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How can food system actors influence food system resilience? A literature review via an actor-based lens

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Abstract

A growing body of research highlights the central role that actors play in shaping food system resilience. While individual studies have examined the contributions of specific actors, there remains a lack of synthesis that captures cross-sectoral patterns and underlying mechanisms. This review addresses this gap by analysing empirical evidence on how food system actors influencing food system resilience in the face of disruptions—not through abstract system properties alone, but through their concrete activities, capacities, and relationships. Drawing on studies that focus on producers, intermediaries in the supply chain, and consumers, this review identifies four recurring mechanisms through which actors influence food system resilience: (1) actors' capability and agency to act under pressure; (2) the diversity of actors and their functions; (3) the connectivity and connections among actors; and (4) actors' capacity to learn and adapt. These mechanisms underpin the system's ability to sustain or reconfigure essential functions during crises. In addition, the review highlights the importance of supportive structures that bind actors to one another and to the broader food system. These include physical and institutional infrastructures such as logistics, energy, natural resources, digital platforms, and governance systems. Actor influence is also shaped by geographic location and position within the value chain, which affect their access to resources and ability to respond. Recognising that actors' interests may not always align with system-level resilience, it is imperative to critically explore whose resilience is being supported, and for governance approaches that foster collective, system-oriented agency.

1. Introduction

The food system encompasses all aspects of food dynamics, from production and processing to transportation, retailing, and consumption. It is widely recognised as a complex adaptive system where food system actors operate and interact at multiple levels and scales (Zurek *et al* 2022). However, these actors and the subsystems have distinct vulnerabilities and are unequally exposed to external and internal threats (Snow *et al* 2021, p 2). Food systems have expanded in scale and become more globally integrated (Anderson 2015), which is accompanied by heightened vulnerability—reflected in ongoing food insecurity, deepening food poverty, environmental degradation, and increasing exposure to climate-related disruptions (Nzwalo and Cliff 2011, Hannum *et al* 2014, Maitra and Rao 2015, Adenle *et al* 2017, Ba *et al* 2018). Addressing these challenges requires restructuring, prior planning and developing novel solutions that consider the food system's intricate interdependencies (MacMahon *et al* 2015).

Resilience, first introduced by Holling (1973) in ecology as an ecological system's ability to maintain itself and recover from disruptions, has since been extended across multiple fields, including psychology, engineering, and social–ecological systems. In social–ecological systems, resilience may involve human actions dealing with issues such as overfishing or pollution (de Abreu-Mota *et al* 2018, Chhetri 2021), while

for societies, it refers to the ability to cope with various social crises (Walker *et al* 2004, Adger *et al* 2009). For businesses, resilience could mean dealing with more competition or changing customer needs (Larsson *et al* 2016).

Since the 1990s, in the context of food systems, resilience has become increasingly central to research and policy debates, particularly given rising exposure to disruptions of varying scale, scope, duration and severity. Definitions have evolved to reflect the complexity of food systems, moving beyond simple notions of system 'survival' toward recognising 'the capacity over time of a food system and its units at multiple levels to provide sufficient, appropriate, and accessible food to all in the face of various and even unforeseen disturbances' (page 19) (Tendall *et al* 2015). Apparently, scholarly discussion of resilience has moved beyond the expectation of keeping the food system operating during crises and has come to emphasise the capability to maintain the functions of the food system despite disruptions.

Building on previous research, Ingram (2017) further offers a useful elaboration, framing food system resilience in terms of (1) robustness—the ability of the food system to resist disruptions to desired outcomes; (2) recovery—the ability of the food system to return to desired outcomes following disruption; and (3) reorientation—the ability to accept alternative outcomes preceding or following disruption. In parallel, numerous case studies examine the challenges of food systems across actors, including adapting to climate change on farms, ensuring food businesses remain operational during natural disasters, utilising local food markets to provide food during pandemics, and coordinating cross-regional and cross-level food supply chains to facilitate food distribution (Hubbard and Onumah 2001).

While the theoretical and empirical discussions on food system resilience have grown substantially, a number of foundational questions remain underexamined. For instance, who or what contributes to food system resilience, and how? Which actors are positioned to influence system-level outcomes, and through what mechanisms? Are actors' interests and efforts aligned and compatible in promoting food system resilience? Brzezina *et al* (2016) even argued that the value judgement of what is resilient or vulnerable to what and over what period of time depends on the beneficiaries. In other words, one of the key issues concerns the relation between actor- and system-level factors and perspectives.

Resilience thinking has often prioritised systemic structures, while underplaying the roles of diverse actors with differing values, goals, interests, and powers in shaping system resilience (Hoque *et al* 2017). Yet resilience does not emerge in abstraction—it is enacted, shaped, and constrained by real actors across different levels in real systems. More importantly, the interconnections of food supply chains and networks allow for risk transmission between actors and levels that such a breakdown at any point may impact the ultimate functioning and functions of the system (Zurek *et al* 2022). Furthermore, actors in the food system are embedded in society, and their well-being is linked to the overall social, political, and economic situation. For example, food inaccessibility may result from insufficient income and delayed welfare payments rather than from a failure of the food system (Benker 2021). It is, therefore, crucial to consider the broader societal context and stakeholders' interests when examining food system resilience.

Building on this insight, recent studies have begun to explore the actor-dimensions of resilience across specific contexts. However, much of this literature remains fragmented across cases, actor types, and scales. Previous literature reviews have explored conceptual and theoretical development (Tendall *et al* 2015, Zurek *et al* 2022), the impact of market power on food system resilience (Merkle *et al* 2021), food supply chain resilience to environmental shocks (Davis *et al* 2021), and the ontology development and impossible trinities for food system resilience (van Wassenaer *et al* 2021), with limited attention to the broader patterns that emerge from empirical studies of actors.

This paper seeks to address this gap by conducting a scoping review to examine the interactions between actors and food system resilience based on empirical evidence. Evidently, this paper is not arguing that either food producers or retailers are more beneficial to food system resilience but rather taking a system-wide view, asking how actors—through their capacities, behaviours, and interactions—collectively shape food system resilience. Noteworthy, while resilience is ultimately concerned with sustaining key system outcomes—such as food availability, accessibility, and quality—this paper focuses on the processes and capacities that underpin those outcomes. Specifically, it approaches resilience through the lens of functioning: how food system actors respond to and manage disruption in ways that affect the system's ability to maintain or adapt its core functions. By concentrating on the activities and relationships that shape resilience in practice, the review aims to shed light on the mechanisms through which resilience is built from within the system, rather than treating it as a static or pre-defined endpoint.

