STUDY REPORT

Resilience of European Food Systems: Research and Innovation Mapping and Insights

Yuna Chiffoleau and Linda Rosengren

SCAR
Standing Committee
on Agricultural Research

SCAR Food Systems
food

Independent Expert Report by

Yuna Chiffoleau, affiliated to INRAE, France, Linda Rosengren affiliated to LUKE, Finland and the RefreSCAR project

Based on a study commissioned by the SCAR Food Systems Working Group

For citation purposes, please refer to the report using the following reference: Chiffoleau & Rosengren (2026), *Resilience of European food systems: research and innovation mapping and insights.* Independent expert report under the RefreSCAR project. Study commissioned by the SCAR Food Systems Working Group.

Disclaimer

Cover image credit: Image by Christian Mackie from Unsplash

Supported by the RefreSCAR project:

Funded by the European Union

The RefreSCAR project has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement no. 101060553

FIGURES

Figure 1: Relationships between food system resilience and related concepts. Source: Chiffoleau, 2025 11
Figure 2: Number of R&I projects according to what they aim to make resilient 15
Figure 3: Number of R&I projects according to beneficiaries of resilience building 16
Figure 4:Number of R&I projects according to the risks which are considered 17
Figure 5: Number of R&I projects according to the innovations which are developed or targeted 18
Figure 6: Clustering of projects based on multiple correspondence analysis (n=163) 19
Figure 7: Main topics studied in R&I projects on food system resilience, with their main R&I frame or funding sources 20
Figure 8: Number of R&I projects according to the targeted food systems outcomes. 37
Figure 9: Number of R&I projects according to the research methods 37

TABLES

Table 1: Case study on analysis and managing cascading risks in food systems 22
Table 2: Case study on population/communities' preparation 40
Table 3: Case study on water scarcity 41
Table 4: Case study related to energy 42
Table 5: Case study related to alternative proteins 43

Table of Contents

Abstract 5
1. Introduction 5
2. Methodology 6
3. Food system resilience from a conceptual perspective 8
3.1 Most common concepts of resilience 8
3.2 Food system resilience 9
3.3 Food system resilience and related terms 11
3.4 Food systems subject to different risks, shocks and stresses 12
4. State of the art in food systems resilience R&I in the European Union 14
4.1 Analytical approach to clustering 14
4.2 Content analysis 19
5. Case studies 21
5.1 Case Study 1: Analysing and managing cascading risks 21
5.2 Case Study 2: Preparing populations to shocks 23
5.3 Case Study 3: Facing water scarcity 23
5.4 Case Study 4: Facing energy-related disruptions 24
5.5 Case Study 5: Developing alternative proteins 24
6. Future research and innovation needs, and policy insights 25
6.1 R&I and policy gaps identified in the survey 25
6.2 Integration of study results for insights and recommendations 27
7. Conclusion 30
Acknowledgements 32
Funding 32
References 32
Appendix 1. Systematic review of the database portfolio analysis: Method of the project abstract coding and additional figures 36
Appendix 2. Multiple correspondence analysis 38
Appendix 3. Case studies 40

Abstract

Resilience has become a major theme in research, innovation and public policy over the past decade, against a backdrop of multiple and interlinked crises. The SCAR Working Group on Food Systems (SCAR Food Systems) commissioned the Horizon Europe-funded RefreSCAR project to conduct a study to better understand the research and innovation (R&I) undertaken to date on the resilience of food systems and to formulate recommendations for Food 2040, the European Commission's forthcoming strategic R&I agenda on food systems. This report presents the main results of this study, based on a synthesis of key resilience concepts, a systematic review of 163 R&I projects identified through database searches, an online survey and five case studies on key themes for food system resilience.

The review identified a marked increase in food system resilience R&I between 2015 and 2025, with the number of funded projects almost doubling after 2020.The analysis shows a significant imbalance in the approach of R&I projects. Most projects focus on strengthening the resilience of primary production to the effects of climate change through a technical approach to resilience aiming to maintain or restore key functions of food systems. Relatively few adopt a transformative approach in which food system resilience is enhanced through profound changes towards sustainability. Content analysis further shows that holistic food system perspectives and organisational innovations are only weakly represented, and explicit consideration of cascading and compound risks is extremely rare.

The findings suggest that the current European R&I portfolio is only partially aligned with the holistic food-system perspective promoted in recent EU food system strategies, highlighting opportunities for Food 2040 to strengthen systemic and transformative approaches to resilience. They point to the need for greater investment in holistic food-system resilience, governance, supply chains, by promoting better coordination between technological and organisational innovation, as well as the need to develop R&I on cascading and compound risks.

Keywords: food system resilience, R&I project: state of the art; research gaps; policy; Food 2030

1. Introduction

A food system refers to the entire network of actors, activities, and resources involved in producing, processing, transporting, distributing, consuming, and disposing of food. Food systems can be local, regional, or global, and they are influenced by numerous factors, including policies, technology, climate change, consumer behaviour and citizen concerns. A well-functioning food system ensures access to safe, nutritious, and affordable food and provides a set of ecosystem services while minimising negative impacts on the environment and society – often referred to as its "food system outcomes". Food systems are closely linked to neighbouring systems, such as water systems and energy systems.

Food systems are highly vulnerable to shocks and stresses due to their complex, interconnected nature. Sudden shocks such as extreme weather events, pandemics, conflicts, economic crises, and pest outbreaks can disrupt food production and distribution. Long-term stresses, including climate change, soil degradation, biodiversity loss, urbanisation, and demographic shifts, further threaten food security. Dependence on global supply chains, resource-intensive agriculture, and policy fluctuations exacerbate these risks.

As pressures intensify, strengthening food system resilience has become a key research and policy priority in the EU. Produced for the SCAR Working Group on Food Systems (SCAR Food Systems) as part of the Horizon Europe funded RefreSCAR project, this report takes stock of how food system resilience has been addressed by R&I in Member States (MS) of the EU. More precisely, the report addresses the following objectives:

1. Produce a concise overview of the most common concepts of resilience.
2. Synthesise existing knowledge on cascading risks and systemic shocks and stressors in EU food systems.
3. Document and gather real life case studies from EU MS on food system resilience.
4. Provide R&I recommendations deduced from these. Identify what kind of R&I needs are (still) valid and need to be addressed in R&I strategies and programmes.
5. Provide suggestions on how resilience can be incorporated in EU Food 2040.

2. Methodology

To achieve the study objectives, the research was structured into three phases:

1. Conceptual understanding
2. R&I mapping
3. Insights and recommendations

Conceptual understanding - Phase I focused on mapping the most common concepts of food system resilience. The literature review was conducted using Web of Science and Google Scholar, employing search terms such as "food system resilience," "resilience of food systems," "resilience of the food system," "food resilience," AND "definition", "concept", "approach". The study also included a review of existing literature on cascading and systemic risks in relation to food systems, using the key words "cascading risks", "compound risks", "systemic risks" AND "food systems". The main outcome of Phase I was an overview of the most common concepts of food system resilience as well as the types of cascading risks addressed in existing studies on the topic.

R&I mapping - Phase II aimed to draw up the state of the art of R&I related to food system resilience using a mixed-methods approach to review funded European and national R&I projects. Data collection consisted of a database search for relevant projects and associated literature. Both quantitative and qualitative methods were applied to analyse the dataset.

A search for funded research and innovation projects related to food system resilience was conducted for the period 2015–2025 (as far as possible) across ten databases: CORDIS (EU portal compiling EU-funded projects through the EU R&I programmes), PRIMA booklets (gathering projects funded under the PRIMA programme, available for the period 2018–2024), and national research council databases from Finland, Sweden, Denmark, Austria, the Netherlands, Germany, and France. Additional sources of national funding were identified in France and Finland due to the authors' countries of origin. The search used combinations of the following keywords: "food system resilience", "resilience of food systems", "resilience of the food system", "food resilience", "resilience of agriculture" AND "food", "resilience of crops" AND "food", "resilience of farms" AND "food", "resilience of farming systems" AND "food", "resilience of animals" AND "food" as well as "cascading risks" AND "food", "compound risks" AND "food", "systemic risks" AND "food".

Project abstracts and related metadata formed a first dataset, resulting in a total of 163 projects included in the final analysis. This dataset was examined using both qualitative (textual analysis of abstracts with CorText Manager tools) and quantitative (descriptive statistics and multiple correspondence analysis) methods. Quantitative data was obtained from coding project abstracts. For this, we used one of the most common frameworks for analysing projects on food system resilience, based on four questions for which we specified various modalities: resilience of what, to what, from whose perspective, and for how long (Zurek et al., 2022; Ingram et al., 2023). In addition, we coded the types of innovations considered or supported in the project (technological, organisational, institutional), the food system outcomes addressed (food security, environmental and/or socio-economic benefits), and the methods used (quantitative, qualitative, modelling, etc.) (see Appendix 1).

It is important to note at this stage—and we will return to this point later—that the documentation on R&I projects is incomplete and sometimes inaccessible (links are no longer active). Identifying projects using keywords was also highly dependent on how the projects have been tagged in the databases. In many cases, keyword searches returned projects that never mentioned "resilience" or "risks" in the related documents, so we did not keep them. For the case studies, we also used a 'snowball' approach to identify projects cited by others as important on the subject, even though they were not identified through keyword searches.

In addition, an online survey was conducted, targeting coordinators and principal investigators of a set of projects (n=60) identified at the beginning of the database search. The survey collected data from 30 projects (50% response rate), representing projects active in 24 countries of the 27 MS. Coordinators and/or principal investigators were asked to describe their projects based on the same variables as those used to code the project abstracts (Appendix 1), that was a way to test the validity of our coding from this sample. Respondents were then invited to identify knowledge gaps related to food system resilience research and innovation, which were useful for Phase III. This second dataset also helped to identify instructive projects for case studies.

Five themes were selected for case studies: cascading risks, water, energy, alternative proteins, and preparation of populations for shocks. The themes were selected based on the topics of interest to the SCAR Food Systems Working Group that commissioned the study (cascading risks, water, energy), the heuristic value of the themes in illustrating the two main concepts of resilience (alternative proteins), and the relevance to the EU's strategy for increasing resilience (preparation of populations for shocks).

Insights and recommendations - Phase III aimed to identify research and innovation gaps and to develop recommendations on how resilience can be further integrated into the EU Food 2040 R&I and policy framework. Based on the combined results of Phases I and II, and feedback from the SCAR Food System Working Group, a set of recommendations was developed to guide future research and policy action.

3. Food system resilience from a conceptual perspective

3.1 Most common concepts of resilience

The term resilience originates from the Latin "resilire", meaning "to leap back" or "rebound". Initially used in the 17th century in physics and engineering, resilience described the capacity of materials to return to their original state after deformation. By the 20th century, the concept expanded into psychology, where researchers such as Garmezy, Werner and Cyrulnik explored resilience as an individual's ability to adapt and recover from adversity (Schechter, Halevi, 2023).

In the 1970s, Holling (1973) introduced resilience into ecology, defining it as an ecosystem's ability to absorb disturbances while maintaining its core functions, relationships, and identity. This broadened the term's application to environmental science, disaster management, and climate adaptation. Building on Holling's work, the Resilience Alliance collective extended the concept of ecological resilience to the social sciences in the 1990s, integrating the interdependence of human and ecological systems through the notion of socio-ecological systems (SES). SES resilience reflects the capacity to persist, adapt, and innovate in response to uncertainty and disruption and focuses on preserving identity and core functions while enabling deliberate system evolution (Walker et al., 2004; Folke et al., 2010). Three key capacities characterise resilient systems: robustness, adaptability, and transformability (Walker et al., 2004). The SES perspective thus stresses resilience as not only an ability to return to the initial state but also as the capacity to transform, and views crises as opportunities for transformation (Folke et al., 2010). By the 21st century, the concept of resilience has been integrated into other disciplines and fields of application (e.g., cybersecurity, urban planning).

