of architectural heritage into the exceptional organoleptic and nutritional qualities of its products. By **defining the concept of the contemporary "urban terroir"**, Alchemetry transforms urban buildings into decentralised production centres, ensuring a resilient food system that distils the essence of the city into highly valuable nutritional experiences.

VISION

In a context marked by the growing fragility of rural agricultural systems, Alchemetry aims to drive change by bringing food production back into the heart of cities, bridging the gap between resources and consumption. The company promotes the **transition towards more resilient, sustainable and healthy models** by encouraging diets based on **alternative proteins** with a lower environmental impact than traditional animal sources. By repurposing architectural heritage into production hubs, Alchemetry **transforms urban areas into self-sufficient centres** capable of effectively responding to global challenges, **defining a new food paradigm** that is perfectly integrated into the **metropolitan context**.

Visual Identity and Brand Language

LOGOTYPE

The Alchemetry logotype is designed to ensure complete **versatility**, adapting effectively to both digital interfaces and physical media. The design features **minimalist**, **clean lettering** that deliberately evokes the **technological aesthetic and scientific rigour** of laboratories, reflecting the precision that characterises the new urban production model. The brand identity is expressed through two fundamental **graphic stylisations** that are perfectly integrated into the original typographic rhythm. The **letter M** is reinterpreted through three vertical strokes that evoke the **silhouette of the urban context**, visually anchoring the company within its operational territory. Finally, the **degree symbol (°)** has been graphically transformed to

recall the essential **shape of a plate**, symbolising the completion of the transmutation process carried out by Alchemetry, where the complexity of urban parameters finds its final synthesis in the realm of food. Both graphic interventions have been calibrated to precisely respect the visual footprint of the standard typeface, keeping the area occupied by the lettering unchanged and ensuring a constant and harmonious compositional balance.

Logo (standard)



Logo without pictograms



Colour Variations





Logo Space





Logo Dimensions (standard and minimum)



PALETTE AND TYPOGRAPHY

The choice of typeface and colour palette was guided by a desire to communicate a **scientific and elegant aesthetic**, capable of balancing the rigour of the laboratory with strong visual recognition. The aim is to transmit a sense of technological precision through a **minimalist and clean design** language, while ensuring **excellent legibility** in every context. The typographic system is based on the use of the **0Arame Mono** font, chosen for its geometric structure and minimalist appearance, which immediately evokes the data-driven

and scientific nature of the urban production system. This minimalist typeface is not only functional in conveying clear information, but also serves as a graphic element that **reinforces the company's tech-oriented image**, evoking the formal cleanliness and discipline typical of advanced research environments. As for the colour palette, it is built on a predominantly **black-and-white base**, evoking the aseptic and orderly atmosphere of laboratories. This neutral pairing is complemented by the colour **purple #9F83BB** as a strategic **accent colour**, used to highlight key details and the logo's graphic elements, breaking the chromatic monotony and adding depth to the company's visual identity.

Logo Typography

0Arame Mono

ABCDEFGHIJKLMNOPQRSTUVWXYZ
0123456789°

Title Standard

LOREM IPSUM

Font used: *0Arame Mono*
Color: *Black*
Dimension: *30pt*
Character spacing: *0*

Logo Palette

C 100	**R** 0	**C** 44	**R** 159
M 100	**G** 0	**M** 53	**G** 131
Y 100	**B** 0	**Y** 0	**B** 187
K 100	#000000	**K** 0	#9F83BB

C 0	**R** 255
M 0	**G** 255
Y 0	**B** 255
K 0	#FFFFFF

TONE OF VOICE

Alchemetry's tone of voice is designed to act as a **bridge between the scientific rigour of production** and the **sensory experience of consumption**. As the company engages directly with the public through a B2C distribution model, its communication must be able to **translate the technological complexity** of the production process into clear and **inviting language for its food products**. The company's technical and professional soul is accompanied by a **synesthetic and evocative language** capable of transforming the city's technical parameters into a narrative of taste. This language allows the message to be adapted to each specific urban context using **metaphors that link architecture to the nutritional qualities** of the final products, **guiding the consumer in the discovery of the new metropolitan terroir**. The **keywords** chosen to reflect the company's tone of voice are therefore:

- ***PRECISE:*** It sets the standard for **technical accuracy and scientific rigour** in communicating the **production process**, ensuring a professional image that validates the quality and safety of new food products.

- ***CLEAR:*** It represents the ability to **simplify the complexity of technological processes** by translating the creation of flavour into a **clear and easily accessible message** for the consumer.

- ***EVOCATIVE:*** It uses **synesthesia and metaphors** to **translate technical product specifications into taste characteristics**. It represents the most emotional aspect of corporate communication and aims to **make products appealing to consumers**.

7.3 Integrated Urban Food System

The new urban food system proposed by Alchemetry is an **integrated production model** that brings agri-food production directly into the heart of the city by repurposing distinctive **urban settings**. Based on the principles of **integrated urban agriculture**, the system identifies buildings where specific production modules for novel foods are integrated, creating a production and distribution ecosystem described in the System Blueprint ***(Fig. 7.1)*** and structured across **three main phases**. The first phase, known as **Metabolic Food Synthesis**, concerns the production of raw materials, where a network of sensors captures environmental parameters from the urban context and transforms them into optimal biological conditions within controlled-environment systems. This process enables the stimulation of targeted biological reactions in the crops used, defining unique nutritional and organoleptic profiles which, once produced, represent the system's primary output. Running parallel to this technical process is the **Urban Terroir Narrative**, a phase dedicated to building cultural and gastronomic links between the food and its urban context. This activity is led by the new professional figure of the **Urban Sommelier**, who coordinates both the technical management of production and the product's narrative to make it appealing and rooted in the urban environment. This narrative is then visualised on the **packaging** and explored in greater depth within the **service app**, which act as key touchpoints between the company and the consumer. The final phase, known as **Systemic Service Fulfillment**, constitutes the B2C component of the system and manages the customer interface via the digital application and the associated urban micro-logistics network. This final step ensures that fresh, ready-to-eat food reaches citizens directly, efficiently closing the production cycle. To demonstrate in practice how this new production ecosystem works, **Casa Fenoglio-Lafleur** ***(Fig. 7.1)*** in Turin has been chosen as the first pilot lab. The application to this historic Art Nouveau building is envisaged for around **2050,** at a time when the strategic and technological conditions highlighted earlier in the roadmap will allow this new production paradigm to become established, before potentially being extended to other geographical and architectural contexts.