In the subsequent sections, section 2 describes the methods and literature selection process and the results of this paper; section 3 focuses on empirical observations—that is, how different actors across the food system have contributed to or influenced resilience in concrete contexts; section 4 sums up the supportive roles that allow food system actors to exert their influence on the food system resilience; section 5 synthesises across these observations to identify underlying resilience mechanisms—the recurrent,

system-level features or processes through which actors exert influence. Section 6 concludes the review with identifying research gaps and providing suggestions on future research directions.

2. Methods and materials

2.1. Research boundary and questions

For this scoping review, 'food system' refers to levels ranging from local to global, while 'food system actors' include those involved in various aspects of the food production and distribution process, from production and processing to transportation, consumption, and waste disposal. Although actors within the food system are diverse and heterogeneous, this review focuses on the integrated food system rather than on specific food types or subsystems. Food system resilience can be influenced not only by actors, but also relies on a number of key linkages or supports provided by natural, social and economic systems. To guide the review process and ensure comprehensive coverage of the literature, this paper formulates four research questions:

(1) What types of food system actors have been given attention in empirical research on food system resilience?
(2) How do these actors contribute to food system resilience during disruptions?
(3) What are the key supportive roles that link actors to the wider food system and influence systemic resilience outcomes?
(4) What mechanisms mediate the influence of food system actors on system-wide resilience?

2.2. Data sources and search strategy

This paper adopts Web of Science Core Collection and Scopus databases to assemble publications on actors and food system resilience. The search was restricted to articles in English with publication years from 1994 to November 2022. Non-English language sources were excluded for practical reasons, though this may have resulted in the omission of several relevant papers.

A Title-Abstract-Keyword search was conducted in Scopus, while a Topic search was applied in the Web of Science. The search strategy used in this review is (TITLE-ABS-KEY (food AND system AND resilience) AND TITLE-ABS-KEY (actor OR player OR stakeholder OR sector OR participant)). This search incorporated quantitative, qualitative and mixed methods articles.

This review intentionally adopts an integrated food system lens, rather than focusing on specific subsystems or individual actors, as it aims to explore cross-sectoral and cross-level interactions that shape systemic resilience. While we acknowledge that using broader actor-related terms (e.g. 'farm', 'processor', 'consumer') may have increased the initial volume of search results, the decision to centre the search on the combined terms 'food system resilience' and 'actor' (and their synonyms) reflects our conceptual commitment to understanding the food system as a complex, interconnected whole. A broader set of search terms targeting individual roles might risk fragmenting the analysis and diluting the systemic perspective that this review seeks to maintain. The goal of this study is not to assess the resilience of specific actors in isolation, but rather to move beyond siloed assessments of resilience and identify how actors—through their roles, interactions, and embeddedness.

This paper notes the exponential growth of scientific literature globally focusing on food system resilience and governance following the COVID-19 outbreak in 2020. However, the purpose of this paper is not to compare how food systems perform across geographical contexts or to provide a timeline-specific analysis, but rather to synthesise empirical insights on how different types of food system actors—regardless of location—contribute to systemic resilience. Therefore, this review does not narrow the scope to specific regions or focus on specific timeframes. The global nature of food system challenges, combined with the fact that actors often play comparable roles across contexts, supports the case for a broad empirical base. While regional variation and crisis-specific dynamics, such as those associated with Global South and North discussions or COVID-19, are undoubtedly relevant, they are not the primary focus of this analysis.

2.3. Study selection

In the search, Web of Science returned 858 publications, of which 847 are in English, while Scopus returned 878, 862 of which are in English. After removing duplicates from the combined 1709 records, 1126 unique articles remained. All remaining abstracts were imported into Zotero, and key points of the papers can be tagged and categorised. To ensure a focused and relevant evidence base, a two-stage screening process was applied using a set of inclusion and exclusion criteria.

Stage 1—title and abstract screening: at this initial stage, records were screened to remove irrelevant or inaccessible literature. The following exclusion criteria were applied:

Table 1. Number of referenced studies by thematic subsection.

Section/subsection	Number of referenced studies
3.1 Producers	34
3.1.1 Autonomy of the producers	6
3.1.2 Diversification of products and producers' business models	9
3.1.3 Producers' knowledge and management	7
3.1.4 Producers' willingness and capability to respond…	4
3.1.5 Self-organisation and association of producers	7
3.2 Intermediaries in the food system	45
3.2.1 Mainstream food supply chain actors	7
3.2.2 Alternative food networks	27
3.2.2.1 Co-operatives of local food supply chains…	4
3.2.2.2 Informal retail to complement mainstream…	8
3.2.2.3 Social distribution networks…	2
3.2.2.4 Self-help supply based on smaller units…	6
3.3 Consumers	12
4.1 Nature and relevant agricultural systems	10
4.2 Energy systems	4
4.3 Venue infrastructure	2
4.4 Logistics and food distribution networks	9
4.5 Food storage schemes at various geographical scales	5
4.6 Digital technologies for information sharing	8
4.7 Institutional care/support	6
5.1 Actors' capability and agency for resilience	8
5.2 Diversity of actors and functions	17
5.3 Connectivity and connections	25
5.4 Learning and knowledge	6

(1) Articles without empirical evidence (i.e. purely theoretical or conceptual work);
(2) Articles with no reference to food systems. These included, for example, articles focused solely on consumer behaviour or crop productivity without any discussion of system-level dynamics;
(3) Non-peer-reviewed materials (e.g. conference abstracts, reports, opinion pieces);
(4) Article that could not be retrieved in full text or were not accessible to read.

After applying these criteria, 134 articles remained for full-text screening from an initial pool of 1126 records.

Stage 2—full-text screening: full-texts of the 134 articles were then assessed against refined inclusion criteria:

(1) The study must adopt a food system lens or explicitly link subsystem dynamics to food system-level outcomes. In this review, the term *food system* is understood as an overarching framework that encompasses a range of interconnected subsystems—such as production, processing, distribution, retail, and consumption. This criterion was applied to assess whether a study, even if focused on a specific subsystem (e.g. agriculture or logistics), situated its analysis within a broader system perspective or examined how subsystem-level processes affect the outcomes of the food system as a whole ($n = 9$);
(2) Where multiple publications by similar group of scholars investigated the same case or intervention, only the most comprehensive or recent study was retained to avoid redundancy ($n = 2$);
(3) Studies must have already explored interactions across actor types or system levels—that is, how actions of one actor or group influence other parts of the food system, thereby shaping system-wide resilience capacities (termed here as cross-level influence). By doing so, this review will be better positioned to identify the actors in the food system whose efforts have cross-level effects on system resilience and to describe how these effects occur ($n = 17$).