However, some tension can be observed in the literature in relation to whether resilience should be understood as a neutral system property or alternatively as a quality with positive connotations (Elmqvist et al., 2019). Especially outside the scientific arena, the term resilience has become widely used to refer to something positive, but also within sustainability science, resilience is often implicitly presented as something positive. The Sixth Assessment Report of the IPCC (2023) puts forward the following definition of resilience: The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation. In systems research, on the other hand, resilience is considered a systems attribute that is neither "good" nor "bad". Organised crime can, for example, according to this interpretation, be very resilient. However, numerous reviews point out that resilience has evolved from a primarily analytical and descriptive concept to a normative goal or management approach (Moser et al., 2019).

The second line of debate in the literature on resilience concerns the focus on resistance or recovery vs. transformation, in other terms on 'bouncing back' vs. 'bouncing forward' in the face of a shock. While bouncing back relies on incremental changes to return to the initial state, bouncing forward involves major, fundamental change. Many researchers thus point out that the application of resilience is often limited to bouncing back, as in most work on urban resilience (Muñoz-Erickson et al., 2021), whereas social and ecological challenges require bouncing forward, which has prompted a growing body of literature on transformative resilience (Asadzadeh et al., 2022). These debates also permeate the literature on food system resilience.

3.2 Food system resilience

The most widely cited definition of food system resilience was proposed by Tendall et al. in 2015 and refers to the capacity over time of this system and its units at multiple levels to provide sufficient, appropriate and accessible food to all, in the face of various and even foreseen disturbances (Tendall et al., 2015). In light of the first debate on resilience mentioned above, according to these authors, resilience in a food system is something desirable and positive. Their normative definition excludes the risk of enhancing resilience where it produces undesirable outcomes, such as food insecurity or environmental degradation. In this definition, other social and environmental outcomes of a food system are not explicitly taken in account but considered as favourable to the system's resilience. In this perspective, sustainability is one of the conditions of food system resilience, while resilience is a dynamic capacity to achieve sustainability.

However, as highlighted in a recent review questioning the possibility of a unified definition of food system resilience, this general definition raises questions, such as what exactly is 'capacity', and what food is 'sufficient' and 'appropriate' (van Wassenaer et al., 2021). Tendall et al. themselves comment that "much has still to be learned to validate food system resilience from an analytical perspective".

In light of the second debate on resilience, our review of the most common concepts of food system resilience leads us to suggest two main approaches. The first approach, in line with Tendall et al., proposes a technical, pragmatic approach to resilience, based on work in ecological resilience, emphasising the importance of resistance and adaptation (or coping). In this approach, transformation is considered necessary especially when adaptation is no longer sufficient. As highlighted in particular in the FAO report following the COVID-19 crisis (FAO, 2021), resistance and adaptation can be prepared for by anticipating crises. Here, technological and/or organisational innovations play an important role, for example to monitor critical resources (water, energy, etc.) in order to anticipate shortages, resist and adapt. This approach focuses on restoring key functions of food systems, particularly that of ensuring food security: we name it **'restorative' or 'technical resilience'**.

The second approach is based on the statement that certain food systems are structurally vulnerable and/or unsustainable, and that their resilience requires profound and even radical changes, not merely a return to normal. This second approach is part of the broader scientific field on **transformative resilience**, mentioned above. The 2017 report of the High-Level Panel of Experts on Food Security and Nutrition (HLPE) is one of the most cited illustrations of this approach applied to food systems (HLPE, 2017). It emphasises the need to develop sustainable food systems to enhance their resilience, thus also referring to technological and/or organisational innovations but with a contrasting objective that is to transform vulnerable and/or unsustainable food systems. This approach has been put forward during the COVID-19 crisis, which highlighted the vulnerabilities of the agro-industrial system as well as the multiple risks associated with the global food supply's excessive dependence on it (Blay-Palmer et al., 2021). Work based on this approach emphasises the importance of diversifying and relocalising food systems, meaning strengthening the production, processing, distribution, and consumption of food within a specific region to reduce dependence on global supply chains. This approach also draws on agroecology and multi-actor governance to ensure food security. The 2025 HLPE report expands the concept of transformative resilience, proposing that of 'equitably transformative resilience', which involves enabling capacities and agency, and strengthening socioecological interdependencies to ensure food security and nutrition for all, while respecting planetary boundaries (HLPE, 2025).

Local food systems have thus been the subject of renewed attention from the perspective of transformative resilience since the COVID-19 crisis (IPES-Food, 2024). However, local food systems can also be analysed along a technical approach to resilience, as in many projects aiming to build the resilience of the local food system through crop resilience. Moreover, while some studies suggest that local food systems contribute to global food system resilience by diversifying food systems (Yoshizumi, Miyaguchi, 2025), others see them more as a suitable scale for analysing the conditions and factors that build resilience, particularly through actor-level agency (Béné, 2020).

Moreover, whatever the scale or the approach, three attributes of resilient food systems are usually put forward (see, for example, Himanen et al., 2016):

- diversity: a variety of food system elements can serve a similar purpose;
- modularity: food system elements have a relative autonomy to function;

- redundancy: multiple or duplicative food system elements can serve the same purpose.

While some authors argue that the transformative approach overcomes the limitations of the restorative or technical approach, in this report we propose that their practical applications could be considered as potentially complementary. We adopted this perspective to carry out case studies, as we will develop below. Before that, we highlight the relationships between this concept and related concepts in the next section, thus going back to the relation between resilience and sustainability.

3.3 Food system resilience and related terms

Political and media discourses often associate food system resilience with other concepts such as food sovereignty or autonomy, while the relationship with sustainability remains under discussion. Figure 1 provides an attempt to clarify the links between these concepts.

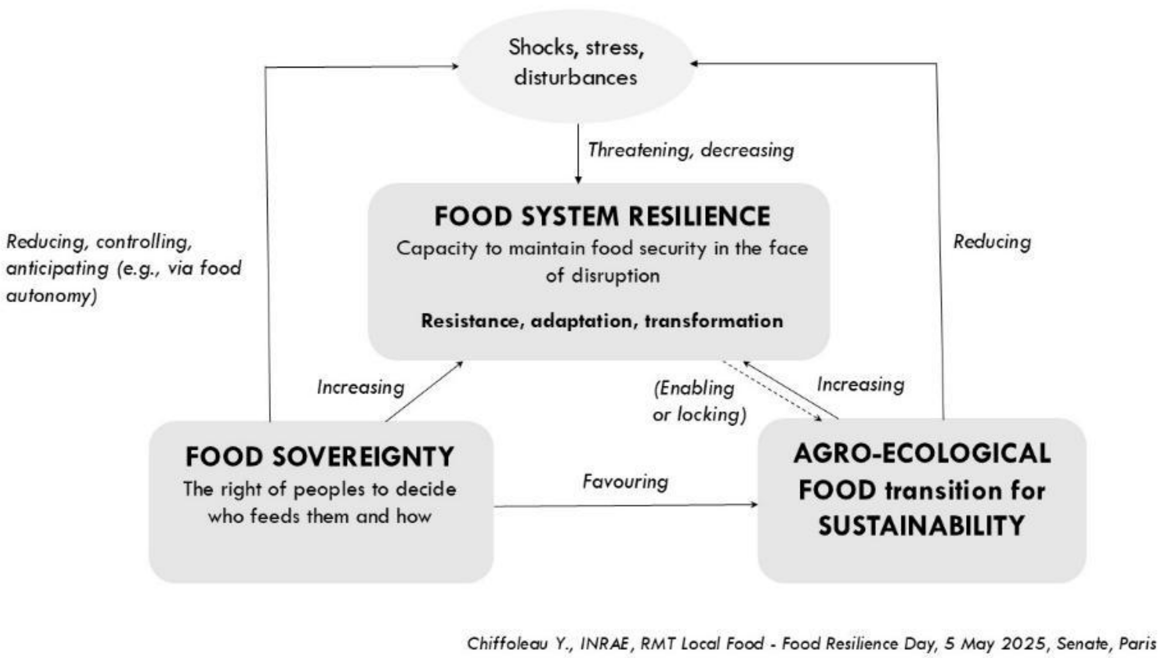

Figure 1: Relationships between food system resilience and related concepts. Source: Chiffoleau, 2025

In Tendall et al.'s definition, resilience is a dynamic capacity to achieve sustainability. Sustainability in food systems refers to their long-term capacity to operate within ecological limits while ensuring economic viability and social well-being. It focuses on maintaining desirable environmental and socio-economic outcomes over time, emphasising efficiency, reduced negative impacts, and intergenerational responsibility (Sgarbi, Nedeu, 2023). Resilience, by contrast, concerns how food systems respond to disruption and uncertainty. It is the capacity to absorb, adapt, and transform when exposed to shocks and stresses—whether climatic, economic, geopolitical, or biological—while continuing to deliver food system functions (Ujjwal et al., 2024). While sustainability defines the long-term goals, resilience describes the ability to navigate risk and uncertainty. The EU Farm to Fork strategy confirms that sustainability is fundamental to long-term food security, underlining "the importance of the resilience of the EU food system, to ensure access to a sufficient supply of affordable food for citizens under all circumstances and to undergo a transition to sustainable food systems in a fair and democratic manner, in line with the European Pillar of Social Rights" (European Commission, 2022).

However, a recent report points out that some elements of adaptive resilience and robustness could also be lock-ins or generate trade-offs that pose barriers for food system transition or transformation towards sustainability (Sgarbi, Nedeu, 2023). The report also stresses "resilience traps", when, for example, an agroecosystem can successfully retain the same function and structure following a disturbance while still delivering poor ecosystem services (Davis et al., 2023, cited by Sgarbi, Nadeu, 2023). This caution is important to consider in R&I reviewing, as well as the potential trade-offs between resilience and sustainability: we included these elements in our analysis of case studies.

The relationship between resilience and sustainability can be also strengthened by drawing on Thompson's work on sustainability, which contrasts two perspectives: functional integrity vs. resource efficiency (Thompson, 1992). Functional integrity, which has its roots in ecological modelling, refers to the ability of an agricultural system (including its ecological, social, and productive elements) to reproduce its key components and maintain their functional relationships over time, within certain limits, so that the system does not collapse or drift toward a fundamentally altered and impoverished state. Applied to organic farming, for instance, this perspective emphasises that the issue is not only to manage resource use, but also to preserve the internal processes, feedbacks, and relationships (soil fertility, crops, livestock, social institutions) that enable systems to renew themselves and remain viable in the future (Halberg, 2012). This concept of sustainability thus emphasises the capacity for resilience and has interesting potential for application to socio-ecological systems, such as food systems. It contrasts with the "resource sufficiency" view of sustainability, which focuses primarily on the availability of sufficient resources and the balance between inputs and outputs (Thompson, 1999).

The analysis of R&I projects on food system resilience can also be usefully supported by considering the different types of risks and shocks that food systems face.

3.4 Food systems subject to different risks, shocks and stresses

In recent years, there has been an increase in academic literature on the challenges of cascading, interconnected, compound, and interacting risks in risk analysis (Pescaroli, Alexander, 2018). However, these concepts have generated multiple and partly overlapping definitions. We therefore in this report consider the most common uses of two of these concepts whose application to food systems was of interest for the SCAR Food Systems Working Group:

- **Cascading risk** involves a chain reaction where an initial shock triggers subsequent, amplifying events across interconnected systems;

- **Compound risk** occurs when multiple stressors collide, creating a total impact that is greater than the sum of their individual parts;

There is not much academic literature on the subject of cascading risks applied to food systems. By incorporating the idea that cascading risks (or 'hazards') generate cascading (disruptive) events (or a 'domino effect'), we can identify three main entries into the subject:

- Cascading risks between regions: The global food system connects different regions of production and consumption around the world. Shocks in high-production regions can weaken countries that are highly dependent on food imports (d'Amour et al., 2016).
- Cascading risks along supply chains: For instance, Davis et al. (2021) conducted an exploratory literature review to examine cascading risks related to environmental variability throughout the food supply chain, including evidence of the propagation or mitigation of this variability, as well as the food products and types of shocks studied. They found that research has mainly focused on maize, rice, and wheat, on agricultural production, and on extreme precipitation and temperatures, highlighting the need to expand research to the entire food basket, to diverse sources of environmental variability, and to the links connecting food production to consumption and nutrition.
- Cascading risks between interconnected sectors:
    - Cascading risks in the water–energy–food nexus: for example, a recent publication by Zaher Serdar et al. (2024) proposes an interesting frame for analysing how climate change can provoke failures that propagate between interdependent water, energy and food systems.
    - Cascading risks due to shocks in critical infrastructures: for example, the Chatham House Report (2023) addresses the risk of severe disruptions at certain ports, maritime straits, and inland transport routes, which could have devastating knock-on effects for global food security.