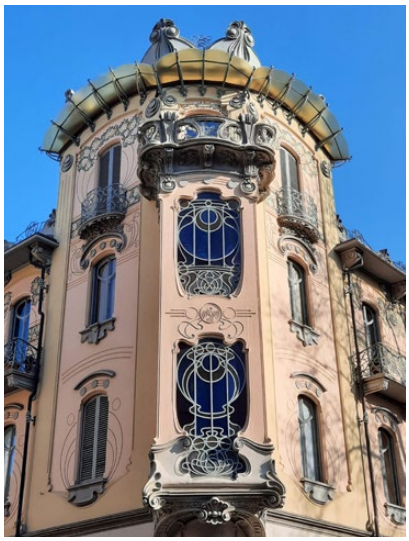
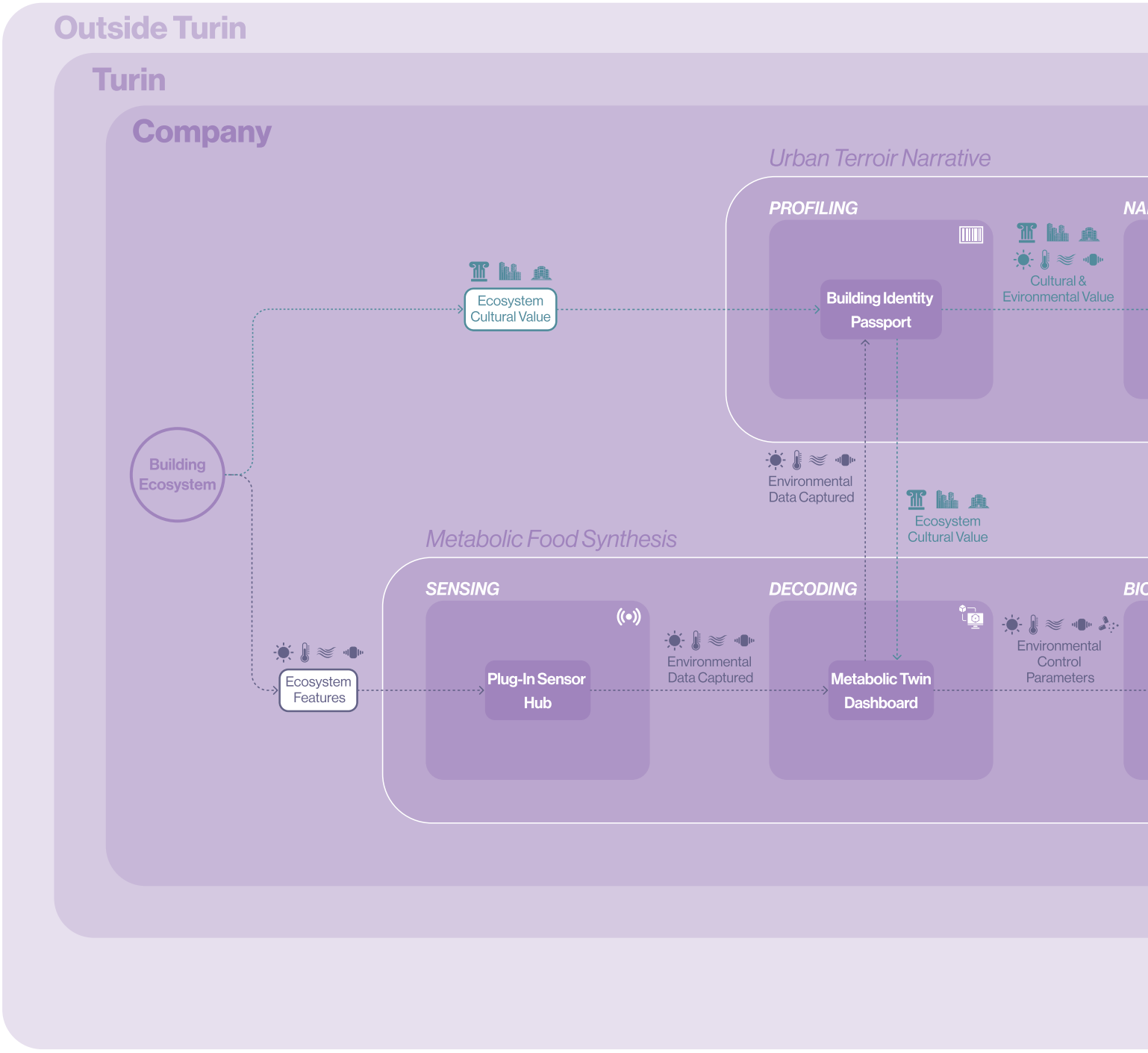
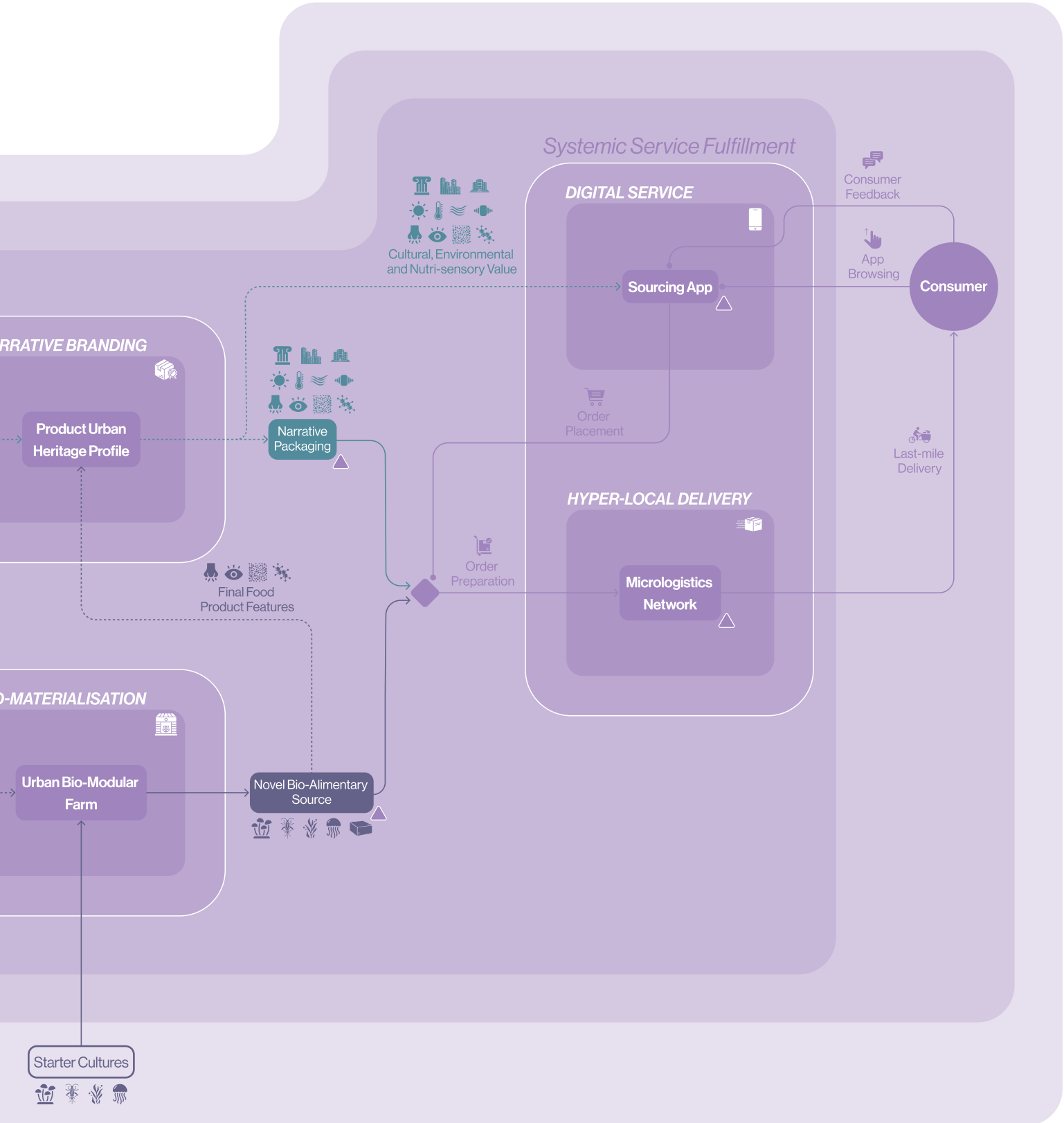


Fig. 7.2 Casa Fenoglio-Lafleur, Turin.



Type of Flows

Value Flow		Information Flow	
Technical Flow		Material Flow	
Service Flow		Digital Flow	



Type of Elements

- Macro-phase
- Specific Phase
- Artifact
- Technical Output
- Value Creation Output
- Technical Input
- Value Creation Input
- Starting Point
- End Point
- Finished product
- Touchpoint

Fig. 7.1 System Blueprint.

Metabolic Food Synthesis

This phase involves the production of organic raw materials based on parameters collected from the specific environment in which the production module is situated. A series of environmental sensors capture data such as **temperature**, **light**, **sound**, **humidity** and **CO2 levels**, which are then decoded and translated into management parameters for the controlled environment where the crops are grown ***(Fig. 7.3)***. As each building has unique characteristics and conditions that vary significantly depending on the time of day and the seasons, the system generates batches of produce that **reflect the specific urban context** in terms of **organoleptic profiles** and **nutritional values**. The initial crop is selected based on the mapping of these parameters, favouring the production of novel foods such as mushrooms, algae, jellyfish and insects, which are well-suited to indoor cultivation using controlled-environment technologies. In the proposed installation at Casa Fenoglio-Lafleur in Turin, the chosen species is **dulse**, also known as **Palmaria palmata** ***(Fig. 7.4)***. It is a red seaweed belonging to the Palmariaceae family, chosen partly because it reflects the organic and floral style of the Art Nouveau building. Found along the rocky northern coasts of the Atlantic and Pacific Oceans, dulse can be eaten fresh, but also fried or dried, developing a smoky flavour so reminiscent of bacon that it is often called **"vegetarian bacon"** (De Angelis, 2025). From a nutritional point of view, dulse seaweed is **richer in nutrients** than most green leafy vegetables, being a significant source of iodine, iron, **vitamin B6** and potassium, despite its sodium content (Britannica, n.d.).



Fig. 7.4 Dulse, Palmaria palmata.

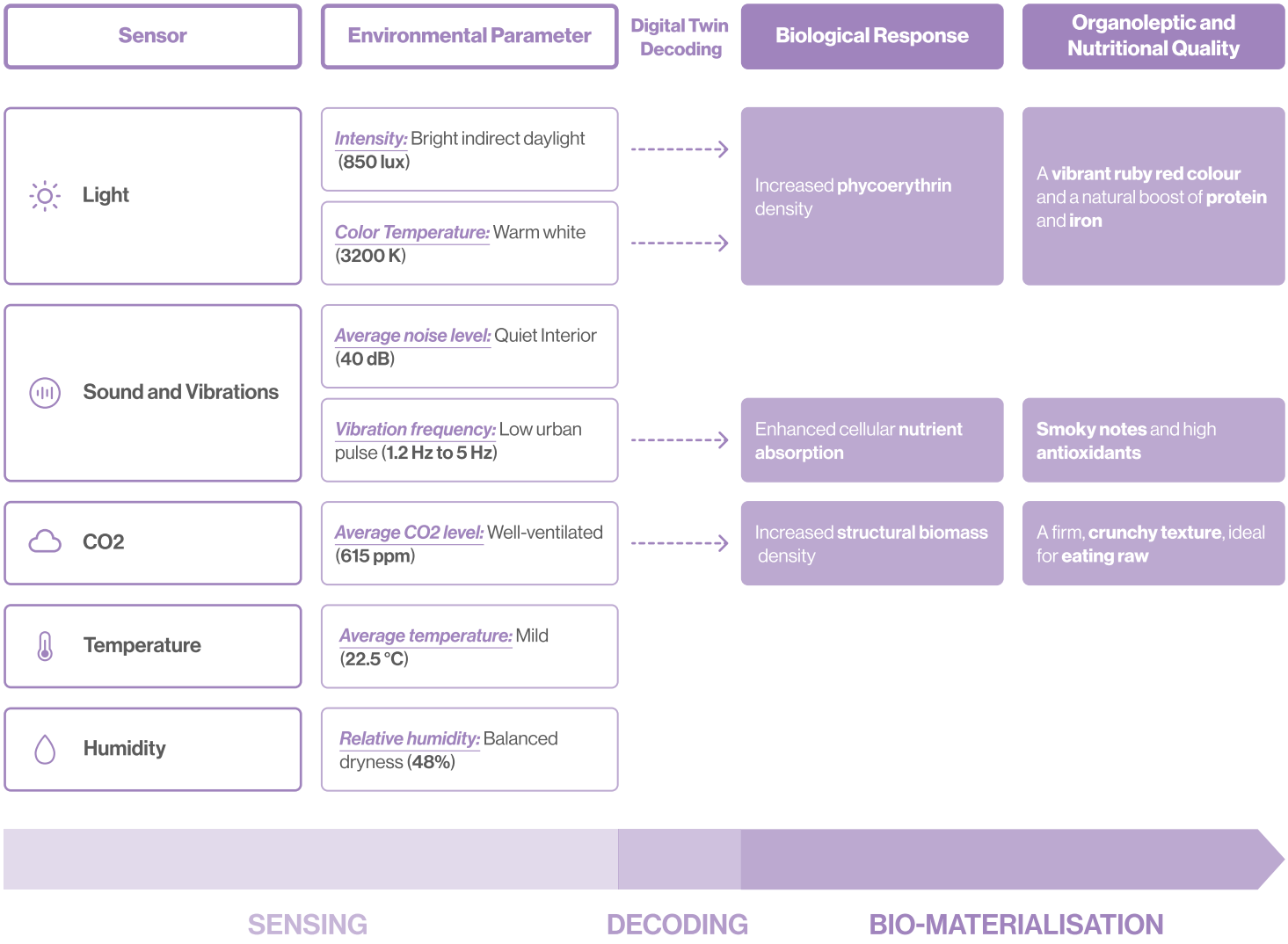


Fig. 7.3 Metabolic Synthesis Map.