Based on the above criteria, 106 articles were eventually included in the review. The selection of topics in sections 3–5 was informed by an inductive coding process during the full-text review. As articles were analysed, codes were assigned based on actor types, enabling infrastructures, and resilience-related mechanisms. Topics were retained as standalone themes where a meaningful pattern of empirical attention was evident—reflected in both the number and diversity of studies citing them. Table 1 summarises the number of referenced studies in each thematic subsection, reflecting the empirical grounding of each topic discussed in sections 3–5.

3. Actors' impacts on food system resilience

Existing literature on food system resilience focuses on three connected levels. At the outermost level, a highly industrialized and globalized supply chain is anchored by multinational and domestic food commodity producers, supermarket chains, and the food service sector. The middle level of analysis focuses on regional food systems, which may involve a mix of industrialised products and localized alternative networks. Depending on the specific study, the region may be described as local, urban, or something else. Finally, the third level of analysis centres on community and household resilience. This level encompasses community and household farming and storage practices, all of which contribute to food system resilience at the grassroots level. In this section, this paper summarises how actors affect systemic resilience based on their roles in the food system, looking at the mainstream actors involved in food system activities, such as producers, processors, transporters, retailers and consumers, as well as emerging actors, such as alternative food networks (AFNs).

3.1. Producers

Food production is the starting point of the food system, providing products for the subsequent value chain, and therefore the resilience of the producers is considered to be the basis for food system resilience. Two interconnected themes emerge in the literature connecting producers and food system resilience: (1) production resilience, i.e. how producers maintain robust food yield in a changing environment (Davis *et al* 2021); and (2) livelihood resilience, i.e. how producers ensure a reasonable economic income for producers to secure their livelihoods and thereby contribute to system resilience (Ado *et al* 2019).

3.1.1. Autonomy of the producers

Studies have shown that food producers with greater autonomy and less external dependence are more operationally resilient and better able to secure supplies to the food system (Meuwissen *et al* 2021, Helfenstein *et al* 2022, Mastronardi *et al* 2022). One typical practice is to internalise all possible activities for production, including reliance on local ecological agricultural production and local sources of inputs (Paganini *et al* 2020). Low-input organic agriculture, for example, can better recognise natural resource degradation and regeneration cycles and enhance the resilience of both natural and human resources, thereby ensuring the long-term viability of the farm and the food system as a whole (Brzezina *et al* 2016). Food producers with these characteristics have also demonstrated their superior ability to cope with disruptions like transport disruptions and labour shortages caused by the COVID-19 pandemic (Paganini *et al* 2020, Helfenstein *et al* 2022). For instance, Mastronardi *et al* (2022) found that dairy farmers with a high level of autonomy in feeding—over 90% of the total dry matter supplied locally—did not have to deal with absentee staff and were able to self-regulate their human resources to continue operating during the lockdown. Conversely, capitalised food systems that heavily rely on external inputs are vulnerable to risks beyond their boundaries (Brzezina *et al* 2016). Farms that outsourced certain functions (e.g. food processing) prior to the pandemic were more severely impacted by the COVID-19 pandemic (Mastronardi *et al* 2022).

3.1.2. Diversification of products and producers' business models

Breeding and crop diversity could diversify people's diets, and increase agricultural productivity and resilience (Finckh 2008, Bailey and Buck 2016, Dwivedi *et al* 2017, Davis *et al* 2021), while more specialised and intensive farms are more likely to feel the negative effects of disruptions (Abson *et al* 2013, Campi *et al* 2021). High specialisation makes farmers more efficient in accessing and applying technology, but specialised farms are highly dependent on the commodity markets in which they operate and are more vulnerable to shocks in the supply chain, increasing their economic vulnerability (de Roest *et al* 2018, Helfenstein *et al* 2022). Furthermore, industrial agri-food systems, mainly consisting of intensive farms, limit farmers' autonomy to resist and adapt to possible ecological and social damages (Hendrickson 2015). Global market integration and the capital investments required for participation reduce operational flexibility. For example, Hendrickson noted that planting herbicide-resistant seeds binds soybean farmers to a specific herbicide through the accompanying management package. This lack of choice further restricts farmers' ability to adapt to change when challenges arise (Hendrickson 2015).

In contrast, farms with more diverse operations can develop cost complementarities between different crops or livestock species and target products for different, market-specific production segments, which helps the farm's overall profitability and resilience to shocks (de Roest *et al* 2018). Land use diversity on farms, such as integrating cereal crops, livestock, dairy, and fodder crops, is crucial for fostering resilient agricultural returns by creating a covariant returns structure that reduces aggregate return volatility and therefore enhances economic resilience in uncertain market and environmental conditions (Abson *et al* 2013). The effect of business model diversification was also evident during the COVID-19 pandemic. A study

in Italy showed that diversified farms played an essential role in avoiding production and supply chain disruptions at the beginning of the lockdown and safeguarding food security afterwards without raising prices by rapidly changing their commercial channels and outlet markets (Mastronardi *et al* 2022). In the Zemgale region of Latvia, efforts were also made to incorporate locally made food products in the tourist attraction. This made local food more visible to a broader audience and helped strengthen the social and economic resilience of rural communities during the pandemic (Kaufmane *et al* 2021).

Notably, while diversification can help farms stabilise incomes and enhance operational resilience, it also requires the cultivation of farmers' marketing skills and the backing of collaborative networks, including farmers' proactive engagement in developing shorter food chains and rebuilding supportive social and economic networks (de Roest *et al* 2018, Manyise and Dentoni 2021, Meuwissen *et al* 2021, Grigorescu *et al* 2022).

3.1.3. Producers' knowledge and management

Agricultural management in knowledge, techniques and institutions are also recognised as supporting natural systems to support food system resilience. Marten and Helicke's (2015) research found that well-planned farm diversification with techniques such as 'bio-intensive cultivation' could improve sustainability and resilience through enhanced water efficiency and nutrient retention while reducing damage from pests and pathogens. Gramzow *et al* (2018) found that introducing improved vegetable species, sound agricultural practices to prevent disease, and integrated pest management practices could reduce negative effects on the environment and make agricultural production and rural livelihoods more resilient to outside shocks like drought and pests. Farms could improve their relationship with the environment by conserving and restoring soil, utilising available local resources efficiently, and respecting and adhering to natural cycles.