With regard to "cascading risks" (s.s.), our analysis suggests that climate change is the main 'primary' or 'first' risk, triggering a risk (or set of risks) considered in the risk cascades studied. However, the literature remains scarce on this concept, indicating a lack of connections between studies on food systems and risk analysis. On the other hand, climate change generates an abundant literature on its 'cascading effects' or 'consequences' (Zhou et al., 2025). The cascading effects of the COVID-19 pandemic have also been widely studied in recent academic literature (e.g., Yuan et al., 2023).

Both climate change and the COVID-19 pandemic have also been addressed through the concept of 'compound risks,' using various terms (e.g., compounding, coincidental). Fan et al. (2024), for example, point out that "the coronavirus disease 2019 (COVID-19) pandemic exemplifies a perfect storm of coincidental risks". Focusing on climate compound risks, a recent review highlights that most adaptation responses are maladaptive, increasing risks and thereby opening important future areas of research (Simpson et al., 2023).

The overview of work on the risks facing food systems also suggests considering two types of risks or stressors: internal and external. Some risks, shocks, or stressors are of external origin, while others are produced largely or partially by the food systems themselves. This distinction is central to the transformative approach to food system resilience, which highlights the risks and stressors arising from the agro-industrial system (greenhouse gas emissions, biodiversity loss, soil degradation, food pathologies, etc.), as these limit its ability to ensure long-term food security for all (IPES-Food, 2024; HLPE, 2025).

4. State of the art in food systems resilience R&I in the European Union

A systematic review of EU and national R&I projects was conducted to establish the state of the art in the field of food system resilience across Europe. These projects were identified through ten national and international databases using targeted keyword searches and cover the period from 2015 to 2025 (see Methodology section).

The portfolio analysis revealed a significant increase in activity over time. During the first half of the study period (2015–2020), 56 projects were identified. This number nearly doubled in the second half (2021–2025), with 107 projects, demonstrating growing interest and investment in food system resilience.

As mentioned in the methodology section, we examined these projects using two complementary approaches: 1) project abstracts were coded and analysed according to different variables (Appendix 1), after which projects were grouped into clusters using multiple correspondence analysis; 2) project abstracts were analysed through content analysis to identify the main themes studied, with the support of CorText Manager tools.

4.1 Analytical approach to clustering

When examining what aspects of the food system these R&I projects aim to make resilient ('resilience of what?'), primary production—especially the resilience of plants—emerges as the main entry point for achieving the resilience of local or global food systems (Figure 2). Interestingly, attention to consumers as actors of resilience increased during the second period. However, some areas remain underrepresented—particularly resilience of processors and retailers, which experienced only modest growth.

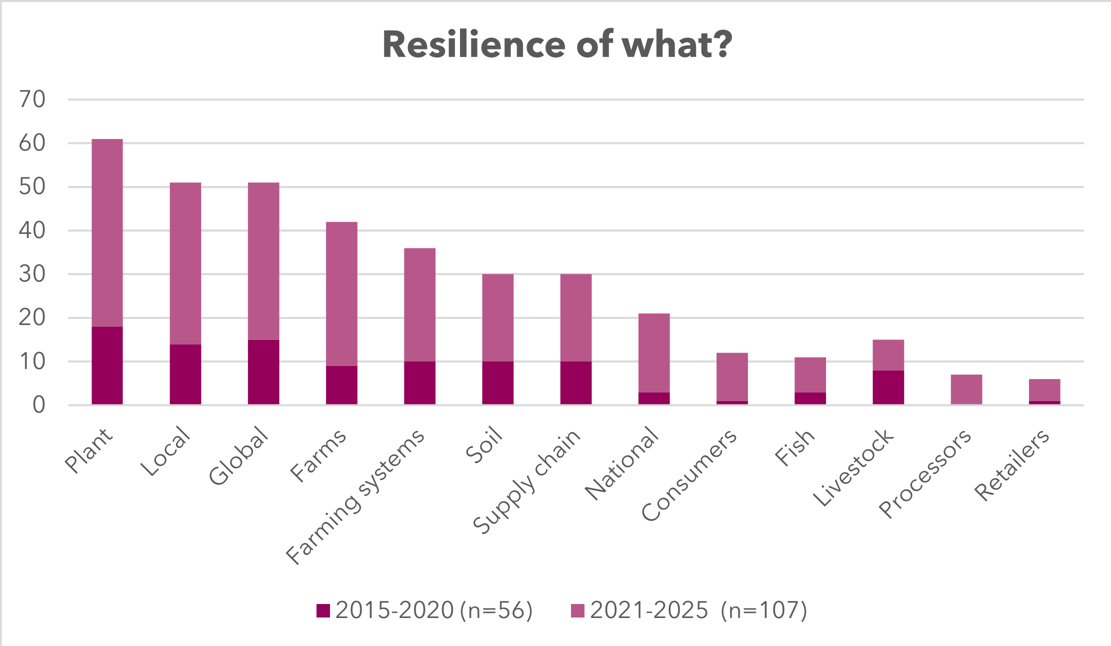

Figure 2: Number of R&I projects according to what they aim to make resilient

The question of 'who' benefits from resilience-building has also evolved. Farmers have consistently been a central focus, but newer projects increasingly consider consumers, input suppliers, processors, and retailers as beneficiaries (Figure 3). This shift suggests a growing recognition that resilience must be built for various actors along the value chain, not just for farmers. It is also worth highlighting the relative importance of input suppliers, as this reflects a focus on a restorative or technical approach to resilience through inputs (e.g., new cultivars, water sensors), whereas projects promoting food system transformation tend to emphasise the need for greater independence from these actors.

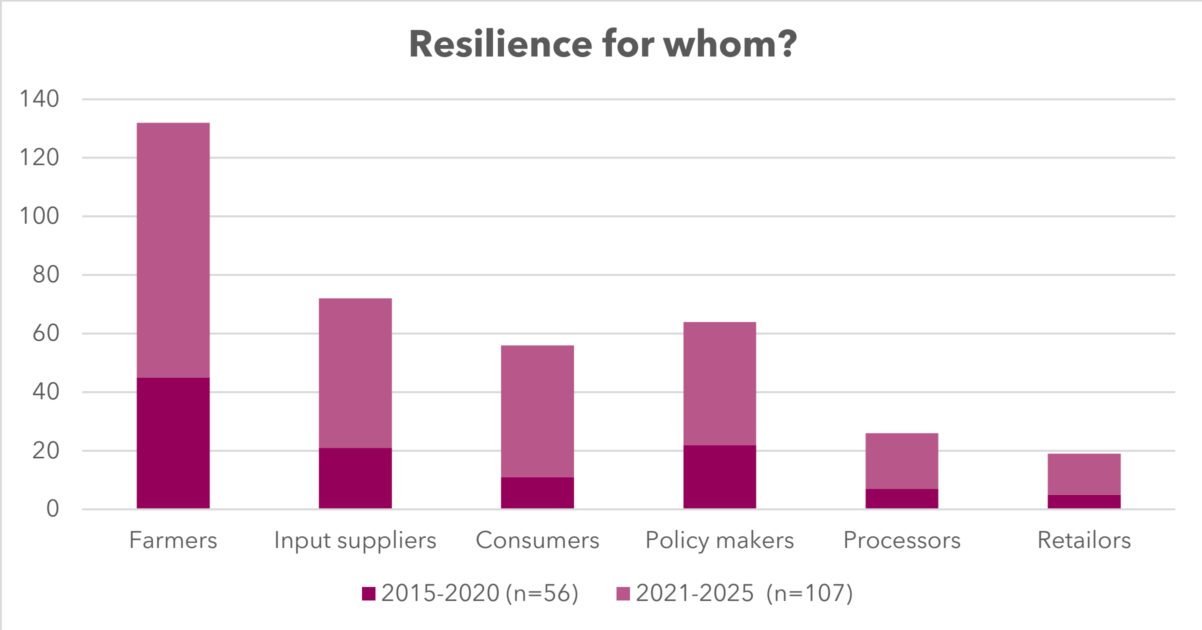

Figure 3: Number of R&I projects according to beneficiaries of resilience building

In terms of risks addressed, climate change continues to be the most prominent concern (Figure 4) throughout the study period, particularly in relation to drought stress. Projects related to a health crisis increased slightly during the second period, although a stronger increase might have been expected following the COVID-19 pandemic. This can be explained by the fact that the pandemic, often cited in projects, is mainly considered an economic crisis. Moreover, despite geopolitical disruptions such as the war in Ukraine, projects focusing on security risks remain limited, partly for the same reason.

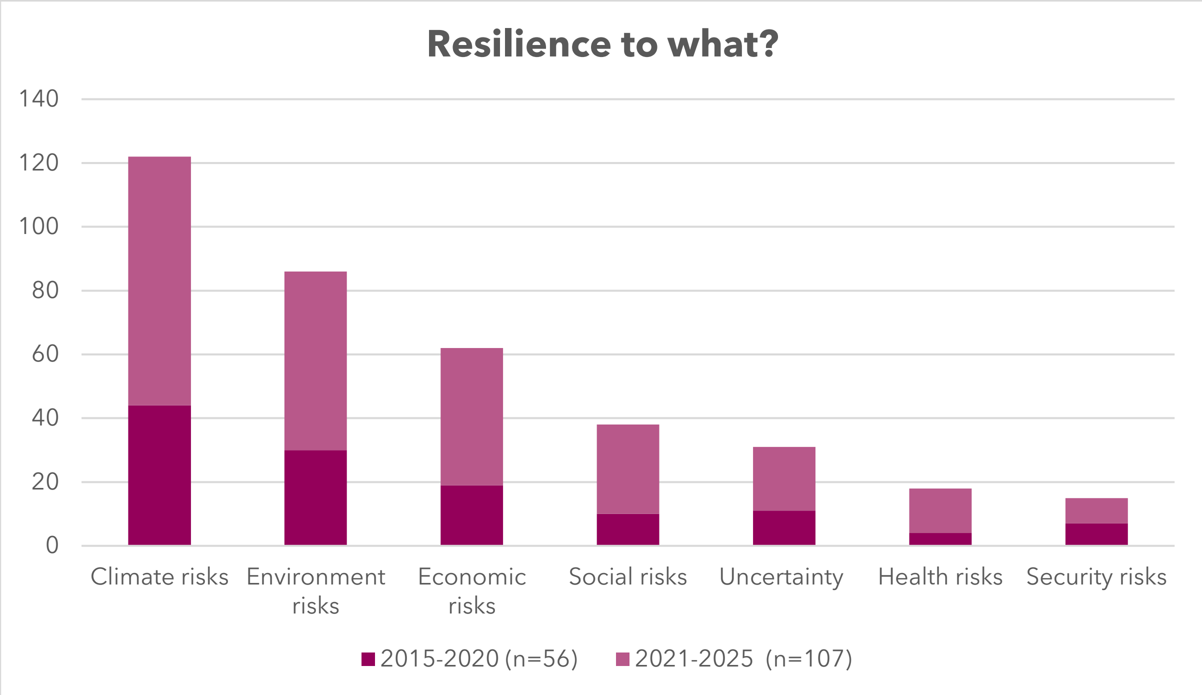

Figure 4: Number of R&I projects according to the risks which are considered

The expected outcomes of these projects are relatively evenly distributed across three categories: socio-economic benefits, environmental benefits, and food security. All three categories experienced substantial growth, with food security showing the most pronounced increase (see Appendix 1). A review of the abstracts suggests that resilience is being framed not only as a means to withstand shocks but also to secure economic activities and reduce the environmental impacts of primary production.