STAGES OF THE METABOLIC FOOD SYNTHESIS

The macro-phase of Metabolic Food Synthesis is **divided into three consecutive sub-phases** that define the process of constructing and producing food raw materials. This process begins with an environmental analysis of the production context in which the module is situated and leads to the generation of raw materials ready for

consumption. The system is developed through the following steps:

1. ***SENSING:*** The first step involves **analysing the location** where the production module is to be installed using a sensor system capable of **capturing environmental parameters**. As shown in the mapping visualisation of the pilot lab at Casa Fenoglio-Lafleur ***(Fig. 7.3)***, the sensing phase maps specific parameters falling into five main categories: **light**, **sound and vibrations**, **CO2**, **temperature** and **humidity**. Each of these categories comprises subcategories of specific parameters that measure different characteristics of the entity in question. In the case of light, a fundamental parameter at Casa Fenoglio given that it is a building characterised by **large windows and glazed areas** with abundant natural light, its intensity and colour temperature are specifically analysed. In terms of noise and vibration levels, the analysis focuses on the average noise level, which determines whether the environment is quiet or noisy, and the frequency of environmental vibrations, which depends heavily on the location and its urban context. For CO2, the average CO2 level is analysed, which is influenced, for example, by the size of the building's rooms, the height of its ceilings, and also by the building materials used. Finally, for temperature, the average temperature at which the module is located is recorded, and for humidity, its relative humidity. In short, the **mapping of all these parameters defines the environmental features of the production context** under analysis, which serve as the input into the system **used to construct the organoleptic and nutritional profiles of the food**.

2. ***DECODING:*** The decoding phase is the stage at which the environmental parameter inputs, mapped during the previous sensing phase, are decoded. This process takes place using **Metabolic Twin**, a system that receives the collected data and **converts it into control parameters** within the production module, **managing the relevant environmental conditions** in which the selected crops will grow, as is the case at Casa Fenoglio for dulse seaweed. This phase is fundamental because it acts as the **bridge linking the sensing phase to the practical phase of food production**, namely bio-materialisation. Through this step, the technical connections necessary to correlate the production environment with the features of the final products are established.

3. ***BIO-MATERIALISATION:*** The final stage of bio-materialisation

is, essentially, the incarnation stage, where the environmental parameters mapped through decoding enable the culture to grow within the production module. In this step, the crops will develop **specific biological reactions** to **achieve the desired organoleptic and nutritional characteristics**. This phase, as shown in the Metabolic Synthesis Map ***(Fig. 7.3)***, is divided into two consecutive steps: one in which the biological response induced by the chosen environmental conditions takes place, and a second which defines the organoleptic and nutritional features of the final food product. These controlled and deliberate biological reactions enable the **definition of specific properties** which, under other specific conditions, would not have occurred in the same way. In the case of the Pilot Lab at Casa Fenoglio, in particular, the mapped **light parameters** are used to **stimulate the production of phycoerythrin**, which gives the final product a vibrant **ruby-red colour and a natural boost of protein and iron**. Similarly, **CO2 levels** are utilised so that the algae convert carbon into "structure" for their stems, ensuring a **firm and crisp texture**, ideal for **eating raw**. In conclusion, depending on the crop and the most distinctive features of the entities mapped within the environment, certain drivers will be utilised more than others to define biological reactions, acting as a hallmark to define the final organoleptic and nutritional properties of the product.

VISUAL ARCHETYPES AN POSSIBLE SYSTEM INTEGRATION IN CASA FENOGLIO

To make the metabolic food synthesis phase clearer and more tangible, **AI-generated images** have been developed to visualise and **imagine what these modular production units might look like**. The research focuses on how such modules would fit into the urban context of **Casa Fenoglio-Lafleur**. To this end, three images have been generated that explore different forms of workshops set within an Art Nouveau context consistent with the building's interior style. Although the three versions differ in terms of the form and aesthetics of the structures, the experimentation has focused primarily on the **approach to integration with the context**, analysing how the new structure interacts and integrates with the environment of Casa Fenoglio. Regarding the style of the production units, as these are systems for algae production, inspiration was drawn from the forms of existing **indoor algae and microalgae cultivation systems**, with the aim of making the generated designs appear realistic.

/Integration 1

Mimetic integration

In this initial visualisation, the aim is to integrate the production unit seamlessly by blending the module with the structural elements of the building's interior. This **fusion with the furnishings** makes the unit as discreet as possible, respecting and **enhancing the beauty of the Art Nouveau heritage**. The structure adapts to its surroundings through the organic morphology of Dulse seaweed, whose **biomorphic nature reflects the building's floral style**, facilitating a fluid and non-invasive integration.


ALCHEMETRY®
ENVIRONMENTAL PARAMETERS
Casa Fenoglio-Lafleur
LIGHT
Intensity: 650 lux
Temperature: 3200 K
SOUND & VIBRATIONS
CO2
TEMPERATURE
HUMIDITY
BIOLOGICAL REACTION
Pulse
Physiosynthesis development

/Integration 2

Installation-led integration

In the second visualisation, the approach shifts towards an installation-based integration. While reflecting the building's style through specific Art Nouveau details, the module remains **less embedded in the context** than the previous version. It acts as a **standalone totem**, recalling existing **decorative elements** yet functioning as an **autonomous presence**. This solution fits into the space by maintaining its **independence**, defining a distinct and clearly identifiable landmark within the interior of Casa Fenoglio.


ALCHEMETRY®
ENVIRONMENTAL PARAMETERS
Casa Fenoglio-Lafleur
LIGHT
Intensity: 850 lux
Temperature: 3200 K
SOUND & VIBRATIONS
CO2
TEMPERATURE
HUMIDITY
BIOLOGICAL REACTION
Dulse
Phycoerythrin development
86%

/Integration 3

Sculptural integration

This final visualisation represents the option that creates the strongest **contrast with the production context**. Although the aesthetic draws on specific Art Nouveau details, it represents a **“heavy” and sculptural integration**, highly scenic and almost dominant within the space. The aim is a **deliberate dichotomy**, making the module both conspicuous and opulent. Far from being invisible, the structure becomes a **protagonist** due to its elaborate aesthetic. This choice seeks to **enrich the context** through a **modernised, technological Art Nouveau style**, resulting in a more **“loud” and intentionally evident presence**.


ALCHEMETRY
ENVIRONMENTAL PARAMETERS
Casa Fenoglio-Lafleur
LIGHT
Intensity. 850 lux
Temperature. 3200 K
SOUND & VIBRATIONS
CO2
TEMPERATURE
HUMIDITY
BIOLOGICAL REACTION
Dulse
Phycoerythrin development
86%

Urban Terroir Narrative

As shown in the Ecosystem Map ***(Fig. 7.3)***, the UrbanTerroir Narrative represents a parallel phase that works in tandem with Metabolic Food Synthesis. While the previous stage focuses on capturing tangible environmental data, this second phase gathers the **intangible** and **cultural values** that define the urban context. It addresses the "delight" factor of the system, focusing on factors that are less concrete but essential to **shape the product's identity**. In this process, a central role is played by the **Urban Sommelier**. This figure is responsible for researching the **history of the building** and its urban surroundings, exploring **architectural styles**, the **spirit of the neighbourhood**, and the specific **vocation of the structure** where the module is hosted. These insights provide the **foundation for the product's storytelling** and **marketing strategy**, allowing the Urban Sommelier to associate historical or cultural narratives with the specific organoleptic characteristics of the food. This wealth of information is **communicated to the consumer** through various **touchpoints**, such as the dedicated **App**, where users can document themselves and explore the heritage behind each product. The **packaging** also plays a key role, as its aesthetic mixes Alchemetry's brand identity with visual references to the specific urban production site. Like the metabolic phase, this narrative has been developed starting from an analysis of Casa Fenoglio-Lafleur and its location in the San Donato district of Turin.

STAGES OF THE URBAN TERROIR NARRATIVE

This phase is divided into **two main sub-stages**, which serve to establish the product's visual and cultural identity, **reinforcing its deep connection with the building** and the relevant production context. These two key steps are:

1. ***PROFILING:*** The profiling phase involves **mapping the relevant urban context** and consists of gathering all information regarding the **building** and the **neighborhood** under analysis. This work is not limited to technical aspects alone, such as the study of architecture or building materials, but aims to identify, above all, the **set of factors that define the cultural and historical essence of the place**. The goal is to bring to light the intangible values linked to history, style, and functional purpose that define its identity in a broader and deeper way. With regard to Casa

Fenoglio-Lafleur, this analysis made it possible to gather a series of fundamental pieces of information that were then organised into **three main categories**, which are:

- *ARCHITECTURAL LANGUAGE & STYLE:* The Fenoglio-Lafleur House, **designed in 1902 by engineer Pietro Fenoglio**, is one of the **finest examples of Turin Art Nouveau** and an international manifesto of the style. Built for the 1902 International Exhibition, the building was initially conceived as the **architect's home and studio** and later sold to the **La Fleur entrepreneurs**. The work stands out for its extreme stylistic consistency, which pervades every detail, from the facades to the smallest elements of the furnishings. The most striking element is the **corner tower**, where the two wings of the building converge in a dynamic effect accentuated by the **famous bow window**. Here, the undulating **polychrome glass** filters the natural light, creating a vibrant chromatic atmosphere that interacts with the structure. The decorative elements celebrate the **floral repertoire** through the skilful use of **litocemento** for the friezes and **wrought iron for the balconies**, where the sinuous "whip-lash" line replaces the rigidity of the right angle. The presence of an overhead kiosk, reminiscent of Hector Guimard's Parisian shelters, emphasises the link with the most advanced European architectural culture, making the building a true urban sculpture where **elegance** and **technological innovation in materials** merge into a unique architectural organism.