Many scholars have also appealed for a transformation towards ecological agriculture to increase producers' resilience to future shocks (Rodríguez and González 2018, Tittonell *et al* 2021, Helfenstein *et al* 2022). Technologies and approaches tailored to the agroecological conditions and climate risks of smallholder farms are increasingly being adopted by public agricultural institutions in many developing regions (Lipper *et al* 2014) to support smallholder production and livelihood resilience in climate change (Winowiecki *et al* 2015, Eakin *et al* 2018). While the duration and type of any future disturbance on individual farms will depend on the geographical and political context, scholars argue that agroecological practices that rely on internal resources and are embedded in local networks could promote resilience mechanisms, such as autonomy, social self-regulation, connectivity and local interdependence, which may foster human resources (Brzezina *et al* 2016) and support system's resilience capacity (Perrin and Martin 2021).

3.1.4. Producers' willingness and capability to respond to consumer demand

The willingness and ability of producers to respond to risks have also been highlighted in the literature, for example, by proactively adapting to and rapidly altering their commercial channels and establishing closer ties with consumers (Paganini *et al* 2020, Mastronardi *et al* 2022). A French study found that dairy farms selling their products through short channels received a significant impact from the lockdown even though they had multiple customers. However, the farms developed a variety of new marketing channels based on their strong adaptability, such as drop-off-free service for purchases and farm tours, which ensured their operations and consumers' access to the products they needed (Perrin and Martin 2021).

A strong 'can-do' spirit in agriculture is an important driver for minimising losses and uncertainty (Snow *et al* 2021). In the process, dairy farmers have also strengthened their local interdependencies with other farms to offer their customers an extensive range of products at one collection point (Perrin and Martin 2021). Creating direct links between producers and consumers in a crisis can generate income for the farm by reducing the potential for unsold stocks. More importantly, such direct links involve producers in the consumer-facing retail end and minimise intermediaries, enabling fairer prices for both producers and consumers, and allowing consumers to build a perception of locally produced food (Prosser *et al* 2021).

3.1.5. Self-organisation and association of producers

The degree to which the system is capable of self-organisation is one of the dimensions of resilience (Berkes *et al* 2008). Collaboration among food producers can lead to significant economic and non-economic benefits, such as increased knowledge sharing, supportive networks, additional channels of access to customers, positive publicity, and increased regional brand awareness (Prosser *et al* 2021). A case study in the Solomon Islands showed that collaboration between fishers could prevent system collapse, sustain whole communities under minimum food security levels, and improve ecological performance, thus enhancing the resilience of the whole system to shocks (Hardy *et al* 2016). Similarly, food producer collaborations in Wales provided innovative marketing approaches that maintained trade capacity during the COVID-19 pandemic,

supporting local populations most affected by the outbreak and subsequent restrictions, thereby strengthening the brand image and also providing accessible food to the nation (Prosser *et al* 2021).

However, the producer-led collaborative model may require more effort and engagement from producers, and the costs and benefits of producers' participation are linked to their contribution level (Prosser *et al* 2021). Beyond, the association of producers in more organised forms, such as farmers' unions and producer cooperatives, can bring systemic benefits to small-scale farmers, including the power to negotiate with the government for support and with other value chain actors for fair prices and reduction in farm management costs through partnerships among farmers (Eidt *et al* 2020, Paganini *et al* 2020, Soubry *et al* 2020). While the decision-making power may be further away from producers than in producer-led collaborations (Prosser *et al* 2021), a cross-regional study in Indonesia and Africa found that small-scale farmers need a certain amount of social capital to build their transformative power and good organisation to supplement the supply of local food systems (Paganini *et al* 2020). Farmers' unions can help them cope with crises and reorient themselves more effectively, leading to greater overall system resilience (Tittonell *et al* 2021). Notably, some studies have also cautioned against excessive concentration and consolidation among producers, highlighting the additional vulnerabilities that may arise from monopolistic control over certain products (Rotz and Fraser 2015).

3.1.6. Producers' summary

In summary, producers influence food system resilience through five interconnected mechanisms:

(1) autonomy, reducing reliance on external inputs and services and thereby limiting exposure to shocks and changes;
(2) diversification of products and business operations, increasing flexibility and income to cope with risks;
(3) knowledge and agroecological management practices, supporting environmental sustainability and long-term adaptability;
(4) willingness and capability to engage with consumers and adapt market strategies, emphasising the agility and responsiveness to disruptions; and
(5) collaboration and association, enabling share knowledge and resources, collective action and institutional influence.

All of the preceding can be interpreted as assisting actors in the production system to remain reasonably operational and profitable during a crisis, i.e. to meet the needs of producers while also fulfilling their responsibility to the food system (Cabell and Oelofse 2012, Perrin and Martin 2021). The agency of producers is the key joint driving force that enables the above mechanisms. However, smallholder farmers are particularly susceptible to certain shocks, such as those related to climate change. Despite employing various risk-coping strategies, these efforts often remain insufficient due to constrained resources, limited capacity, and gaps in knowledge, ultimately hindering the widespread adoption of effective adaptation strategies (Harvey *et al* 2014). Several studies have also shown that government support for producers' agency could have been more robust (Paganini *et al* 2020), even though producer-driven solutions often have a low threshold and do not call for much in the way of finance or programming. The profitability of small-scale farming is affected by the supply chain dominance of large-scale supermarkets, which place financial strain on the coping strategies deployed by farmers to strengthen their resilience in response to climate change impacts, market pressures, and transport issues (Singh-Peterson and Lawrence 2017). Consequently, many adaptive transformations based on farmers' motivation face financial barriers between concept and implementation, hence reducing food system resilience (Tu *et al* 2019). While producers have considerable initiative in terms of their own circumstances and resilience, this does not mean that there is not significant room for improvement in mechanisms for support from institutional structures, including those of the state and public authorities; i.e. from bodies who are ultimately tasked with government of the common weal and so the system as a whole at whatever geographical scale.

3.2. Intermediaries in the food system

Throughout the food system, the food supply chain connects producers to consumers. The supply chain is also a value chain in which long-term partnerships between actors who produce, transport, process, and sell products or services are essential for the food system to efficiently deliver agricultural products from producers to consumers' tables (Manyise and Dentoni 2021).

3.2.1. Mainstream food supply chain actors

Research exploring actors' impact on food system resilience in supply chains has focused significantly on the retail end close to consumers. Traditional food retail locations such as supermarkets and farmers' markets

help the food system to fulfil its function of securing the food supply in a given region, both in normal times and crisis.