Innovation types also show evolving trends (Figure 5). Technological innovations remain the dominant focus throughout the entire period. However, there has been a significant rise in organisational innovations, particularly at the farm level (e.g., crop diversification, water reuse), while fewer projects address supply chain reorganisation, community initiatives, or cross-sector collaboration. There has also been a significant increase in projects aimed at institutional innovation, with their results being incorporated into policies.

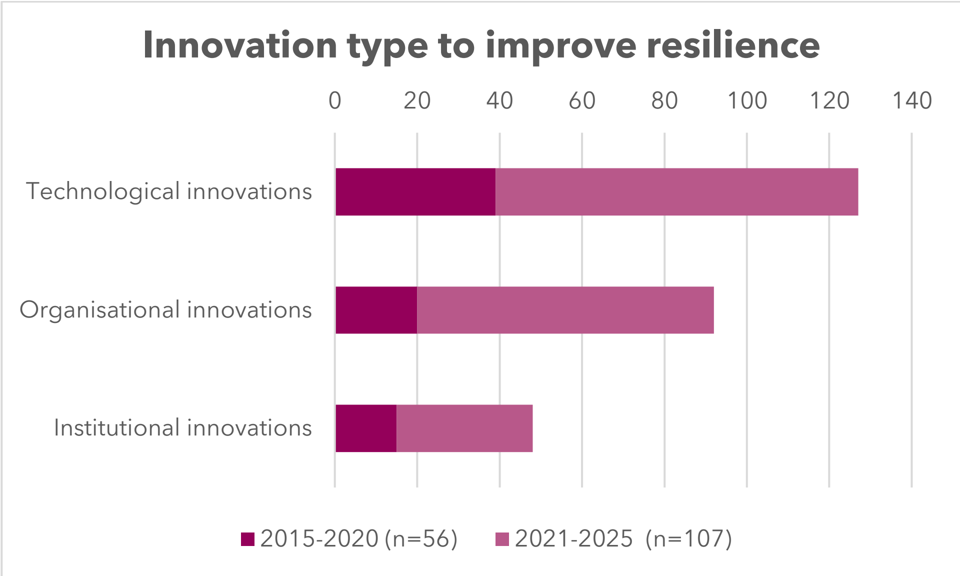

Figure 5: Number of R&I projects according to the innovations which are developed or targeted

Finally, the methods used in resilience research have become more diverse. While quantitative approaches and modelling remain common, there is a growing use of mixed methods, qualitative research, and real-life case studies (Appendix 1). Even though in many cases this remains at the farm level (e.g., on-farm trials), this methodological expansion is expected to help better capture the complexity of food systems and develop solutions that are grounded in practical realities.

Quantitative data from the coding of six variables (resilience of what, for whom, to what, for which outcomes, innovation types, methods) were used to group similar projects together, based on a multiple correspondence analysis. Three consistent clusters were identified through this method (Figure 6, and details in Appendix 2).

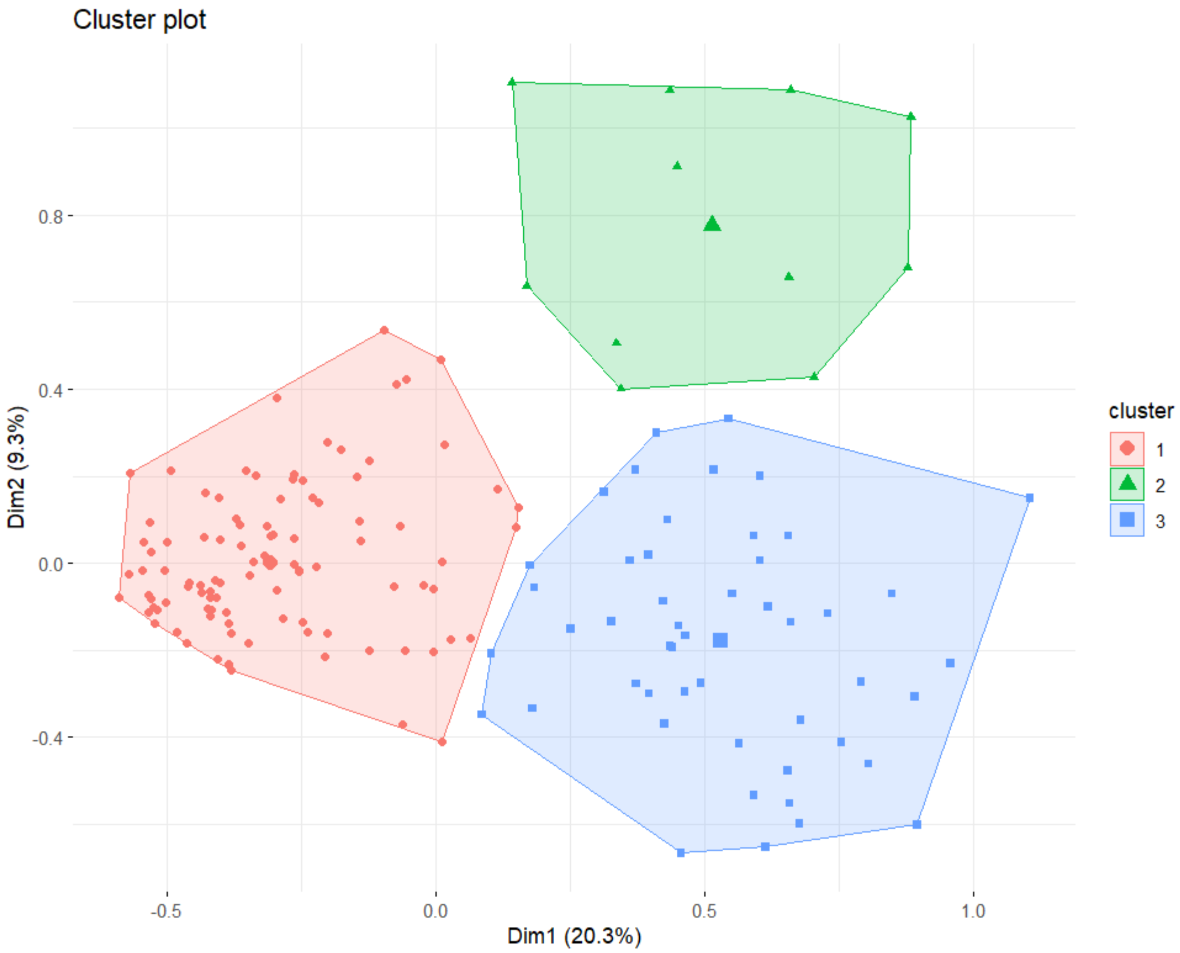

Figure 6: Clustering of projects based on multiple correspondence analysis (n=163)

The red cluster is the most important (n=103) and corresponds to projects focusing on plant resilience, technological innovations, and quantitative methods. The blue cluster (n=49) consists of projects targeting the resilience of local and global food systems, benefiting policymakers, and promoting institutional innovations. The green cluster, which comprises few projects (n=11), differs from the other two in that it focuses on supply chain resilience, economic risks, and organisational innovations. Content analysis of the abstracts provides additional insights for mapping R&I on resilience.

4.2 Content analysis

Content analysis of the project abstracts confirms the central importance of topics related to primary production and climate change as entry points for R&I on food system resilience (red and yellow clusters, Figure 7).

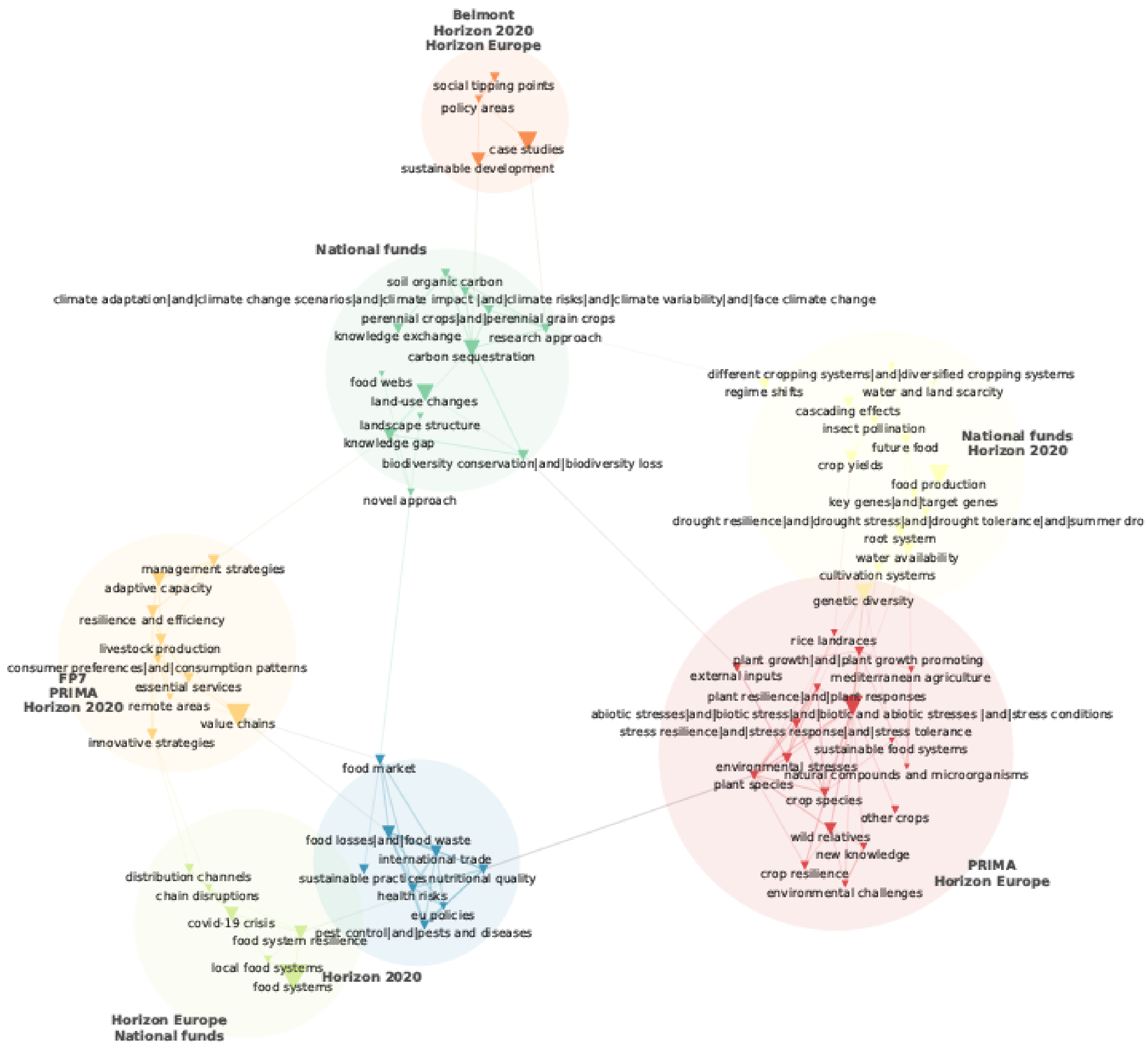

Figure 7: Main topics studied in R&I projects on food system resilience, with their main R&I frame or funding sources. Figure based on CorText Manager tools - through identification of the 120 most frequently used two-word groups in abstracts and mapping the links between these groups; larger triangles indicate more frequent usage of a group of two words in the abstract

National frameworks and funds contribute to diversifying R&I on food system resilience, for example through projects targeting land-use change and landscape structure. Issues surrounding livestock farming appear to have been studied more in R&I programmes prior to Horizon Europe, which may be explained by a stronger emphasis on the greening of agriculture and food in Horizon Europe.

Content analysis also provides information about the relative importance of technical/restorative versus transformative approaches to resilience: 'agroecology' (or 'agroecological practices,' 'agroecological transition'), 'grassroots' or 'bottom-up initiatives,' and 'transformation,' which are key concepts in the transformative approach, are respectively cited in only 17/163, 2/163, and 11/163 projects.