  Keywords: Art Nouveau, Organic, Floral, Sinuosity, Dynamicity, Polychromy, Elegance

- *NEIGHBOURHOOD & SPIRIT:* The **San Donato district**, particularly the area stretching between Corso Francia and Via Principi d'Acaja, captures the most refined and **elegant soul of early 20th-century Turin**. Originally developed as an expansion area for the **upper middle class** of the time, the district still retains a distinct identity today, characterised by an **atmosphere of prestige and decorum**. Alongside the grandeur of its Art Nouveau architecture, San Donato is alive with an authentic vitality made up of **local markets**, **artisan workshops**, and **small antique shops**. It is a district where craftsmanship and attention to detail are still central values, reflecting a **tradition of craftsmanship** that has been handed down over time. Life in these streets fol-

lows a **slower, more refined pace**, where the beauty of historic buildings blends with the everyday life of neighborhood shops.

Keywords: Craftsmanship, Prestige, Liberty, Vitality, Refinement

- *BUILDING FUNCTIONAL VOCATION & HISTORY:* Pietro Fenoglio built this building with the aim of making it his **home and studio**. For this reason, **the interior atmosphere is dominated by silence** and **calm**, essential conditions for someone like him who needed to concentrate on research and design. **The light** entering through the bow windows was a fundamental working tool, **designed to illuminate the hours dedicated to culture and knowledge**. It is a place that conveys an intimate and personal dimension, where every detail was created to protect the tranquility necessary for creation. Even after passing to the La Fleur entrepreneurs, the building has retained its **intimate and intellectual soul**, remaining the mirror of a very intimate and silent professional vision.

  Keywords: Silence, Calm, Intimacy, Intellectual, Tranquillity, Light

NARRATIVE BRANDING: The next stage is Narrative Branding, the aim of which is to **synthesise the information gathered during the profiling process** to construct what is known as the **Product Urban Heritage Profile**. This profile outlines the territorial and cultural identity of the new food product created within that specific building and urban context. During this stage, the information gathered is filtered to **select the most relevant elements**, linking them through **evocative language** to the **product's culinary dimension**. The ultimate goal is to build a genuine heritage and an **urban gastronomic identity** that develops specifically in that place, which directly influences its final characteristics. The heart of this operation is the **reversion of the concept of terroir from rural to urban**: just as specific agricultural contexts define the quality and value of a product, here it is the urban context that determines the excellence and uniqueness of the food. This narrative of **urban gastronomic heritage** will then be used for **storytelling and marketing** communication through the main touchpoints, which are the final packaging and the delivery app interface. In this way, **the visual and communicative identity emer-**

ges in a distinct way for each product, making it unique **based on its specific production context**.

BRANDING ARTIFACTS AND COMMUNICATION TOUCHPOINTS FOR URBAN TERROIR NARRATIVE

The entire UrbanTerroir Narrative process has helped to **establish an urban and visual identity for the new food products**, forging a deep connection between the product, the building and its specific production context. This synthesis of values and information reaches the end consumer through the system's two main touchpoints: **the packaging** and **the app**. The aim of these artefacts is to **highlight the intrinsic link between the food and its place of origin**, visually and textually **evoking the cultural heritage of the production context**, which in this case features Dulse seaweed as the protagonist within Casa Fenoglio-Lafleur. The design of the packaging and the app thus incorporates evocative, **metaphorical and synaesthetic communication**, capable of **connecting the sensory sphere** of taste with the **cultural status and identity of the urban area**.

PACKAGING DEVELOPMENT AND VISUAL IDENTITY

The packaging has been designed in a **cylindrical shape** and made from a durable, **transparent plastic materia**l; it is clean and free of any graphics or text on the main body. This design is intended to **maximise the value of the Dulse seaweed inside**, bringing out its colours and **freshness through a vacuum-sealing system** made possible by a one-way valve integrated, which is essential for ensuring the preservation and retention of the product's organoleptic qualities. At each end, **two caps** in the distinctive Alchemetry purple colour #9F83BB have been fitted, featuring **minimalist graphics detailing the product's key characteristics** and, above all, its production context. The pack, approximately **25 cm tall** with a **diameter of 12 cm**, contains around **250 g of fresh Dulse** seaweed, just produced within the production unit. The durability of the material allows the container, once the product has been consumed, to be **sterilised and reused for other purposes** in the kitchen, such as a container for seasonings, thereby **extending the object's life cycle**. As for the packaging's visual identity, the aim was to **capture the Art Nouveau style and spirit of Casa Fenoglio**, as analysed during the UrbanTerroir Narrative phase, whilst seeking to **emphasise the**

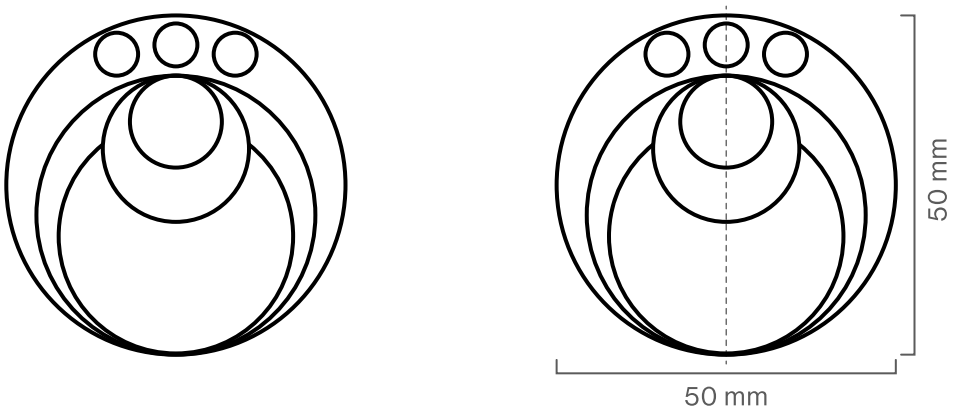
product's connection to the place through the following elements:

- ***GRAPHIC ELEMENTS:*** the main element is the **stylised version of the iconic window of Casa Fenoglio**, used as a graphic motif and distinctive seal to highlight and affirm the product's connection to its place of production.

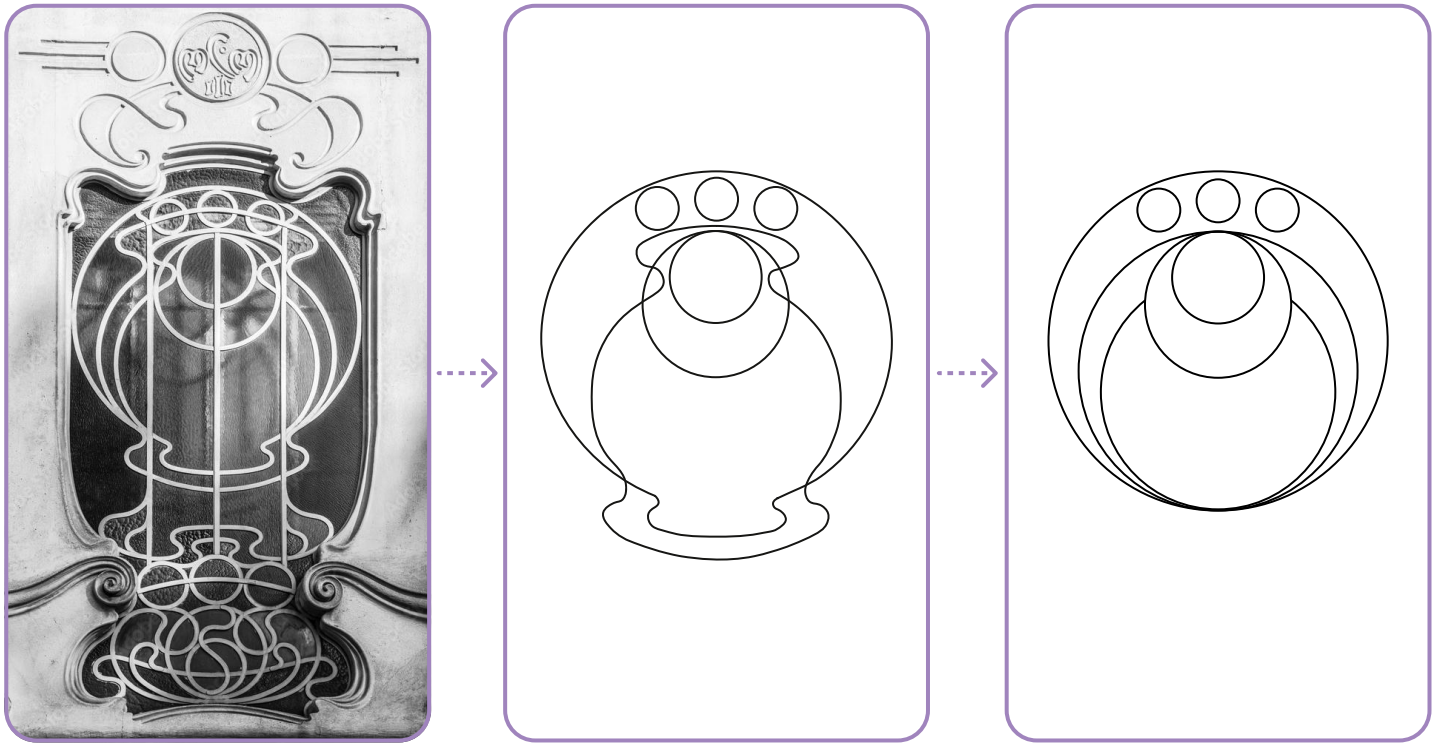
- ***TYPOGRAPHY:*** **Montserrat** (Regular and Italic) has been added to Alchemetry's signature **0arame mono** font, seeking to evoke the sinuousness and elegance of the Art Nouveau style whilst complementing the more technical style of 0arame.