Farmers' markets allow consumers to learn about and connect with local agriculture. Farmers and consumers can learn from each other's feedback, which facilitates mutual understanding of the complex dynamics of the food system and improves their adaptive capacity via influencing consumer choice and farm management. By building bridges between actors, farmers' markets can help build social networks and trusting relationships in the food system, thereby enhancing local food systems' socio–ecological resilience and sustainability (Singh-Peterson and Lawrence 2017).

Large corporations, such as supermarkets, contribute to securing supply by managing contracts and providing knowledge, capital, and infrastructure (Dunning *et al* 2015). Industrial food systems have been highly successful in providing affordable, safe, and diverse food products to growing populations of consumers (Kummu *et al* 2020, Matthews 2020), with supermarkets representing the retail end of the industrial food system. A just-in-time delivery system that depends on long-distance road transport (MacMahon *et al* 2015) makes supermarkets well-equipped to handle fresh bulk goods, which helps keep the region's food supply resilient and efficient (Merkle *et al* 2021). Supermarkets can also exert influence on the supply chain through procurement. Restoring a central market system and mandating that supermarkets purchase fresh products through it is considered one method to ensure that all farmers receive a fair price for their production (Singh-Peterson and Lawrence 2017).

In the context of regional crises, the scale of a food retailer can be an asset. The power and influence of large corporations such as supermarkets in the food system have been equated to the role of 'keystone species' (Osterblom *et al* 2015) that are critical to ecosystem function (Merkle *et al* 2021). Global infrastructure and good logistics allow supermarkets to move supplies between regions where they are made (Merkle *et al* 2021). Food shortages in one region can be mitigated by sourcing food from other regions, making long food chains that utilise regional or global networks more resilient to environmental disasters (MacMahon *et al* 2015). Researchers also looked at how retailers dealt with food supply problems during the pandemic through collaborative innovation and technological solutions (Prosser *et al* 2021). Supermarkets have assisted in selling and distributing food during the crisis by incorporating local suppliers and offering home delivery services (Dunning *et al* 2015).

In summary, mainstream food supply chain actors—particularly supermarkets and large retailers—support food system resilience through their expansive infrastructure, procurement networks, and logistical capacities. Their ability to shift sourcing across regions and maintain just-in-time delivery systems can help stabilise food availability during periods of disruption. Additionally, their engagement with local suppliers in times of crisis highlights their potential for adaptive integration. However, their market dominance may marginalise smaller actors and undermine system diversity. As such, while large retailers contribute structural robustness, their centralised control can also introduce systemic vulnerabilities, making their role in resilience both enabling and, at times, constraining. This tension is further explored in section 3.2.3.

3.2.2. AFNs

Beyond the mainstream food supply chain, and building on these reflections, AFNs are essential and dynamic parts of a resilient food system (O'Connell *et al* 2021). Much research has been done on how AFNs affect the food system's functioning and functions in times of crisis (Grigorescu *et al* 2022). We categorize the AFN that aids food system resilience into four categories.

3.2.2.1. Co-operatives of local food supply chains that skip middlemen and link producers and consumers with shorter connections, e.g. farmer partnerships, consumer cooperatives, food hub social enterprises, etc

In addition to the associations between producers mentioned in the previous section, many studies have focused on the consumers' associations to ensure their food procurement needs. Vieira *et al* (2019) found that the Brisbane Food Hub had established direct links with small-scale farmers and their social networks, making it one of the few places to get fresh food after floods. During the pandemic, Glaros *et al*'s (2021) research in Canada found that connecting local producers to urban markets relied on cross-scale mobilisation and extensive collaboration and deployment of resources by civil society and government. Solidarity purchasing organisations in Rome represented a vital food supply channel during the lockdown, as they paid local farms and had greater flexibility and agility in moving and handling goods, contributing to the resilience of local agri-food structures (Tarra *et al* 2021). Consumer cooperatives directly connecting producers and consumers in urban areas can serve the impacted populations and address the growing demand during COVID-19 pandemic (Atalan-Helicke and Abiral 2021).

3.2.2.2. Informal retail to complement mainstream retail and improve food access

Alternative retail networks, also referred to as informal vendors and small traders in some literature studying the global South, tend to be scattered in areas where potential consumers often congregate, such as schools, transport hubs, and lower-income communities (Keck and Etzold 2013, Kinlocke and Thomas-Hope 2019, Nickanor *et al* 2019). Given that conventional retailing locations for supermarkets or farmers' markets have spatial limits (Nickanor *et al* 2019, McEachern *et al* 2021), informal retailers are therefore seen as complementary to those not catered for by the conventional formal retail sector, helping to secure their food needs (Nickanor *et al* 2019).

A study in Namibia found that informal retailers were thriving by occupying product niches that formal retailers have not yet monopolised, such as cheap meats, wild foods, cooked foods, and offal. However, expanding supermarkets into low-income areas has put informal vendors under pressure to be squeezed out (Nickanor *et al* 2019). Similarly, research in Jamaica showed that small informal retailers have played a crucial role in providing relatively cheap food to poor urban households, but they are often subject to regulatory challenges that threaten the sustainability of their trade. Their relief and capacity-building interventions may be limited by insufficient public funding (Kinlocke and Thomas-Hope 2019). Research in Dhaka showed that informal rice and fish wholesalers were resilient and helped to meet the food needs of households that could not afford supermarket shopping and had not yet received food aid after the flooding. Such informal retailers could do so because they already had trusting customer relationships (Keck *et al* 2012). However, a lack of support or even eviction of informal retail by local governments have threatened the resilience of urban food systems by hindering the ability of informal retailers to operate (Keck and Etzold 2013).

Informal retailers are not limited to the Global South, but may have different forms of expression in the global North. McEachern *et al* (2021) advocate for establishing community-led food retailers in the United Kingdom. This transformative model can both formalise small traders and engage and unite community members, reintegrating food production and consumption into the social system. By securing space for more minor actors to survive, community-led food retailers in the community food system can help generate ethical, sustainable and resilient solutions at the local level (Turetta *et al* 2021). In other words, as noted above, a diversity of sizes of food actors appears to be important and advantageous, at both system and actor levels, and AFNs seem to have promise in the needed rebalancing to a diversity of small actors regarding often highly-concentrated current food systems.