5. Case studies

Case studies are useful for gaining a practical understanding of research and innovation into food system resilience, and for identifying R&I and policy avenues. Looking more in depth at projects provides a basis for reflection on what policy and R&I actions have been implemented across the EU. We have selected five cases illustrating themes related to resilience by combining several criteria:

- Relevance to the SCAR Food Systems Working Group
- Relevance to the EU's strategic approach to resilience
- Heuristic value to illustrate various approaches to resilience, R&I, and policy actions
- Current topics in scientific literature on food system resilience

The five cases are: i) analysis and management of cascading risks; ii) preparation of populations to shocks; iii) solutions to water scarcity; iv) resilience related to energy; v) development of alternative proteins.

Each case has been illustrated by two R&I projects identified through the database search, reflecting different approaches to resilience as far as possible, particularly restorative/technical versus transformative approaches. Projects have been reviewed using the 5W analytical framework for food system resilience (Ingram et al., 2023), and incorporating the 3Rs approach (Zurek et al., 2022) into our distinction between restorative/technical and transformative resilience. We also suggested insights—or ways to go further—with a view to formulating recommendations for research and policy, drawing on scientific and operational literature.

Below, we first present a comprehensive case study on cascading risks, followed by the key messages from the four other cases, which are detailed in Appendix 3.

5.1 Case Study 1: Analysing and managing cascading risks

Only three projects explicitly address 'cascading risks' among the identified R&I projects (n=163), as most of the others refer to the consequences of a crisis, particularly climate change, but do not analyse these consequences as 'risks'. All of them address cascading risks due to climate change, but at a different scale and with complementary results (Table 1).

Table 1: Case study on analysis and managing cascading risks in food systems

Projects	**CASCADES CAScading Climate risks: towards ADaptive and resilient European Societies**	**CREATE - Cross-Border Climate Vulnerabilities and Remote Impacts of Food Systems of the EU, Turkey and Africa: Trade, Climate Risk and Adaptation**
Link	https://www.cascades.eu/	No longer active
Funder	EU, Horizon 2020	EU, FOSC ERA-Net
Period	2019-2023	2021-2023
Countries	European countries	The Netherlands, Turkey, Morocco, Egypt
Resilience of what	European food systems	Supply food chains for key traded crops (rice, apricot, etc.)
Resilience to what	Cascading risks due to climate change impacts in non-European countries	Cascading risks due to climate change impacts in non-EU exporting countries
Resilience for whom	EU policymakers, companies, investors	Policymakers, local communities, farmers
Resilience with what (innovations, solutions for resilience)	Assessment-simulation tools and models (interconnectedness, choke points) Serious games	Climate-risk assessment methodology
Contribution to research (doi of central articles)	New knowledge on cascading risks, interconnectedness of sectors and countries	New knowledge on climate change impacts on trade patterns, incl. virtual water profiles
Recommendations for public policies (if formulated)	21 policy recommendations (e.g., EU inter-service resilience agenda, preparing populations...); cited in COP26-28 reports	'New policies to reduce climate risk'
Resilience type (technical or transformative)	Technical, but models can be used for transformation as promoted in policy recommendations	Technical
Insights for recommendation (identified with the help of literature)	New business on risks/derisking promoted in the project could mainly benefiting insurance companies to the detriment of small-scale farmers	Ambition to cover both GHG and water footprint of imports but food dependence of EU countries to non-EU countries not called into question

The first project targets policymakers and proposes tools and models to better understand the interconnection of sectors and countries around the world, and the cascading risks within this interconnected system. The approach is primarily technical but can be used to transform food systems. The project has produced numerous recommendations, but it is worth noting, with regard to the question of 'resilience for whom', that the suggested derisking tools may serve the interests of insurance companies more than those of farmers. The second project targets import chains for key food products in Europe and addresses the potential propagation of risks along these chains from climate-change risks. The approach is also technical, with an interesting analysis of water embedded in food production, but it does not question import dependencies and does not address the possibility of reducing these imports, as promoted in the European Commission's 2022 communication to reinforce food system resilience (European Commission, 2022).

5.2 Case Study 2: Preparing populations to shocks

The publication of the EU's Preparedness Union Strategy, published in March 2025, was a major step forward in strengthening Europe's resilience to crises (European Commission, 2025). It emphasises the need to prepare populations. This topic had been anticipated in two national projects identified through our database research, which inform our case study.

In Finland, population preparedness has been a central element of national policy for over a century and is the subject of a proactive governmental approach. The R&I project identified is part of a transformative approach that promotes knowledge exchange and the co-creation of tools within multi-stakeholder networks. It supports the broader national ambition of population preparedness coordinated by Finland's National Emergency Supply Agency (Huoltovarmuuskeskus, HVK). This agency is a central authority responsible for national preparedness and the maintenance of strategic reserves. Established in 1991, HVK builds on a historical framework of civil defence and supply security developed since Finland's independence in 1917.

The agency ensures the continuity of critical functions during crises, including disruptions in food, energy, medical supplies, and industrial operations. It collaborates with private-sector stakeholders to maintain resilience in essential services and infrastructure. An analysis of Finland's approach shows a systemic integration of state planning, industrial cooperation, and citizen-level preparedness, offering a model for comprehensive national security.

The French project, initiated in the wake of COVID-19, is based on the premise that the risk of food disruption remains largely unconsidered by both the French government and local authorities. It analyses different ways and tools for preparing populations (e.g., stress tests), combining a transformative and a technical approach, and highlighting the importance of territorial and at-home storage.

5.3 Case Study 3: Facing water scarcity

Many projects are studying drought-resistant species or varieties through genetic analysis. This work clearly illustrates a technical approach to resilience, based on the substitution of vulnerable species with more resilient ones. Other technical approaches include, for example, water monitoring (through sensors), innovative irrigation systems, or soilless agriculture.

The projects developed within the framework of the Partnership for Research and Innovation in the Mediterranean Area (PRIMA) have long studied water scarcity due to the greater exposure of the countries involved. From this set of projects, we propose another technical but highly relevant approach in our case study, taking advantage of the opportunity presented by the 2024 amendment to European regulations on the reuse of wastewater for irrigation. We complemented the case study by presenting a second PRIMA project focused on agroforestry and mixed farming systems, supporting a transformative approach to resilience, namely reducing water use in food systems, in addition to water reuse.

It should be noted, however, that many PRIMA project websites are no longer active or do not present the project results, which makes accessing the knowledge produced difficult.

5.4 Case Study 4: Facing energy-related disruptions

The database search yielded very few projects dealing with this subject. Furthermore, the projects identified are relatively recent (starting in 2024). In this case study, we propose two projects: the first targets the resilience of farms to fluctuations in fossil fuel prices, helping farmers through financial and decision-support tools; the second addresses the vulnerabilities of farms due to their dependence on these fossil fuels and develops renewable energy sources that are readily accessible to farmers.

5.5 Case Study 5: Developing alternative proteins

The development of alternative proteins is associated with resilience in several projects, which primarily highlight their contribution to climate change mitigation (more or less explicitly through comparisons with animal protein production). Their importance is sometimes framed as a response to compound risks, namely climate change, demographic pressure, the depletion of natural resources, and problems associated with the use of synthetic fertilisers. However, none of the projects identified directly addresses Europe’s challenge of protein self-sufficiency or reducing dependence on nitrogen fertilisers imported from outside Europe, issues that are highlighted in the EU’s food system resilience strategy (European Commission, 2022).

The case study focuses on two projects: the first developed alternative proteins from waste or novel raw materials (insects) up to the stage of food prototypes but highlights the cultural and regulatory barriers to their commercialisation. The second project analyses the genetic diversity of legumes and adapted cropping systems to facilitate their wider use in the Mediterranean basin, which would reduce the use of nitrogen fertilisers. This type of project could usefully be linked to another major disruption studied in other identified projects, namely the decline in agrobiodiversity and the threat to minor crops, such as many legumes, which are underutilised and neglected in Europe (Notz et al., 2023).

6. Future research and innovation needs, and policy insights

6.1 R&I and policy gaps identified in the survey

To further map existing research problems and knowledge gaps related to food system resilience in the EU, we conducted an online survey (see Methodology). Based on the results, nine gaps related to both R&I and policy were identified. We present them below and then relate them to our mapping of R&I in Europe, in order to transition to our recommendations.

1. Lack of data

Several respondents emphasised incomplete, outdated, or missing data in official statistics on food systems, which are nevertheless needed to monitor resources and anticipate crises. In particular, food flows, retail networks, and storage capacities are not well known at the regional scale. More broadly, data are not sufficiently disaggregated or collected at relevant scales to reflect regional or local realities, for example in mountain and marginal areas. Assuming implicitly that data collection can be challenging, some respondents highlighted the value of innovative data generation methods, such as citizen science initiatives, partnerships with socio-economic actors, and the use of artificial intelligence.

2. Insufficient capacity to assess and model resilience

Some respondents pointed out the need for integrated, multi-scalar modelling frameworks linking local farm dynamics with regional markets and ecosystems. They also stressed that existing models capture robustness and adaptability but rarely transformability. The lack of coherent indicators and metrics that capture environmental, social, and economic aspects of resilience was cited several times, while some respondents emphasised the need for simple, practical assessment tools usable by farmers, policymakers, and local stakeholders.

3. Fragmented innovation and lack of integration

Several respondents highlighted the overemphasis on technological innovation in R&I on resilience, with limited attention to social and institutional change. One respondent also stressed the risk of cyber-dependence and new vulnerabilities. The lack of integration between farm-level innovation, policy frameworks, and ecosystem management was cited, as well as the underuse of traditional knowledge and intergenerational learning. Finally, comments raised the weak cross-sector collaboration between research, policy, and practice.

4. Limited risk preparedness across food systems

Several respondents noted that policy frameworks are reactive rather than proactive, especially regarding climate extremes and supply chain crises. One respondent emphasised that cross-border vulnerabilities–such as climate impacts in exporting countries–are poorly understood. Another highlighted that over-reliance on digital technologies creates new exposure to cyber risks. More broadly, several respondents suggested that a better characterisation of risks, stresses, and shocks, both endogenous and exogenous to food systems, should be developed.

5. Weak long-term planning and foresight

Several respondents emphasised that actors lack tools for long-term forecasting related to climate, markets, and resource availability, as well as weak institutional capacity for strategic foresight and future-oriented planning. They also noted that insufficient incentives and subsidies constrain the uptake of long-term resilience measures.

6. Fragmented value chains and trade systems

Several respondents emphasised the need to analyse the conditions for shifting from global dependence to regional interdependence to enhance food system resilience, or how trade can prioritise sustainability or resilience over competitiveness. The issue of local storage, particularly in urban and peri-urban areas, was highlighted as under-supported or dismantled.

7. Inadequate governance structures and power relations

Several respondents pointed out that the concentration of power in large processing, retail, and regulatory institutions acts as a barrier to enhancing food system resilience and stressed the need for local and collective governance in resource management and crisis response. Others emphasised that smallholders, women, youth, and remote regions remain underrepresented in governance and markets. More broadly, several comments highlighted that structural inequalities restrict access to resources, information, and decision-making, which are key components for resilience.

8. Limited understanding of behavioural drivers of resilience

Another set of comments concerned the lack of R&I on motivations and barriers influencing farmers and consumers to anticipate, prevent, cope, or transform in relation to crises, both at the individual and collective level (collective action). R&I should be developed on incentives and communication, which are currently insufficient to drive behavioural change.

9. Knowledge gap in crop diversity and resilience

Some respondents pointed out that underutilised crops remain marginal and poorly integrated into markets and breeding programmes, despite being a potential source of resilience. Other comments mentioned knowledge gaps on crop responses to combined abiotic and biotic stresses, especially below-ground traits, as well as on resilient germplasm.

These insights from project coordinators or principal investigators usefully complement the state of the art based on project abstracts. By also highlighting policy gaps or barriers, they provide concrete avenues for orienting R&I to support policy change or the integration of items into policies to strengthen the resilience of European food systems. Most of the comments on R&I

gaps seem justified in view of the state of the art, except for the one concerning resilient crops, which is already widely covered in the projects identified in the databases.