- ***COPY:*** in keeping with the company's tone of voice, the **clear and precise language** is **accompanied by an evocative element** that seeks to describe the product through the phrase "Il gusto sinuoso ed elegante del Liberty torinese", aiming to convey this **correlation between taste and production context** in a metaphorical and synaesthetic way.

Pack Graphic element



Stylisation process



1 - Iconographic Source:

Identification of **iconic architectural details** from Casa Fenoglio-Lafleur to **define** the **visual language** and **graphic components** of the system.

2 - Formal Synthesis:

Simplification of **decorative motifs** and structural refinement, aimed at **preserving iconic features** within a balanced and **coherent geometric synthesis**.

3 - Serial Standardisation:

Engineering of the **graphic design** through the **integration** of **basic circular shapes** and tangents, ensuring that the visual identity is fully **replicable** and **scalable**.

Pack Typography

0Arame Mono

ABCDEFGHIJKLMNOPQRSTUVWXYZ
0123456789°

Montserrat

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt Uu Vv Ww Xx Yy Zz 0123456789 ”/#[]°%:

Logo

LOREM IPSUM — ***Font used:*** *0Arame Mono*
Dimension: *18pt*

Headline

LOREM IPSUM — ***Font used:*** *0Arame Mono*
Dimension: *15pt*

Sub-header

Lorem Ipsum — ***Font used:*** *Montserrat Medium*
Dimension: *11pt*

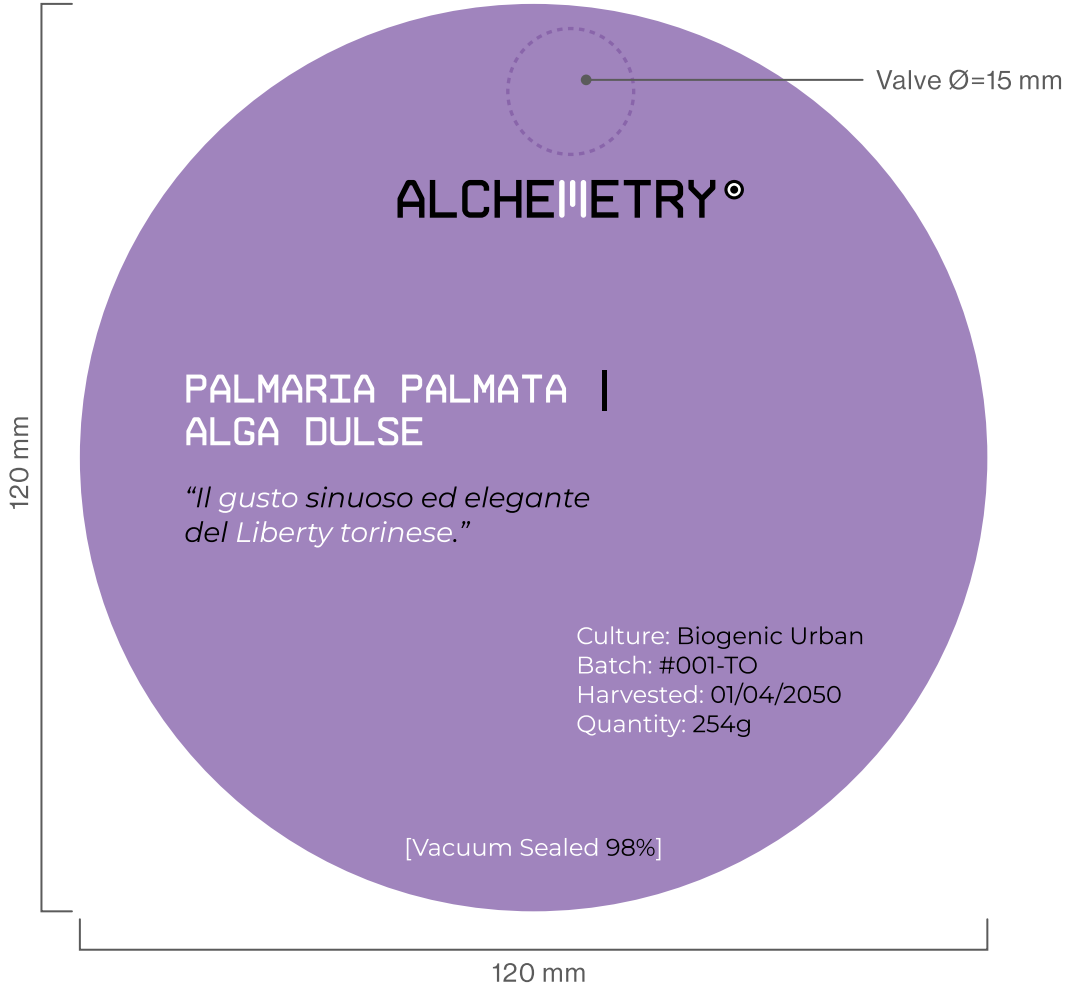
Claim

Lorem Ipsum — ***Font used:*** *Montserrat Italic*
Dimension: *10.5pt*

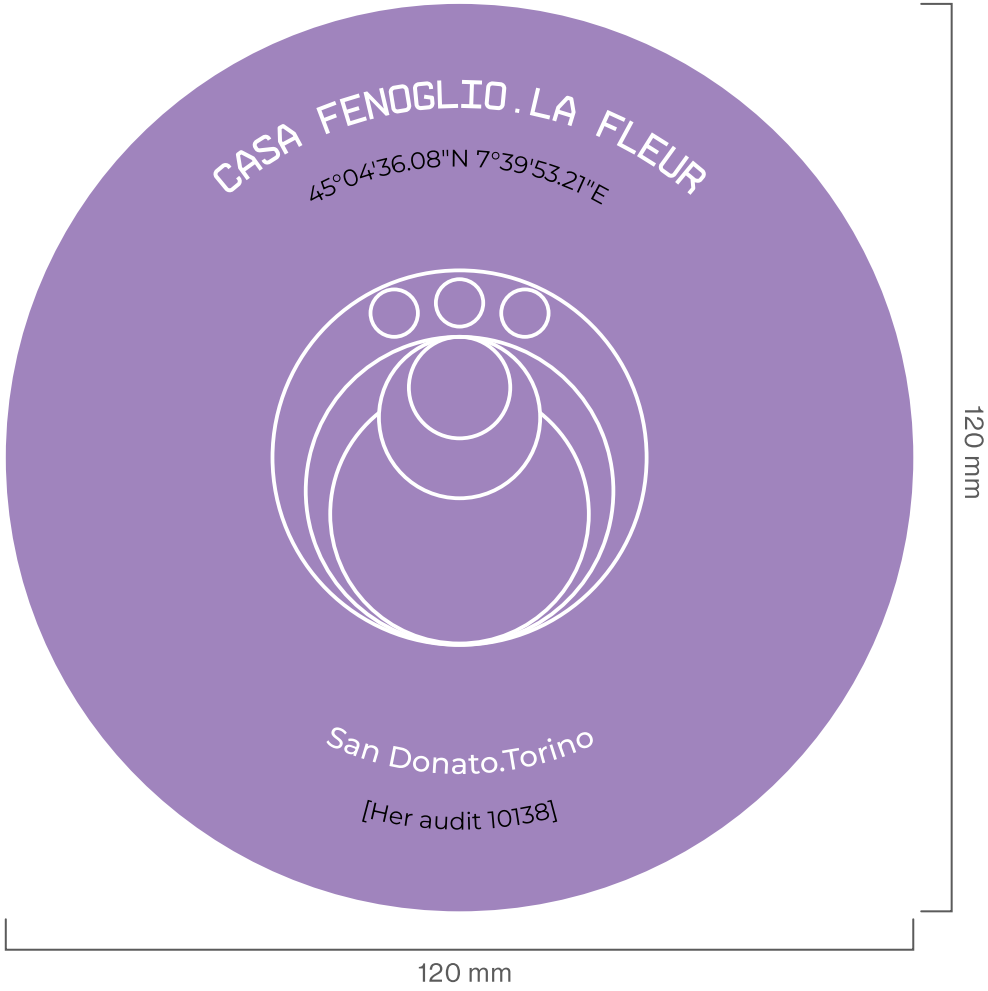
Body text

Lorem ipsum — ***Font used:*** *Montserrat Regular*
Dimension: *9pt*

Top cap artwork



Bottom cap artwork




ALCHEMETRY©
PALMARIA PALMATA |
ALGA DULSE
Culture: Biogenic Urban
Batch: #001-TO
Harvested: 01/04/2050
Quantity: 254g
Nectum Sealed


CASA FENOGLIO . LA FLEUR
45°04'36.08"N 7°39'53.21"E
San Donato, Torino
[Her audit 10138]


ALCHEMETRY©
PALMARIA PALMATA |
ALGA DULSE
"Il gusto sinuoso ed elegante
del Liberty torinese."
Culture: Biogenic Urban
Batch: #001-TO
Harvested: 01/04/2050
Quantity: 254g
[Vacuum Sealed] 98%

Systemic Service Fulfillment

As shown in the Ecosystem Map ***(Fig. 7.3)***, Systemic Service Fulfillment constitutes the **final stage of the process**, marking the crucial transition from the production of food to its **distribution within the social fabric**. While the previous stages focus respectively on physical production and the construction of cultural identity, this third stage represents the **B2C service aspect of Alchemetry**, namely the point at which the system and the company interact directly with the end consumer. The core of this phase lies in the integration of the digital platform with a **low-environmental-impact urban micro-logistics strategy**. The dedicated app enables consumers to browse a catalogue of local produce and **order fresh, hyper-local food directly within their city**. Distribution is then managed capillarly, ensuring delivery directly to the home or to strategic **collection points located in the neighbourhood**. This latter solution, in particular, not only meets criteria of logistical efficiency but aims to preserve and **enhance the relational aspect of shopping**. The idea is to transform collection points into genuine hubs of social interaction, a sort of **contemporary urban market** that **restores value to the community and the local area**. This final phase highlights how Alchemetry does not simply act as a producer, but operates as the manager of an integrated service capable of closing the loop of the new urban production ecosystem. In this way, the company accompanies the food throughout its entire journey, transferring the value generated in the urban laboratory directly to consumers' tables.