3.2.2.3. Social distribution networks, including charities and food banks, primarily supporting vulnerable people and help alleviate food poverty

As traditional food charities, food banks not only help consumers in need of food but also help reduce food waste. The operation of food banks relies on a range of other actors and resources, including donors, public support and government backing. During the Covid-19 pandemic, a number of food banks, despite facing initial challenges due to delivery disruptions and lockdowns, also provided special assistance packages for those affected by the COVID-19 pandemic (Dekkinga *et al* 2022). While support for food banks is a sign of social solidarity, the increase in recipients may make providing food aid perceived as fragile and unsustainable. There is also criticism that the essence of food charities is that governments across the world, in both rich and poorer countries, have abdicated their obligation to ensure the right to food, leaving the responsibility of providing food to the poor to third-party organisations (Riches and Silvasti 2014). When the underlying causes of the need for food aid are not addressed, food aid networks established through food banks may end up undermining the resilience of societies, particularly the ability to ensure dignified access to adequate food (Dekkinga *et al* 2022).

3.2.2.4. Self-help supply based on smaller units—from urban, community to family farming

Tendall *et al*'s (2015) definition of the resilient food system clearly emphasises its 'capacity to provide adequate, appropriate, and accessible food 'rather than the 'realisation of capacity'—the implicit neoliberal connotation here requires consumers also to put in some efforts in order to reach the end of food supply (Benker 2021). However, the lockdown caused by the pandemic made it hard for people to shop, especially in cities. This has stimulated discussions of super-local supply beyond traditional peri-urban production, encouraging a radical re-thinking of how food system resilience can be reconceptualised and practised on a global to local scale (Turetta *et al* 2021). From urban agriculture and community gardening to even family farming, it is possible to re-imagine new scales and systems of food production, distribution, consumption and waste management (Glaros *et al* 2021, Langemeyer *et al* 2021). Centring on empowering smaller units to participate, these practices can provide additional security for low-income populations who are often marginalized (Piso *et al* 2019) and expand food supply sources, moving beyond a system overly reliant on large-scale operations.

Community food systems seek to build community food resources, including supermarkets, farmers' markets, gardens, transportation, community-based food processing businesses and urban farms, to meet community needs and promote better linkages on local agriculture between farmers and consumers (Turetta *et al* 2021). Household-level transformations are also gaining traction. The case of Rome demonstrates the resilience of small-scale, sustainable family farming coupled with spatially and socially embedded food systems during the Covid-19 pandemic, where grassroots actors played an important role in ensuring food access, availability and distribution, especially for the most vulnerable populations in a context of delayed or insufficient action by mainstream food system actors and institutions (Zollet *et al* 2021).

3.2.2.5. AFN's summary

Overall, AFNs influence resilience through relational mechanisms such as

(1) shortening supply chains to reduce dependence on intermediaries and increase agility and transparency;
(2) establishing trustworthy relationships and social capital among producers, consumers, and civic organisations;
(3) enabling bottom–up mobilisation, adaptability, and innovation in times of disruption;
(4) fostering social networks and connections by supporting marginalised groups and community-level food security.

Nonetheless, AFNs have still been deemed incapable of addressing broad food security challenges due to their limited scale (MacMahon *et al* 2015). Even so, diverse sizes of food actors appear to be important and advantageous, at both system and actor levels. There is also a need to go beyond any hypostatized/fetishized scale, not just the 'global' viz. neoliberal default ideas of 'bigger and more global is better' but also 'local'. AFNs seem to have promise in the needed dynamic rebalancing to a diversity of small actors of varying sizes and reach regarding often highly-concentrated current food systems.

The development of AFNs also faces challenges in terms of unequal access to opportunities and support compared to conventional food retailers and distributors. For instance, despite the significant need for greater food access among the population following the floods, a study from Dhaka revealed that the local government chose to shut down informal retailers due to administrative challenges and a lack of trust in these vendors (Keck *et al* 2012). Before the Covid-19 pandemic, small-scale and informal food sectors were primarily excluded from government support, unlike mainstream supermarkets (Paganini *et al* 2020, Zollet *et al* 2021). Governments' perception that managing AFNs is more troublesome and less cooperative than conventional retailers has affected the unequal distribution of resources and exacerbated existing socio-economic disparities among food system actors. Consequently, either transforming the current mainstream system or mainstreaming AFNs so that they can play a more significant role in the food system would be more difficult (Paganini *et al* 2020, Zollet *et al* 2021). Therefore, research suggests that the decision-making process should include more diverse actors to increase the possibility of creating different socio-economic models (Vieira *et al* 2019). More importantly, the resilience of food systems depends on the whole socio-economic and ecological system in which the food system is embedded. Declining earnings, unemployment, labour shortages, and other challenges caused by crises will likely result in food poverty, a phenomenon that the complementary functions of the AFN proved insufficient to address alone during the COVID-19 pandemic (Dekkinga *et al* 2022). The cruel truth is there are limits to what even the most resilient food system can deliver.

3.2.3. Debates on long and/or short food supply chains (SFSCs)

From the discussion of traditional large retailers and alternative local food networks, the debate here centres on whether longer and more industrialised or shorter and more localised food supply chains are more conducive to food system resilience. Overall, supply chain resilience is considered to be built on agility (i.e. the ability to respond quickly and cost-effectively to shocks), visibility (i.e. the identity, location, status, and all necessary information of supply chain transit entities captured in timely messages about incidents), flexibility (i.e. the ability to adapt to changes with minimal time and effort), collaboration (i.e. the adequate capacity to work together to achieve common goals), and information sharing to mitigate risks (Perrin and Martin 2021). Of course, given that both non-local and local factors can affect food system resilience, it needs to be acknowledged at the outset that this is not an either/or issue. Resilience and vulnerability exist in both long and SFSCs (MacMahon *et al* 2015), but each has strengths in several of the above characteristics.

From a resilience perspective, despite the persistent criticism of food miles caused by global food trade, the ability to provide food whenever needed is an essential feature of a resilient food supply chain (Macfadyen *et al* 2015). Consequently, food systems become more global while distribution networks expand significantly to provide food to populations worldwide. Extensive infrastructure, logistics, and technological

resources have been developed accordingly (Rotz and Fraser 2015). Although disruptions, such as production losses due to extreme weather events or pest outbreaks, are also accompanying, global food supply chain can help ensure that agricultural landscapes and food supply are professionally managed to guarantee food availability and withstand such shocks (Macfadyen *et al* 2015).