6.2 Integration of study results for insights and recommendations

Key message 1: The dominant technical pathway leaves R&I gaps, calling for greater complementarity between technical and transformative approaches of resilience, as well as consideration of cascading risks.

Resilience-related R&I in the European food system follows two main pathways, but there is a significant imbalance between them. The first, largely dominant, focuses on plant-level resilience against climate change stresses, achieved through technological innovations and quantitative approaches. This pathway illustrates the technical approach to resilience and represents efficiency- and effectiveness-oriented projects aimed at improving technical solutions for farmers, often in connection with (and benefitting) input suppliers.

A second, smaller group of projects takes an institutional perspective, addressing the resilience of local or global food systems, governance arrangements, and policy processes. This second, less developed cluster reflects a more systemic approach that engages multiple actors across the food system, including policymakers, and places a stronger emphasis on institutional innovations that could result from their findings.

However, most of these projects still maintain a technical approach to resilience, providing models or monitoring tools to stakeholders and policymakers. The transformative approach to resilience remains underdeveloped in all of the projects identified, which is reflected in particular in the low number of projects combining resilience and agroecology. On the other hand, when proposed, the transformative approach could be reinforced by increased collective (technical) monitoring of resources.

As a result, key dimensions of food system resilience remain insufficiently developed. Either on plants or governance, technical or transformative, all pathways give little attention to supply chains and trade. Few projects examine how disruptions propagate across supply chains or how resilience can be built collectively across actors—from input suppliers to processors and retailers, including consumers and citizens. In particular, cascading and compound risks are rarely addressed explicitly. Climate change remains the primary risk considered, while other systemic threats are acknowledged but typically treated in isolation or only indirectly. Addressing cascading risks requires more integrative, cross-sectoral approaches that move beyond singular stressors and strengthen resilience across the entire food system.

Redressing the imbalance between resilience approaches is crucial, as many stresses originate within the agro-industrial system itself. In parallel, there are many R&I projects on food system transformation, but these do not appear in the R&I mapping on resilience. It would be important to better link these issues in the next R&I programme, explicitly examining the trade-offs between resilience and sustainability. For example, several identified projects link resilience to the need for more transparency in supply chains and propose using blockchain technology, without taking into account the associated risks (dependence on IT suppliers, cyberattacks, etc.) and environmental impacts (energy consumption). It would be also important to highlight and promote the complementarity of technical and transformative approaches to resilience in future projects.

Key message 2: Advancing integrated methods is essential to address future food system resilience challenges.

Building food system resilience in the EU requires a shift from fragmented, sector-specific, and technocentric efforts toward an integrated research and innovation agenda. Current studies often focus on isolated components of the food system and overlook interdependencies between data infrastructures, governance arrangements, innovation pathways, and social dynamics. Strengthening resilience therefore calls for coordinated, multi-scalar, and participatory research capable of capturing complexity and supporting both technical and transformative approaches.

Future research must develop integrated and dynamic modelling tools that link farm-level decisions with regional markets, trade networks, and governance structures. Such tools should move beyond short-term stability to analyse how systems reorganise under stress and how cascading shocks and feedbacks propagate across ecological, economic, and social domains. Equally critical is the development of open, high-quality, and spatially detailed data infrastructures, co-produced with food system actors, to enable more robust modelling, monitoring, and decision-making.

Greater attention to social and behavioural dimensions is needed to understand how incentives, communication, and knowledge-sharing shape the adoption of resilience strategies across the value chain. Likewise, cross-sectoral and institutional innovation should be systematically integrated, ensuring that technological advances are connected to governance reforms and policy processes, and do not create additional dependencies or negative externalities.

Finally, building long-term resilience requires strengthening foresight, risk preparedness, and strategic planning. Anticipating cascading shocks—from climate extremes to cyber disruptions—through scenario analysis and proactive coordination between research, policy, and practice will be crucial to support a more adaptive and equitable food system.

Key message 3: Strengthening knowledge sharing through open, harmonised R&I databases is essential for advancing food system resilience.

Our review drew on eight national research funding databases in addition to the EU-level platforms CORDIS and PRIMA. While this provided valuable insights, the process revealed significant barriers to accessing and integrating information on resilience-related R&I across Europe. Several national databases could not be included because they were not available in English or did not provide open access. Moreover, the databases we consulted varied considerably in structure, terminology, and search functionalities, making systematic identification and comparison of projects unnecessarily cumbersome.

To improve knowledge sharing and support coordinated resilience-building efforts, we recommend greater harmonisation, openness, and accessibility of R&I databases across MS. Ensuring that publicly funded research information is available in English and released through open, searchable, and interoperable platforms would significantly enhance transparency and enable more comprehensive mapping of research activities.

Such improvements are not only important for the research community but are particularly critical for food system resilience. Because resilience is inherently multidimensional and cross-sectoral, relevant knowledge is distributed across disciplines, ministries, and funding schemes. Fragmented data infrastructures make it difficult to identify synergies, avoid duplication, monitor investments, or track how different strands of research contribute to system-wide resilience. Improved data accessibility would facilitate more integrated analysis, foster collaboration across countries and sectors, and ultimately strengthen resilience of European food systems.

Key message 4: The European Union's strategic approach to resilience can be consolidated by R&I, and vice versa.

The EU's strategic approach towards building resilience encompasses various initiatives aimed at enhancing the EU's ability to withstand and adapt to challenges: i) Water Resilience Strategy; ii) Resilience 2.0; iii) Preparedness Union Strategy; iv) resilience dashboards, dedicated to monitoring capacities and vulnerabilities in MS; v) Communication from 2022 for reinforcing the resilience of food systems.

As part of the preparedness strategy, the European Food Security Crisis Preparedness and Response Mechanism (EFSCM), initiated in November 2021, assesses how to improve cooperation between the public and private sectors and evaluate risks when crises arise. The EFSCM group of experts provided concrete recommendations on ways to mitigate risks and vulnerabilities, and, in particular, supported the inclusion of new data into the FAO dashboard on food security and food supply. Nevertheless, the EU resilience dashboards only include two indicators related to food system issues (farmland birds, pesticide use), although they could be usefully enriched by integrating the dashboard on food security and food supply.

The European strategy for food system resilience is also encapsulated in Food 2030, the EU's research and innovation policy framework supporting the transition towards sustainable, healthy, and inclusive food systems that respect planetary boundaries. Greater synergy between the preparedness strategy and Food 2040 in preparation, supported by R&I findings, could consolidate the EU's strategy for food system resilience. This implies that the forthcoming Food 2040 should rebalance R&I topics by supporting research on transformative resilience, organisational and institutional innovations at the system level, and addressing shocks beyond climate change, in line with the EU's resilience strategy, which addresses all these elements and challenges.

Moreover, since the CAP shapes the EU's agricultural sector, the report on food system resilience research gaps produced by the Institute for European Environmental Policy (IEEP) highlights that this policy does not include resilience as a main goal. The CAP measures are mostly oriented towards economic robustness, and not towards the two other Rs (recovery and reorientation) (Sgarbi, Nadeu, 2023). Greater consideration of the role of governance and networks in shaping food system resilience would provide an additional argument to extend financial support to the second pillar of the CAP, dedicated to rural development and transition.

For instance, policymakers have promoted the rebalancing between resilience approaches within the Strategic Advisory Group of the European Committee of Standardisation (CEN-SAG) launched by the German standardisation body (DIN) in 2024 to explore the need for standardisation to enhance the resilience of agri-food systems. In line with the results of the R&I mapping, some stakeholders tended to reduce resilience to a technical approach based on technological innovation. The French Ministry of Agriculture and Food Sovereignty, which chaired the group for several months with the support of INRAE and the French standardisation body (Afnor), supported the principle of standardisation also considering the transformative approach. INRAE, which took over as convenor of the group in 2026, helped the group to take both of these approaches into account and to draw up standardisation recommendations tailored to these two issues (Chiffoleau, Bourget, 2026).

7. Conclusion

In a context of 'polycrisis' (Marsden, 2024), it is crucial to analyse the conditions for developing the resilience of European food systems and to innovate with this objective in mind. This study, carried out at the request of SCAR Food Systems, highlights that numerous R&I projects have been funded on this theme, particularly since 2021. However, it also shows an imbalance in the themes and approaches developed in these projects, with a bias towards work on primary production, analysed using quantitative methods and a technical approach to resilience, and prioritising technological innovation. We therefore suggest not only rebalancing topics and approaches through the future Food 2040, but also better articulating the European R&I with the EU's strategy for resilience.

Our study finally confirms the findings of the report produced for the IEEP on research gaps in food system resilience (Sgarbi, Nadeu, 2023) and supports greater consideration of transformative resilience. This transformative approach is strongly promoted in the HLPE 2025 report but is also included in the EU's strategic approach to resilience, while it is reflected very little in funded R&I. However, our findings also suggest a complementarity between technical and transformative approaches, which are often opposed and whose combination could be explicitly integrated in the next EU and national R&I programmes.

This study clearly has its limitations, due to the broad scope of the field and the difficulty of accessing all the knowledge produced on this topic. This leads us to recommend improving R&I

databases in Europe in order to make the most of all the knowledge and innovations produced, and to help regularly monitor the R&I gaps that need to be filled.

Acknowledgements

We would like to thank the SCAR Food Systems Working Group for their trust and valuable advice.

We also thank Professor Pasi Rikkonen and Dr. Karoliina Rimhanen for their contributions to the study. We furthermore extend our gratitude to the respondents of the online survey, as well as to Manon Pradère and Marc Barbier at INRAE, who assisted in processing the data.

Funding

This study has received funding from the European Union's Horizon Europe research and innovation programme under Grant Agreement number 101060553.

References

Asadzadeh, A., Khavarian-Garmsir, A. R., Sharifi, A., Salehi, P., Kötter, T., 2022. Transformative Resilience: An Overview of Its Structure, Evolution, and Trends. Sustainability, 14(22), 15267. https://doi.org/10.3390/su142215267

Béné, C., Frankenberger, T.R., Nelson, S., Constas, M.A., Collins, G., Langworthy, M., Fox, K., 2023. Food system resilience measurement: principles, framework and caveats. Food Sec. 15, 1437–1458. https://doi.org/10.1007/s12571-023-01407-y

Blay-Palmer, A., Santini, G., Halliday, J., Malec, R., Carey, J., Keller, L., Ni, J., Taguchi, M., van Veenhuizen, R., 2021. City Region Food Systems: Building Resilience to COVID-19 and Other Shocks. Sustainability, 13(3), 1325. https://doi.org/10.3390/su13031325

Chiffoleau Y., 2025. La résilience des systèmes alimentaires: définitions et enjeux. CNRA parliamentary day, Senate, Paris, France, 5 May 2025.

Chiffoleau, Y., Bourget, K., 2026. Report of the Strategic Advisory Group on the Resilience of Agri-food Systems. European Committee for Standardization.

d'Amour, C.B., Wenz, L., Kalkuhl, M., Steckel, J.C., Creutzig, F., 2016. Teleconnected food supply shocks. Environ. Res. Lett., 11, 035007. https://doi.org/10.1088/1748-9326/11/3/035007

Davis, A.G., Huggins, D.R., Reganold, J.P., 2023. Linking soil health and ecological resilience to achieve agricultural sustainability. Frontiers in Ecology and the Environment, 21(3), 131-139. https://doi.org/10.1002/fee.2594Digital

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., Folke, C., 2019. Sustainability and resilience for transformation in the urban century. Nature Sustainability, 2, 267-273. https://doi.org/10.1038/s41893-019-0250-1

European Commission, 2022. Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. Safeguarding food security and reinforcing the resilience of food systems. COM(2022) 133 final. Brussels.

European Commission, 2025. EU Preparedness Union Strategy to prevent and react to emerging threats and crises. JOIN(2025) 130 final. Brussels.