STAGES OF THE SYSTEMIC SERVICE FULFILLMENT

This phase is divided into **two main sub-phases designed to structure the distribution service** through which the company interacts directly with end consumers. The aim is to **complement the purely production-oriented aspect with an effective sales and delivery system** for new food products grown in urban settings, ensuring a direct link between the production unit and the local market. The two key steps are:

- ***DIGITAL SERVICE:*** At the core of this phase, there's the digital service provided by the **Alchemetry app**. The main goal is to **let people buy food produced in their local urban areas**, acting as a real bridge between the producer and the end consumer. Through this platform, **people can discover products grown in**

their own city and connect directly with the place where they're produced. The app works in a similar way to a **standard delivery service** but with a strong focus on **communicating local value**. In addition to home delivery, users can choose to collect their orders from specific **neighbourhood collection points**, aiming to encourage people to meet and interact, and transforming the act of shopping into an experience similar to contemporary markets, where the **social aspect once again plays a central role**. Among the other features on offer is a service dedicated to **managing unsold stock and daily surpluses**, similar to what Too Good To Go does. Through the app, it is possible to purchase any production surpluses from the various urban outlets at reduced prices, ensuring the system's efficiency and **preventing food waste**. Another key role of the app is to **raise awareness of these new foods**. It is therefore essential to **describe them clearly and technically**, explaining their properties to consumers whilst always maintaining a strong link to the urban context from which they originate. In this way, users can become familiar with these innovative foods and feel actively involved in the gastronomic and cultural identity of their neighbourhood.

- ***HYPER-LOCAL DELIVERY:*** The Hyper-local Delivery phase **completes the digital service** by **managing the physical distribution of food ordered via the app**. The role of logistics is to ensure that products reach consumers' homes or neighbourhood hubs quickly, guaranteeing a seamless transition from online purchase to actual consumption. This distribution is designed to **minimise environmental and social impacts within the city**. As journeys are very **short and hyper-local**, the service uses only **low-environmental-impact vehicles** such as **cargo bikes**, bicycles and small **electric vehicles**. This approach drastically reduces CO2 emissions associated with the last mile and ensures fast, punctual delivery to consumers. In addition to environmental sustainability, the choice of these vehicles is driven by the aim of r**educing noise pollution in urban areas**. The use of quiet vehicles ensures that the perceived quality of urban environments is not compromised, respecting residents' social lives and **limiting the noise disturbance** typical of traditional delivery services. In this way, Alchemetry's distribution logistics do not merely transport a product, but integrate into the neighbourhood in a discreet and respectful way, also seeking to improve the perceived quality of the urban environment in which it operates.

DIGITAL APP INTERFACE AND SERVICE FLOW

For the digital services component, an app has been designed following the **workflow of standard food delivery apps**, with the aim of selling food whilst adding a key **urban dimension to link production sites** to their various contexts and local landmarks. **Three interfaces** have been designed to reflect the **main sections flow**:

- ***HOME SCREEN:*** The interface starts by showcasing the **four primary categories of novel foods** produced by the company within the city. This is followed by a section highlighting the **main production sites situated near** the user's current location. At the base, a **Nav Bar** facilitates navigation, **allowing users to discover** the app's **core sections** and features.

- ***ALGAE SECTION:*** Following the home screen, this dedicated section allows users to **search and filter by algae species**. The interface showcases the **local network's favourite algae production sites**, presenting c**onsumer ratings** and **distance** to provide a minimal overview of quality and proximity.

- ***PRODUCTION SITE DETAILS:*** The third interface provides details of **individual production sites**. After selecting a building, users can find the **products currently available** at that site and **add them to their basket** to finalise the purchase.

APP VISUAL IDENTITY AND AESTHETICS

From an aesthetic perspective, the **black background** was chosen to highlight the product images and convey a **premium feel**. The visual identity incorporates the Alchemetry colour palette, whilst **transparency effects on cards** and graphic elements mirror the aesthetic of both the laboratory and the packaging. Regarding typography, **0arame Mono** is retained for headings and branding, whilst **Neue Haas Grotesk Display Pro** is used for informational text to ensure better **readability**.

Home Screen


9:41
VIA CAMANDONA, 4
Che cibo vorresti provare oggi?
ALGHE
FUNGHI
INSETTI
MEDUSE
Scopri cosa cresce vicino a te
CASA FENOGLIO
Batch 001
VILLINO RABY
Batch 003
CASA DEI DRAGHI
Batch 006
Home
Esplora
Ordini
Profilo

Algae Section



Production Site Details



LAST MILE DELIVERY AND SERVICE FUNCTIONING

The final part of the system concerns the distribution of food once it has been ordered by consumers via the app for delivery directly to their homes. This **hyper-local service follows the logic of the food delivery model** while relying on a **micro-logistics network** designed for **minimal environmental** and **social impact**. The system uses vehicles such as **electric cargo bikes** and bicycles, which generate very few emissions and are extremely quiet, thus **avoiding noise pollution**. As the routes and journeys are short and hyper-local, the use of these vehicles does not worsen traffic congestion and ensures a **minimal impact on the quality of the local urban environment**. As mentioned earlier, the service offers **home delivery** or collection from specific **neighbourhood collection points**. These spaces are designed to encourage people to get out and about and foster interaction among consumers, seeking to **preserve the social aspect** associated with food and recreating the atmosphere of a local market dedicated to these new products.


ALCHEMETRY

7.4 Urban Sommelier

Within the designed system, the Urban Sommelier emerges as an **eclectic and hybrid professional role** responsible for managing the entire production and distribution process of these novel foods. By acting as a **bridge between the scientific laboratory and the market**, this figure occupies a unique position halfway between the sciences and the humanities while working to raise public awareness of the new urban terroir. The role involves managing **technical tasks** like chemistry and biology for crop monitoring alongside an **analysis of urban architectural heritage** to find the narratives that will best engage and educate consumers. Furthermore, the Urban Sommelier uses **strategic storytelling for product positioning** and takes responsibility for **certifying the nutritional and organoleptic profiles** of the food through direct **taste testing**. His work alternates between hands-on laboratory tasks and moments of tasting or sensory analysis, eventually leading to the construction of a narrative identity. By applying communication and design tools, the Urban Sommelier transforms a technical output into an appealing product while **educating citizens** on the validity of the system and the **discovery of the new urban gastronomic heritage**.

Professional Profile and Competencies

The Urban Sommelier is a role characterised by a **highly diverse technical background**, as they are required to switch between **different tools and disciplines** throughout the various stages of the new system designed by Alchemetry. Their deeply multidisciplinary nature allows them to move easily between **technical and scientific fields** and areas more closely linked to **culture and the humanities**, integrating skills ranging from territorial analysis and the development of taste to storytelling and product marketing. These skills alternate in line with the project's progression, where initially the **chemical** and scientific knowledge required for mapping and crop cultivation takes precedence, later complemented by skills related to gastronomy and **sensory design**. At the same time, the construction of the Urban Terroir Narrative requires an in-depth **study of the architectural and historical characteristics** of the urban context to identify those social and cultural elements that make a difference to the narrative. Finally, the more **strategic and design-oriented skills** come to the forefront, dedicated to developing product identity and managing touchpoints, with the ultimate objective of **communica-**

ting the new urban territorial identity, making these foods appealing and appreciated by consumers.

AREAS OF EXPERTISE

The Urban Sommelier acts as a bridge between diverse fields, blending technical and scientific knowledge with humanistic, economic, and communicative disciplines. This multidisciplinary nature allows the role to manage the product from its initial development in the laboratory to its final narrative within the urban setting. **Chemistry** and **Biology** represent the technical core of the role, focused on research and development within the laboratory to monitor biological growth and environmental parameters. Alongside this scientific foundation, **Gastronomic Sciences** are used to define the nutritional and organoleptic profiles of the products, ensuring they are both high-quality and appealing to the market through continuous tasting and refinement. On the humanistic side, the Urban Sommelier conducts research into **Cultural Heritage**, studying the history and social significance of buildings and urban contexts where production takes place. Finally, **Design and Communication skills** are employed to build the overall narrative and storytelling. These competencies are fundamental for developing the various touchpoints like the packaging and the digital app, which communicate the new urban gastronomic identity of the food and make it accessible to the consumer.

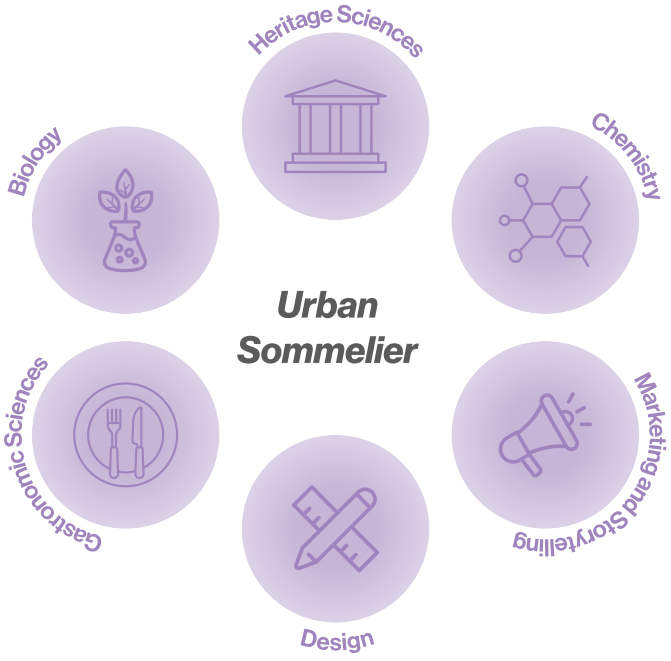


Fig. 7.5 Urban Sommelier, Areas of Expertise.