However, a study in Queensland found that long chains supplying retail venues such as supermarkets were vulnerable when the flooding cut off roads, while civic agriculture, despite showing resilience, remained marginal to the food needs of most Queensland consumers (MacMahon *et al* 2015). Transportation is not the only challenge; lack of regional production and processing capacity is another reason why regionally based SFSC are unlikely capable of fully replacing traditional food supply chains soon (Marusak *et al* 2021). Additionally, SFSC struggle to compete with large grocery groups in terms of convenience, food variety, and low prices (Marusak *et al* 2021), suggesting that consumers' shift to AFNs during crises may be only temporary (Zollet *et al* 2021).

Other studies have argued that SFSCs add redundancy and complementary resilience to the food system by letting actors respond quickly and getting help from the local government (O'Connell *et al* 2021, Jones *et al* 2022). In contrast to larger systems, local food systems have shifted from primarily livelihood-oriented food production and consumption systems to increasingly complex multi-local networks (Spies 2018). Many members in SFSC are themselves collectives, groups, or cooperatives with extensive networks so that suppliers affected by disruptions can easily be replaced (McDaniel *et al* 2021, Michel-Villarreal *et al* 2021). Thus, SFSC based on regional/local food systems also have some equity advantages for local actors due to greater local engagement (Meuwissen *et al* 2021), as well as promoting the resilience of local communities by offering political and economic capital and a sense of community pride and belonging (McDaniel *et al* 2021).

There has been a significant increase in SFSC research since the COVID-19 pandemic, apparently because the impediment to transportation and mobility caused by the epidemic has driven the expectation that food should come from a source closer to the consumer. Relying on global supply chains, supermarkets have been criticised for crowding out the market and growth space of smaller local competitors. However, such large actors are still seen as more reliable suppliers (Smith and Lawrence 2018) and thus are favoured by governments to have received more support (Paganini *et al* 2020, Zollet *et al* 2021). SFSC, characterised by locally engaged actors, are not considered to have the potential to substitute traditional food webs. Instead, they can act as a reinforcement of local food systems. Local food systems, discussed here dialectically at the geographical scale, can improve nutrition and access to quality food for urban populations while increasing the incomes of household farmers (Sambuichi *et al* 2020). Moreover, some possibilities exist for integrating mainstream food supply chains with local actors and incorporating localised sourcing and distribution with supermarkets' industrial infrastructure to improve food system resilience based on building public–private partnerships around shared interests and goals (Dunning *et al* 2015). But how long and short supply chains, traditional and AFNs, can be combined to maximise resilience in a given region-based food system is necessarily a question to be considered holistically in the context of the specific geographical endowment.

3.3. Consumers

The traditional 'farm-to-fork' paradigm of food systems has worked for many years but is criticised for fragmenting the connection between consumers and food producers (Marten and Atalan-Helicke 2015). For example, consumers felt closer to restaurants than those who grew their food (DuPuis *et al* 2022). However, in the recent literature, we have noticed an increasing focus on how consumers' consumption behaviour and patterns generate market signals and potential feedback mechanisms on food system resilience through the food value chain (Marten and Atalan-Helicke 2015, Miller 2021, Fava *et al* 2022).

The most important part of making this feedback system work is to connect consumers to the food system. Local food markets are seen as a gateway for consumers to be educated and informed about, and connected to, agriculture, potentially leading to consumers' revaluation of local food and facilitating a rebalancing of equity within the food system via adjusting the consumer behaviours. At the same time, consumer demand is also a leverage point for partnerships between locally produced food and supermarket retailers (Singh-Peterson and Lawrence 2017, Campbell and McAvoy 2020). Such a supermarket food service combined with local sourcing can help to increase system redundancy and diversity, injecting resilience into national and local food networks (Dunning *et al* 2015). This change will provide opportunities for traditionally powerless actors, such as small-scale producers, to reformulate food chains in a way that is more closely linked to their territories, endowing them with resilience capabilities (Fava *et al* 2022).

During the pandemic, it was discovered that consumer behaviour at the household level had both supporting and adverse effects on the resilience of the food systems in which they are located. Improved cooking and food management skills helped increase household flexibility during the lockdown, which has reduced food waste and per capita demand for food redundancy (i.e. the need for stores of food beyond what is actually consumed), resulting in less panic buying transmitted to upstream (Bender *et al* 2022). At the

same time, consumers were observed to expand refrigerated food capacity and increase food stocks to cope with shortages during the lockdown (Benker 2021), leading to larger single orders and less frequent purchases. This type of order could trigger increased demand volatility for upstream actors in the food supply chain. Consequently, the increase in consumers' household food stocks could enhance household resilience at the expense of system-wide resilience (Benker 2021, Bender *et al* 2022), while potentially causing more food waste (Bajželj *et al* 2020). More importantly, consumer behaviour is very susceptible to change. Even if consumers felt the many benefits of local AFN during the lockdown, they are likely to be attracted again by the convenience of one-stop shopping, home delivery and value-added products from large retailers after the outbreak has passed (Hobbs 2021). Even consumers with flexible budgets are less likely to prioritise buying locally-produced food over spending their time and money on other purposes (Marusak *et al* 2021).

In summary, consumers influence food system resilience through both behavioural adaptability and demand-driven feedback mechanisms. During disruptions, household-level strategies—such as stockpiling, reducing food waste, or supporting local producers—can buffer short-term shocks and foster redundancy. Consumers can also shape food system resilience indirectly by influencing upstream actors via purchasing preferences, which can either support or destabilise smaller producers and supply chains. However, consumer behaviour is often inconsistent and susceptible to reversion post-crisis. The large number of consumers, combined with the diffuse and heterogeneous nature of consumer actions and shifting demands, makes their role difficult to trace, but aligning consumer trends with resilience-enhancing practices remains a critical leverage point for system transformation.

4. Supportive roles for food system resilience

From the literature and the previous discussion, we can see that food system resilience can be influenced not only by actors, but also relies on a number of key supportive roles that link them together. In the 105 articles that this review selects, food systems are normally dependent on the nature and agriculture, energy systems, logistics, infrastructure and governance. However, we also note that recent logistical developments and digitisation have made the food system resilience more dependent on internet infrastructures than on physical venue infrastructures in the past. The COVID-19 pandemic has highlighted the critical role of information technology in shaping the actions of various food system actors, while also emphasizing the growing importance of food storage even at the household level. This paper comes a couple of years after the outbreak of COVID-19 pandemic—a worldwide public crisis of socio-economic, including food systems, when this surge in learning has filtered into the literature but not yet been synthesised into a review. In this section, we thus summarise these supportive roles for food system resilience based on the 105 articles in a developing perspective, with an attempt to flag some potentially significant problems and trade-offs.