Fan S., EunYoung Cho, E., Meng, T., Rue, C., 2021. How to Prevent and Cope with Coincidence of Risks to the Global Food System. Annual Review of Environment and Resources, 46, 601-623. https://doi.org/10.1146/annurev-environ-012220-020844

FAO, 2021. The State of Food and Agriculture 2021. Making agri-food systems more resilient to shocks and stresses. Rome.

Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., Rockström, J., 2010. Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecology and Society, 15. https://www.jstor.org/stable/26268226

Fonteijn, H. M. J., van Voorn, G. A. K., de Steenhuijsen Piters, C. B., Hengeveld, G. M., 2022. The ABCD of food systems resilience: an assessment framework. Wageningen University & Research. https://doi.org/10.18174/580782

Halberg, N., 2012. Assessment of the environmental sustainability of organic farming: Definitions, indicators and the major challenges. Can. J. Plant Sci., 92, 981 996.

Himanen, S. J., Rikkonen, P., Kahiluoto, H., 2016. Codesigning a resilient food system. Ecology and Society, 21(4). http://www.jstor.org/stable/26270022

Holling, C. S., 1973. Resilience and stability of ecological systems. Annu. Rev. Ecol. Syst., 4, 1–23.

HLPE, 2017. Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

HLPE, 2025. Building resilient food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

Ingram, J., Bellotti, W., Brklacich, M. et al., 2023. Further concepts and approaches for enhancing food system resilience. Nature Food, 4, 440–441. https://doi.org/10.1038/s43016-023-00762-5

IPCC, 2023. Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st ed. Cambridge University Press. https://doi.org/10.1017/9781009325844

IPES-Food, 2024. Food From Somewhere. Building food security and resilience through territorial markets. https://ipes-food.org/report/food-from-somewhere/

Marsden, T., 2024. Contested ecological transitions in agri-food: emerging territorial systems in times of crisis and insecurity. Italian Review of Agricultural Economics, 79(3), 69-81. https://doi.org/10.36253/rea-15421

Moser, S., Meerow, S., Arnott, J., Jack-Scott, E., 2019. The turbulent world of resilience: interpretations and themes for transdisciplinary dialogue. Climatic Change, 153(1), 21-40. https://doi.org/10.1007/s10584-018-2358-0

Muñoz-Erickson, T.A., Meerow, S., Hobbins, R., Cook, E., Iwaniec, D.M., Berbés-Blázquez, M., Grimm, N.B., Barnett, A., Cordero, J., Gim, C., Miller, T.R., Tandazo-Bustamante, F., Robles-Morua, A., 2021. Beyond bouncing back? Comparing and contesting urban resilience frames in US and Latin American contexts. Landscape and Urban Planning, 214, 104173. https://doi.org/10.1016/j.landurbplan.2021.104173

Notz, I., Topp, C.F.E., Schuler, J. et al., 2023. Transition to legume-supported farming in Europe through redesigning cropping systems. Agron. Sustain. Dev., 43, 12. https://doi.org/10.1007/s13593-022-00861-w

Schechter, C., Halevi, L., 2023. What Is Resilience? Developing the Conceptual Framework. In: Resilient Leadership, Emerald Publishing Limited, Leeds, 13-22. https://doi.org/10.1108/978-1-83753-908-620231002

Simpson N.P, Williams P.A., Mach K.J., Berrang-Ford L., Biesbroek R., Haasnoot M., et al., 2023. Adaptation to compound climate risks: A systematic global stocktake. iScience, 26(2), 105926.

Sgarbi, F, Nadeu, E., 2023. Resilience and sustainability in food systems research: a review of the main issues and knowledge gaps. IEEP, Brussels.

Tendall, D.M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q.B., Kruetli, P., Grant, M., Six, J., 2015. Food system resilience: Defining the concept. Global Food Security, 6, 17–23. https://doi.org/10.1016/j.gfs.2015.08.001

Thompson, P.B., 1992. The varieties of sustainability. Agriculture and Human Values, 3(4), 11-19.

Thompson, P.B., Nardone, A., 1999. Sustainable livestock production: methodological and ethical challenges. Livestock Production Science, 61(2–3), 111-119. https://doi.org/10.1016/S0301-6226(99)00061-5

Ujjwal, Campbell-Ross, H., Godde, C., Friedman, R., Lim-Camacho, L., Crimp, S., 2024. A systematic review of the evolution of food system resilience assessment. Global Food Security, 40, 100744. https://doi.org/10.1016/j.gfs.2024.100744

van Wassenaer, L., Oosterkamp, E., Asseldonk, M., Ryan, M., 2021. Food system resilience: ontology development and impossible trinities. Agriculture & Food Security, 10(38). https://doi.org/10. 10.1186/s40066-021-00332-7

Walker, B., Holling, C.S., Carpenter, S., Kinzig, A., 2004. Resilience, Adaptability and Transformability in Social–ecological Systems. Ecology and Society, 9. https://doi.org/10.5751/ES-00650-090205

Yoshizumi, M., Miyaguchi, T., 2025. A Comprehensive Review of Local Food Systems and Their Resilience. In: Yoshizumi, M., Arata, M., Miyaguchi, T. (eds), Navigating Local Sustainability in Food, Community, and Innovation. Springer, Singapore. https://doi.org/10.1007/978-981-96-8963-7_2

Yuan, H., Wang, X., Gao, L. et al., 2023. Progress towards the Sustainable Development Goals has been slowed by indirect effects of the COVID-19 pandemic. Commun Earth Environ 4, 184. https://doi.org/10.1038/s43247-023-00846-x

Zaher Serdar, M., Lahlou, F.Z., Al-Ansari, T., 2024. Enhancing resilience to climate change: Addressing cascading risks within the energy, water and food nexus. Progress in Disaster Science, 24, 100390, https://doi.org/10.1016/j.pdisas.2024.100390

Zhou, T., Yang, D., Meng, H. et al., 2025. A bibliometric review of climate change cascading effects: past focus and future prospects. Environ Dev Sustain, 27, 5795–5820. https://doi.org/10.1007/s10668-023-04191-z

Zurek, M., Ingram, J., Sanderson Bellamy, A., Goold, C., Lyon, C., et al., 2022. Food System Resilience: Concepts, Issues, and Challenges. Annual Review of Environment and Resources, 47, 511–534. https://doi.org/10.1146/annurev-environ-112320-050744

Appendix 1. Systematic review of the database portfolio analysis: Method of the project abstract coding and additional figures

Projects identified in the systematic review of the ten databases were analysed and coded to create a numerical dataset that enabled quantitative, statistical analysis. When screening the hits from our database search using our given search words, we applied the following inclusion criteria:

1. Timeframe: All or part of the implementation period falls under the time frame 2015 – 2025.
2. Geographical focus: The geographical focus of the project is on at least one EU member state.
3. Thematic focus: The main thematic focus of the project is on food system resilience.

For each selected project, the following information was recorded:

- Item number
- Database the project was found in
- Project title
- Search word by which the project was identified
- Implementation time
- Type of project funding
- Project abstract

The project abstracts were next analysed for the following variables:

- Resilience of what?
- Who benefits?
- Risk?
- Food system outcomes?
- Innovations?
- Methods?

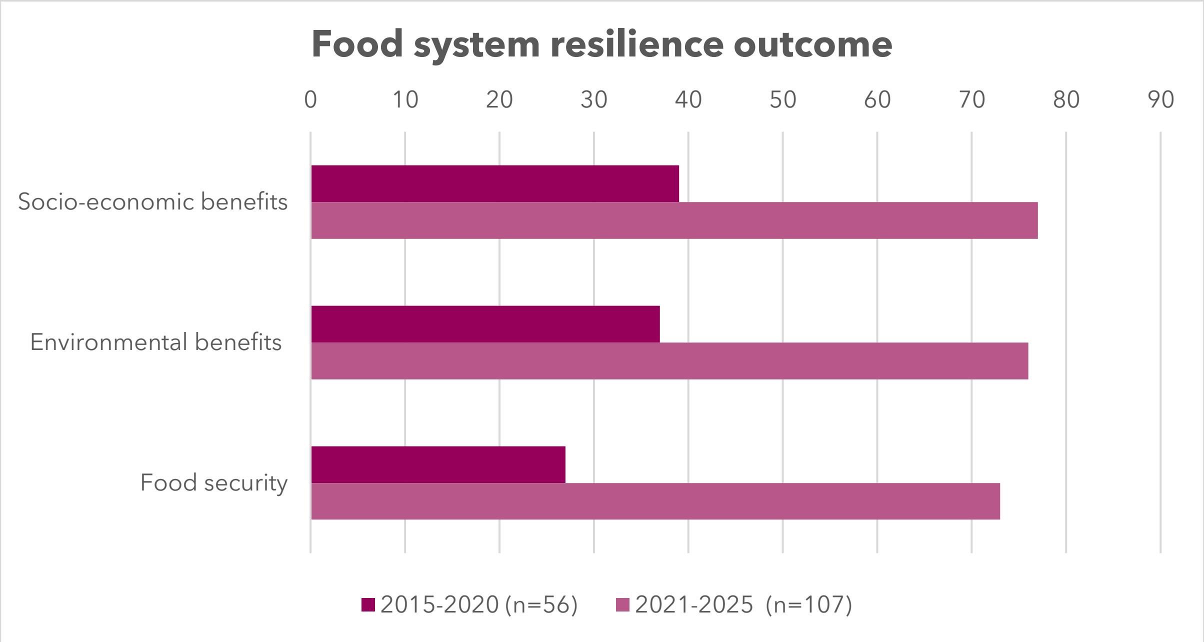

Figure 8: Number of R&I projects according to the targeted food systems outcomes.

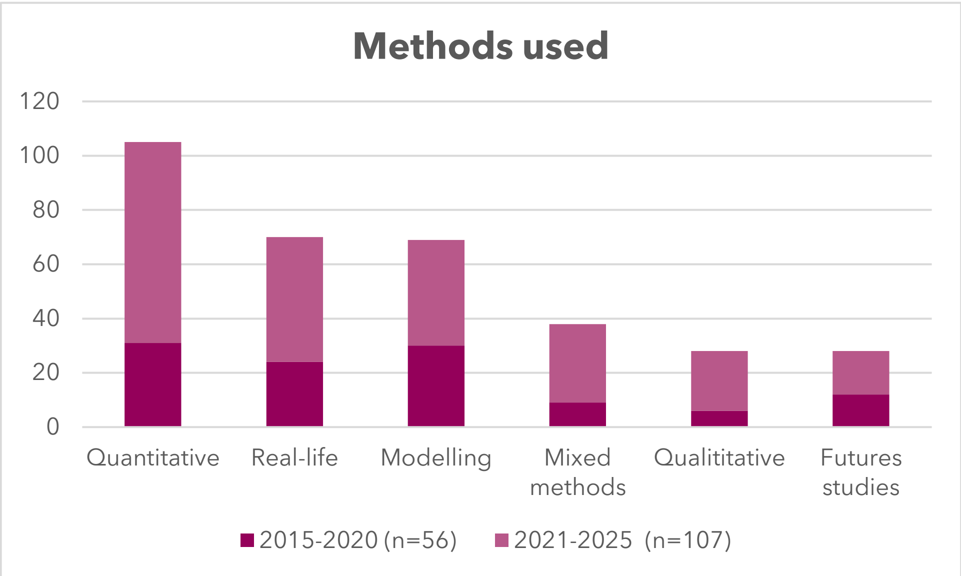

Figure 9: Number of R&I projects according to the research methods

Appendix 2. Multiple correspondence analysis

Characterisation of the three clusters according to the significant variables - the **v-test** compares the mean of a variable (or the coordinate of a modality on an axis) in a cluster the overall mean. The higher the v-test, the more the variable distinguishes one cluster from the others.