KEY SKILLS

Just as with areas of expertise, the Urban Sommelier must possess a **wide range of skills** in order to **manage diverse tasks within the system**. One of the key competencies is the **Urban Heritage Audit**, which enables the assessment of the production context through a comprehensive territorial and cultural analysis of both the building and the surrounding urban environment. This is complemented by **Biogenic Monitoring**, which is essential for the constant monitoring of crops through technical analyses and tests that ensure the proper functioning of biological processes and the stability of production in the laboratory. **Strategic Storytelling and branding** are also extremely important, as they involve the skills needed to communicate and narrate the products, creating a specific image and applying marketing strategies to make them recognisable and attractive. Finally, **Sensory Design** and **Food Design** are crucial for developing the nutritional and organoleptic profiles of new foods, making them appealing to the public. Within the scope of Food Design the sub category of **"Design for Food"** specifically addresses **packaging design** as an object that serves the food without being food itself ensuring a functional and aesthetic bridge between the product and the final user.

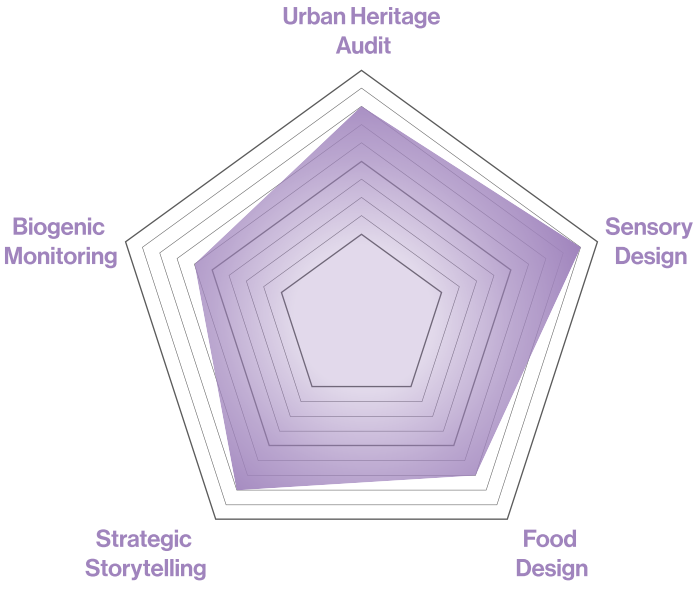


Fig. 7.6 Urban Sommelier, Key Skills.

Urban Sommelier Workflow

The **Urban Sommelier** oversees the **entire lifecycle of food production** within the Alchemetry system, managing every stage from the initial analysis of the urban context through to final distribution. This role involves **carrying out a wide variety of tasks** which, as highlighted above, draw on a diverse range of skills and abilities. Through this workflow, the professional acts as a bridge between urban data and the culinary experience, ensuring that every food product is the result of a coherent and integrated process. The process is divided into **four main, sequential stages** ***(Fig. 7.7)***, each characterised by the use of specific tools that guide the Sommelier from technical research to cultural storytelling.

1. ***MAPPING:*** In this initial phase, the Urban Sommelier is responsible for **researching and selecting the most suitable urban settings** to host future production. The process is divided into two key stages: the first involves a **historical and cultural analysis** of the production sites, which will lay the foundations for the narrative surrounding the products grown there, while the second stage involves a technical survey focusing on the **building's environmental parameters**, such as humidity, temperature, CO2 levels, light, sound and vibrations. This assessment is crucial for **identifying the most interesting and technically suitable locations** for launching production. To carry out this task, the Sommelier uses **biometric probes** equipped with **advanced sensors** capable of **mapping the site's conditions in real time** and evaluating its production potential.

2. ***CODING:*** The Coding phase is the first stage of laboratory work, during which the mapped environmental **parameters are decoded** and **translated into control protocols** for the production modules. The process begins with the conversion of the collected data into **specific codes** that **will define the growth and development conditions for the crops** within the controlled environments. This translation is followed by the actual synthesis phase, in which the species are placed in the greenhouses and subjected to the defined parameters to **stimulate targeted biological reactions**. During this experimental phase, the Urban Sommelier carries out various tests to observe how the plants react to environmental stimulations, using tools such as the **Digital Stereo Microscope** to perform detailed scans and analyse the results with extreme precision.

3. ***CRAFTING:*** The Crafting phase involves **sensory analysis** and **flavour development**, marking the final stage of production within the laboratory. During this stage, the Urban Sommelier selects the crop that has responded best to the conditions of the controlled environment, before refining its organoleptic and nutritional profile. The process begins with **identifying the variety** that has shown the **best biological responses** and the **greatest sensory potential**, before moving on to a precise modulation of flavour and nutritional properties. Here, the Sommelier applies their **gastronomic skills** through **flavour tests and sensory analyses** conducted using **sterile laboratory equipment** such as watch glasses, Petri dishes and precision spatulas, which allow the product to be analysed and tasted without compromising its integrity or original characteristics.

4. ***TELLING:*** This final phase represents the **post-laboratory activity** in which the product that has been developed is presented to the consumer to **communicate its value and identity linked to the urban context**. The process is divided into two main stages, beginning with an analysis of the food's most significant aspects in order to establish its identity and cultural value, thus clearly defining what it represents within the system. This is followed by the actual phase of **communicating and storytelling the product's value**, where the link with the local area and its organoleptic and nutritional qualities are conveyed to the public, primarily through the **app** and the **packaging**, which are key tools for **translating technical data into an understandable experience** capable of engaging the public.

1. MAPPING

Mapping and selection of urban terroirs

Step 1



Historical and **architectural analysis** of the production context.

Step 2



Measurement of **environmental parameters**.

Toolkit



Biometric Probe

2. CODING

Parameter coding and synthesis in lab

Step 1



Translation of the collected data into **crops "growth inputs".**

Step 2



Application of controlled parameters to trigger specific **biological reactions**.

Toolkit



Digital Stereo Microscope

3. CRAFTING

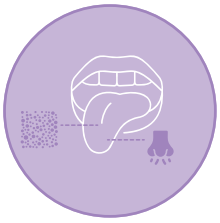
Sensory analysis and taste development

Step 1



Selection of the **best crops** for the identified environmental conditions.

Step 2



Modulation of the **organoleptic** and **nutritional profile** of the crop.

Toolkit



Technical Tasting Set

4. TELLING

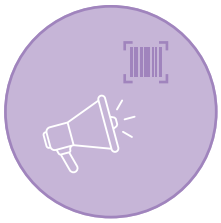
Value creation and storytelling

Step 1



Building the **identity** and **cultural value** of the product.

Step 2



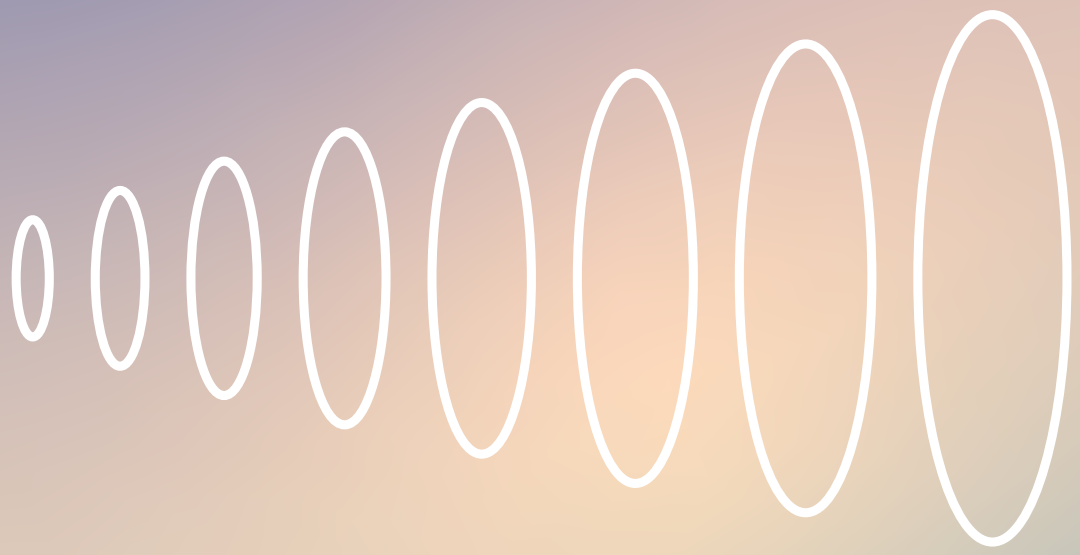
Explanation of the **nutritional properties** and connection with the **urban context**.

Toolkit



App & Packaging

Fig. 7.7 Urban Sommelier, Workflow and Toolkit.



08

Impact

Impact

The final stage of the methodology for identifying impacts concerns the process that takes place after defining the new Alchemetry system model, with the aim of **identifying the changes** it generates both within the agri-food system and at a broader level. This stage continues the **critical analysis** maintained throughout the project, providing a critical reflection on the consequences and changes that this new urban production system may trigger at a systemic level. The aim is to hypothesise both the **critical issues** and the **potential** that the project could bring to the current landscape. This final phase draws on the **Systemic Design methodology** of the **Politecnico di Torino**, which places it at the end of the process, defining it as **"Evaluating the System"** precisely to analyse the **effects generated by the new proposal**. This final exercise is necessary to provide a critical overview of the consequences of the intervention, highlighting the benefits but also the new challenges that this evolution of the system brings with it for the future.

8.1 Impact Flow

EVALUATING THE SYSTEM

The Evaluating the System phase represents the final critical step in the process and **serves to reflect in depth** on the **consequences and changes** that might result **from the adoption of the new system model**. Through this analysis, the aim is to **define the possible impacts at various levels**, taking into account both direct and indirect effects, as well as the interactions between them, regardless of whether they are positive or negative. To carry out this investigation, the systemic design methodology was integrated with the **Futures Wheel**, a tool typical of Strategic Foresight that **allows impacts to be identified and positioned across different levels**, hypothesising the connections and ramifications that link them.

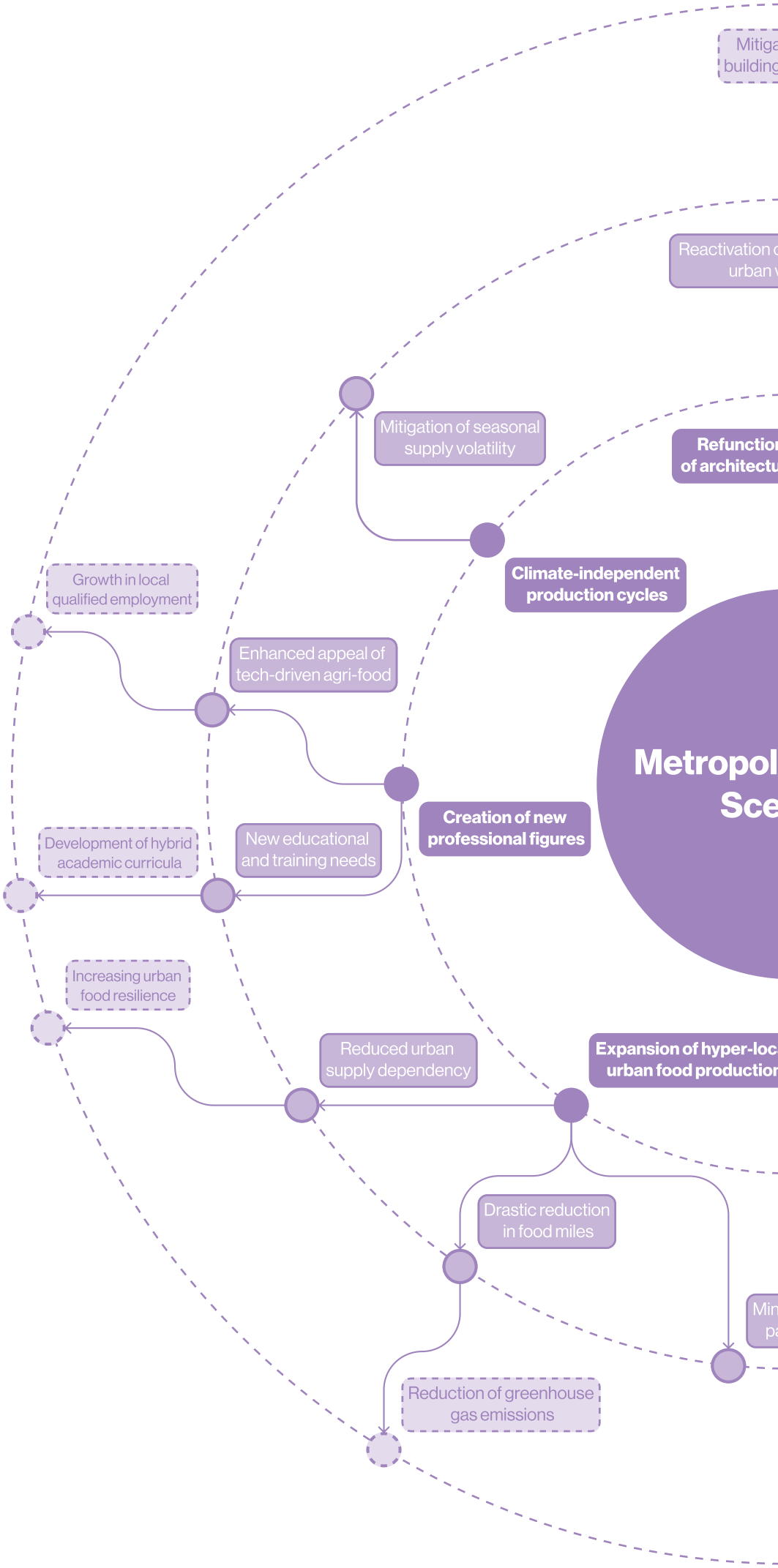
FUTURES WHEEL

The Futures Wheel developed by **Jerome Glenn** is a useful tool for mapping the direct and indirect consequences of a change. **Starting from a central core**, represented in this work by the **Metropolitan Terroir scenario** and the Alchemetry system, the analysis expands outwards, **identifying first-, second- and higher-order impacts of change**. This critical and systematic approach helps us under-

stand how a single transformation can influence various areas such as society, the economy or the environment over time. Using the Futures Wheel therefore means **looking beyond what is visible on the surface**, seeking to **predict how the system might evolve** and what new challenges might emerge, thus **providing a solid foundation** for a more **informed and in-depth planning process**.

8.2 Multi-order Systemic Impact Mapping

In the analysis of the impacts associated with the Metropolitan Terroir scenario, **seven key first-level changes were identified**, represented on the first dotted circle of the Futures Wheel ***(Fig. 8.1)***. These constitute the **most direct consequences of the new model** and, in turn, give rise to a series of second- and third-order cascading impacts shown in the outermost circles of the map. The analysis conducted has made it possible to explore these consequences, **highlighting both the advantages** and the **critical issues** of the new model proposed by Alchemetry. One of the first obvious aspects of this change becomes apparent when we compare this new model of hyper-local, urban agricultural production with the traditional rural system. Thanks to **controlled-environment technologies**, this approach proves to be significantly **more resilient and sustainable**, ensuring **independence from climate shocks** and a drastic **reduction in agricultural land** required. Furthermore, producing food directly within the neighbourhood **eliminates the distance between cultivation and consumption**, drastically **reducing logistics** and **associated pollution**. It is precisely this shortening of the supply chain that makes the agri-food system more resilient and **less vulnerable to external shocks**, promoting urban self-sufficiency capable of ensuring greater local food security. At the urban level, the model acts as a **driver of regeneration** through the **repurposing of architectural heritage**, restoring value to historic buildings otherwise destined for abandonment. At the same time, the introduction of these foods aims to bring about a **positive change in citizens' diets** by **encouraging healthier and more diversified eating habits** capable of reducing the risks associated with nutrient-poor diets. The only real limitation of this new model concerns **economic sustainability**, as maintaining environmental standards makes the process **energy-intensive** and therefore **vulnerable to geopolitical shocks** or sudden **fluctuations in the cost** of resources.


Mitiga
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Reactivation
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Mitigation of seasonal supply volatility
Refunctio
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Climate-independent production cycles
Growth in local qualified employment
Enhanced appeal of tech-driven agri-food
Metropol
Sce
Creation of new professional figures
Development of hybrid academic curricula
New educational and training needs
Increasing urban food resilience
Reduced urban supply dependency
Expansion of hyper-loc
urban food productio
Drastic reduction in food miles
Mi
pa
Reduction of greenhouse gas emissions

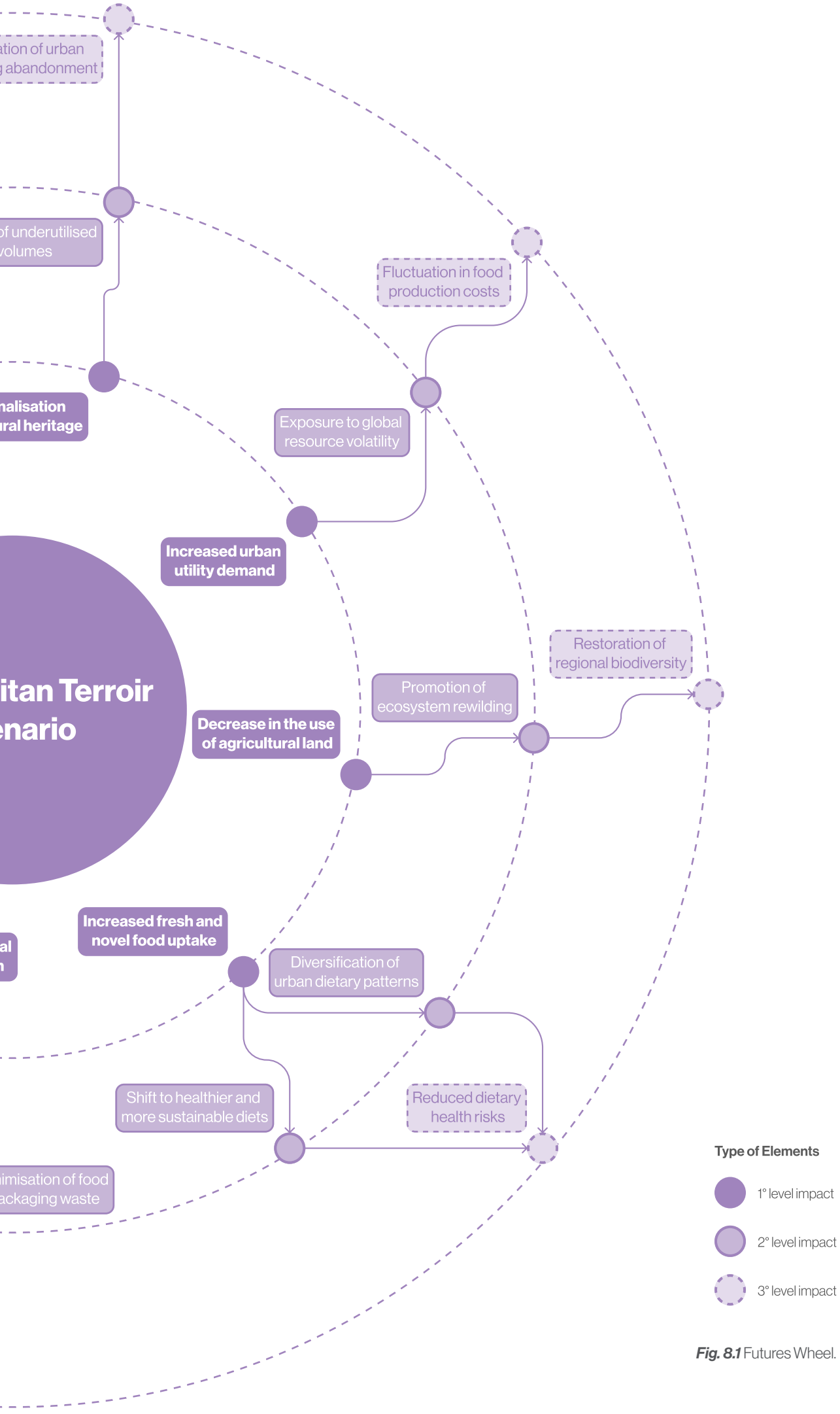


Fig. 8.1 Futures Wheel.

09

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Bibliography & Sitography

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