Cluster	Variables	v-test
1	WhatLocal=WhatLocal_No	8.52716937536883
1	WhatGlobal=WhatGlobal_No	8.52716937536883
1	InnovationsInst=InnovationsInst_No	8.33376068338908
1	WhoPolicyMakers=WhoPolicyMakers_No	7.8582161882125
1	WhatPlant=WhatPlant_Yes	7.41504584527667
1	RiskSocial=RiskSocial_No	7.25230141867433
1	OutcomeSocec=OutcomeSocec_No	7.01149799682242
1	WhoConsumers=WhoConsumers_No	6.92946948844188
1	RiskUncert=RiskUncert_No	6.36452980687497
1	WhatSupplychain=WhatSupplychain_No	6.17263841558105
1	RiskEconomic=RiskEconomic_No	6.03937373142727
1	WhoFarmers=WhoFarmers_Yes	5.92197511504465
1	MethodsFuture=MethodsFuture_No	5.7837450496403
1	InnovationsTech=InnovationsTech_Yes	5.64493151418161
1	WhatNational=WhatNational_No	5.36749258214175
1	WhoInputSuppliers=WhoInputSuppliers_Yes	5.14783965088805
1	MethodsQuant=MethodsQuant_Yes	4.8957427488887
1	MethodsQualit=MethodsQualit_No	4.8897509521174
1	InnovationsOrg=InnovationsOrg_No	4.68326251604645
1	RiskSecurity=RiskSecurity_No	4.66032690628507
1	WhatSoil=WhatSoil_Yes	4.59501447003856
1	MethodsReal=MethodsReal_Yes	4.5682890921988
1	WhoRetailors=WhoRetailors_No	4.40976726481801
1	OutcomeEnv=OutcomeEnv_Yes	4.34104252242006
1	RiskHealth=RiskHealth_No	4.18566415231149
1	WhatConsumers=WhatConsumers_No	3.94880068446918
1	MethodsMixed=MethodsMixed_No	3.73332606840418
1	RiskClimate=RiskClimate_Yes	3.60640453935377
1	WhatProcessors=WhatProcessors_No	3.37974993028441
1	WhatFarmsyst=WhatFarmsyst_Yes	3.32555118575698
1	WhoProcessors=WhoProcessors_No	2.32038380325421
1	WhatRetailers=WhatRetailers_No	2.1984019244644
2	WhatProcessors=WhatProcessors_Yes	6.18527849766443
2	WhatSupplychain=WhatSupplychain_Yes	6.05245199505073

2	RiskHealth=RiskHealth_Yes	5.67849269992337
2	WhatLocal=WhatLocal_Yes	4.84853931740146
2	WhatGlobal=WhatGlobal_Yes	4.84853931740146
2	WhoProcessors=WhoProcessors_Yes	4.28032334513956
2	WhatRetailers=WhatRetailers_Yes	3.76654796272949
2	RiskEconomic=RiskEconomic_Yes	3.60668236287899
2	WhoRetailors=WhoRetailors_Yes	3.54811410670046
2	InnovationsOrg=InnovationsOrg_Yes	3.19388438972693
2	OutcomeFood=OutcomeFood_Yes	2.90278378639154
2	WhatPlant=WhatPlant_No	2.83016489450401
2	WhatFarms=WhatFarms_Yes	2.65464588377667
2	WhoConsumers=WhoConsumers_Yes	2.58232648663268
2	OutcomeSocec=OutcomeSocec_Yes	2.31655881907045
2	RiskClimate=RiskClimate_No	2.09389331954838

3	InnovationsInst=InnovationsInst_Yes	8.68493817756689
3	WhoPolicyMakers=WhoPolicyMakers_Yes	8.4196104625668
3	RiskUncert=RiskUncert_Yes	6.92886677614248
3	RiskSocial=RiskSocial_Yes	6.80546913938164
3	InnovationsTech=InnovationsTech_No	6.76452184537676
3	WhatPlant=WhatPlant_No	6.23709367945176
3	MethodsQuant=MethodsQuant_No	6.15407543981085
3	OutcomeSocec=OutcomeSocec_Yes	6.08285532621803
3	WhatLocal=WhatLocal_Yes	5.96417725725582
3	WhatGlobal=WhatGlobal_Yes	5.96417725725582
3	MethodsFuture=MethodsFuture_Yes	5.81232174953119
3	WhoConsumers=WhoConsumers_Yes	5.68125009018622
3	WhoFarmers=WhoFarmers_No	5.63724935588934
3	WhoInputSuppliers=WhoInputSuppliers_No	5.56420883503902
3	OutcomeEnv=OutcomeEnv_No	5.00711044551271
3	MethodsReal=MethodsReal_No	4.98082627986579
3	MethodsQualit=MethodsQualit_Yes	4.94031166334318
3	WhatNational=WhatNational_Yes	4.61072574511899
3	WhatSoil=WhatSoil_No	4.53742228814146
3	RiskEconomic=RiskEconomic_Yes	4.26300822774108
3	MethodsMixed=MethodsMixed_Yes	3.69512377697996
3	RiskSecurity=RiskSecurity_Yes	3.53735909716892
3	WhatFarmsyst=WhatFarmsyst_No	3.39171649220134
3	InnovationsOrg=InnovationsOrg_Yes	3.22981875560919
3	WhatConsumers=WhatConsumers_Yes	3.22702390789389
3	RiskClimate=RiskClimate_No	2.53238709576363
3	WhatSupplychain=WhatSupplychain_Yes	2.51215278040867
3	WhoRetailors=WhoRetailors_Yes	2.14630964664285
3	RiskEnvironment=RiskEnvironment_No	1.97547553132427

Appendix 3. Case studies

1. Case study on population/communities' preparation

Table 2: Case study on population/communities' preparation

Projects	**Atlass 2**	**Strengthening rural and food system actors' competence and developing Finland's food system security of supply, resilience, and climate-smartness**
Link	https://projet-atlass.org/	https://www.ilmastoviisas.fi
Funder	National funds	National funds
Period	2021-2023	2024-2027
Countries	France	Finland
Budget	150 000 euros	
Resilience of what	National and local food systems	Food system and rural actors
Resilience to what	Food shortages, seen as economic, social and security risks	Climate change, supply chain disruptions, systemic risks in food production
Resilience for whom	Consumers, policy-makers	Farmers, rural entrepreneurs, food industry actors, advisors, experts, teachers, and students in agriculture
Resilience with what (innovations, solutions for resilience)	**Preparation of populations/communities to shocks** Storage, stress tests, serious games	**Preparation of populations/communities to shocks**
Contribution to research	Territorial approach of food system resilience	Promotes agroecology-based approaches and multi-actor networks, integrates risk management into food system planning, supports knowledge sharing and capacity building
Recommendations for public policies (if formulated)	Teach people how to store food, cope with the frustration of shortages, and behave appropriately in times of crisis; develop food storage systems controlled by public policy, integrating the risk of food shortages in local food policies	Not explicitly stated yet; expected to inform food system resilience and climate adaptation policies
Resilience type (technical or transformative)	Technical and transformative	Transformative
Insights for R&I and policy recommendations (according to us)	Need to consider the environmental impact of storage to include this strategy in food system transformation	

2. Case study on water scarcity

Table 3: Case study on water scarcity

Projects	**SAFE - Sustainable water reuse practices improving safety in agriculture, food and environment**	**TRANSITION - Innovative resilient farming systems in Mediterranean environments**
Link	https://mel.cgiar.org/projects/1826	https://www.transition-med.org/the-project/
Funder	EU, Horizon 2020, PRIMA	EU, Horizon 2020, PRIMA
Period	2022-2026	2020-2024
Countries	Italy, France, Morocco, Lebanon, Greece, Spain, Tunisia	Spain, Italy, Algeria, Egypt, France, Greece
Budget	2,145 million euros	1,150 million euros
Resilience of what	Farms	Farming systems, farms
Resilience to what	**Water scarcity**	**Water scarcity**
Resilience for whom	Farmers	Farmers
Resilience with what (innovations, solutions for resilience)	Water reuse for agricultural field irrigation, ensuring safety	Agroforestry and mixed farming systems, in addition to water reuse
Contribution to research	Development, test and validation of novel low cost and low energy urban decentralised wastewater treatments	New avenues to optimise agroforestry benefits, and identification of resilience levers at farm level
Recommendations for public policies (if formulated)	N/A	Identification of policy barriers to agroforestry and mixed farming systems
Resilience type (technical or transformative)	Technical (substitution of conventional water by non-conventional water)	Technical and transformative
Key points to consider (according to us)	Informing of the new EU regulation 2024/1261 which completed UE 2020/741 with technical specifications Developing synergy with reorientation of farming systems and change in irrigation techniques for more efficiency (as in the TRANSITION project)	The benefits in terms of reduced water usage are not quantified, calling for synergy with a technical approach of resilience (water monitoring).

3. Case study related to energy

Table 4: Case study related to energy

Projects	**AgEnRes - AnalysinG of fossil-ENergy dependence in agriculture to increase RESilience against input price fluctuations**	**CombiFarm - Combining low-cost biochar, biogas, and cyanobacteria fertigation technologies with low-input crops for sustainable bioproducts in smart circular farming systems**
Link	https://agenres.eu/about/the-project	https://mel.cgiar.org/projects/1979?iframe=true
Funder	Horizon Europe	Horizon Europe, PRIMA
Period	2024-2027	2024-2027
Countries	The Netherlands, Greece, Italy, Hungary, Germany, France, Poland, Sweden, Switzerland	Tunisia, Germany, France, Slovenia, Morocco, Turkey
Budget		825 000 euros
Resilience of what	European farming system	Farms
Resilience to what	**Fossil fuel price fluctuations**	**Vulnerability due to dependence to fossil fuels**
Resilience for whom	Farms	Farms
Resilience with what (innovations, solutions for resilience)	Financial tools and support-decision tool for farmers to navigate variations in energy prices	Developing renewable energy sources for farms (solar energy, biochar and biogas production); development of Low-cost pyrolysis cook stoves following an Indian-type design
Contribution to research	Integrating fossil energy and energy-sensitive inputs in socio-economic modelling on multiple scales	New knowledge on circular farming systems combining energy, carbon and nutrient recovery systems based on low-cost farm-scale biochar and biogas production
Recommendations for public policies (if formulated)	Urgent need to adapt existing policy frameworks to better reflect the realities of agricultural energy use and fossil fuel dependence	N/A
Resilience type (technical or transformative)	Technical	Transformative
Insights for R&I and policies	Combining with low/alternative energy-based farming systems and/or extending to supply chains	Ensuring the affordability of equipment, avoiding new dependence on equipment suppliers, managing potential competition between

		agriculture and bioenergy for food and bioenergy

4. Case study related to alternative proteins

Table 5: Case study related to alternative proteins

Projects	**NextGenProteins – Bioconversion of underutilized resources into next generation proteins for food and feed**	**LEGU-MED: Developing Biodiversity-Based Agriculture with Legume Cropping Systems in the Mediterranean Basin**
Link	https://nextgenproteins.eu/	https://mel.cgiar.org/projects/legu-med2
Funder	Horizon 2020	Horizon 2020, PRIMA
Period	2019-2023	2019-2022
Countries	Iceland, Finland, Italy, Sweden, Germany, Israel, France, United Kingdom	Italy, Germany, Spain, Algeria, Tunisia, Turkey, Lebanon, and Croatia
Budget	9,250 million euros	1,24 million euros
Resilience of what	Global and local food systems	Farming systems
Resilience to what	Climate change, growing population	Environmental stresses linked with climate change
Resilience for whom	Farmers, food producers, consumers	Farmers, consumers
Resilience with what (innovations, solutions for resilience)	**Production of alternative proteins from microalgae, single cell protein and insects, using waste**	**Greater use of legume diversity in farming systems**
Contribution to research	New knowledge on alternative proteins, production processes and impacts; safe food prototypes	New knowledge on legumes genetic diversity and ecosystem services provided by legumes
Recommendations for public policies (if formulated)	Policy brief "Alternative Proteins: towards a more resilient food system" https://zenodo.org/records/11262675 (suggestions for labelling, public food procurement, equal tax system, revise the novel foods regulation)	N/A

Resilience type (technical or transformative)	Technical	Technical and transformative
Insights for R&I and policy	Co-creation with consumers could have helped reduce reluctance and facilitate marketing; requires ensuring low-energy production	Could be linked to the disruption of cultivated biodiversity loss and dependence on major crops and imported proteins; to be consolidated with a value chain and consumption approach.