4.1. Nature and relevant agricultural systems

Natural systems provide the fundamental resources including climate, water, and soil for food systems (Ruhf 2015, Bailey and Buck 2016). Agricultural activities, such as irrigating, fertilising and feeding, use natural resources to produce food. Agriculture accounts for roughly 70% of global water withdrawals, with water needed throughout the food chain, from breeding and irrigation for food production to food waste disposal (Uhlenbrook *et al* 2022). Investments in water infrastructure, such as reservoirs and irrigation, can enhance the resilience of agricultural production to water-related risks (Zurek *et al* 2020). However, these investments can also have negative consequences, such as soil salinization, groundwater depletion, and regional inequities in water access, which may undermine overall resilience (Uhlenbrook *et al* 2022).

Similarly, the land is a critical component of agricultural production (Skog *et al* 2018). A finer-grained land use pattern based on existing local land use can improve the resilience of individual farms while sustaining overall production across the agricultural landscape (Abson *et al* 2013). However, sustainable land use and management must carefully balance agricultural production and other uses. For example, large-scale bioenergy and carbon sequestration projects for climate change mitigation may promote land grabbing, negatively impacting smallholder livelihoods and food security (Rosenzweig *et al* 2020). Thus, it is crucial to prioritize stakeholder participation in land management practices to ensure that land use does not undermine the resilience and sustainability of the food system.

Many studies have raised concerns that food systems may only operate in or near the safe operating space of the planetary boundaries by 2050 even if multiple measures are implemented immediately and simultaneously (Conijn *et al* 2018). Food systems account for a third of global anthropogenic greenhouse gas emissions (Crippa *et al* 2021). Food production has also led to 25% of the world's arable land degradation, while agricultural deforestation and intensification of agricultural landscapes are substantial contributors to biodiversity loss (Webb *et al* 2020). As food production expands to meet growing demand, there is a risk of further environmental degradation and damage to natural resources.

Moreover, food systems are affected by their impact on natural systems and the risks posed by natural systems. For example, floods significantly risk food production, storage, and distribution (MacMahon *et al* 2015). Although only correlations between food system activities and natural system risks can be identified rather than judged as causal, it is essential to confront the potential conflicts and trade-offs between food systems and the nature.

4.2. Energy systems

Every part of the food system, from growing crops to disposing of food waste, needs direct fuel and electricity from the energy system to work. Indirect energy use for fertiliser, pesticide and machinery production has contributed to significant food production increases (Woods *et al* 2010). However, the globally connected food system maximises spare allocation capacity in an extremely energy-inefficient way (Rotz and Fraser 2015), and such activities remains an important source of anthropogenic greenhouse gas emissions (Woods *et al* 2010). Food prices are linked to fossil energy prices and improving food production and distribution patterns to make the food system use less energy is seen as one of the most important ways to make the food system more sustainable (Wakeland *et al* 2012). During the COVID-19 epidemic, many consumers have increased their food storage capacity, and refrigerators and freezers are among the most energy-intensive equipment in most homes (Bender *et al* 2022). Not only does the energy system directly assist the functioning of food system actors, but it also backs up the operation of the food system's supportive roles.

4.3. Venue infrastructure

The availability and diversity of venues is closely related to the food system resilience during crises, including retail venues such as supermarkets and farmers' markets, dining venues, distribution venues and relevant venues for charitable organisations (DuPuis *et al* 2022). For example, in January 2011, the State of Queensland experienced widespread flooding due to a series of extreme rainfall events, affecting a significant portion of its land area. The floods resulted in extensive damage, including the loss of farmland, road closures, destruction of infrastructure and resources, the inundation of homes and businesses, and fatalities. Amid these challenges, the Brisbane Food Hub became one of the few places where fresh food was available after the floods, and the venue's availability aided the resilience of the local food system (Vieira *et al* 2019).

However, while venues are still necessary, the development of e-commerce and delivery-to-home services has gradually shifted the key to ensuring the proper functioning of the food system from the availability of venues to ensuring the proper logistics of food in a multiplicity of consumption scenarios. This has, in part, influenced a shift in the need for venues in the food system from centralised to more decentralised, even community-based venues.

4.4. Logistics and food distribution networks

Logistics link the actors of the food system, including delivery from farms to processors, processors to retailers and retailers to homes or restaurants (Wakeland 2012). Hurricanes in the United States, protests and strikes (e.g. by truck drivers in the United Kingdom due to a sudden rise in fuel prices), and landslides caused by heavy rains in Nepal have all caused food supply crises by disrupting the food distribution networks (Marten and Atalan-Helicke 2015, Spies 2018). The smooth functioning of logistics systems in times of crisis is a prerequisite for securing the livelihoods of food system actors and also meeting the needs of consumers and is therefore an essential enabler for achieving food system functions and resilience (Marten and Atalan-Helicke 2015, Paci-Green and Berardi 2015, Coopmans *et al* 2021).

However, there are some problems with the logistics system that are not necessarily caused by or could be handled within the food system. For example, traffic jams around cities make it harder to move freight efficiently and raise the costs that freight companies and shippers have to pay. The current design of the food distribution system, which relies on large retailers, has resulted in limited food availability in poorer urban areas. The pattern of consumers shopping in centralised locations and making self-last-mile delivery may further exacerbate congestion (Miller 2021).

Regional food supply chains could adopt logistical best practices that improve efficiency, which is particularly important for regional food supply chains to remain competitive after the pandemic ends (Marusak *et al* 2021). At the same time, logistics remains a crucial contributor to food waste and environmental emissions throughout the food chain (Wakeland 2012, Bajželj *et al* 2020). Therefore, actors should make ecologically sustainable choices at all stages of food distribution, such as optimising the location of supply chain nodes, improving distribution routes and reorganising supply chains to embrace more innovative approaches to distribution and transport systems (Miller 2021, Mastronardi *et al* 2022).

The logistics system contributed significantly to the functioning of the food system during the pandemic, with research revealing that empty shelves were more frequently the result of initial panic buying and untimely replenishment than the food system's supply and distribution (Coopmans *et al* 2021). Research has

also found that providing 'last mile' home delivery helped meet consumers' food needs during the lockdown. However, home delivery has been questioned for its high capital investment costs and sustainability. Home delivery exposes drivers to poor working conditions and time pressure on perishable food, which would make home delivery socially and environmentally unsustainable. Moreover, home delivery is believed to sever the direct linkages between sellers/producers and consumers by diminishing the social role of the market's urban area, rendering producers invisible and unable to communicate sustainability issues in the food supply chain (Fava *et al* 2022). Therefore, how the logistics system, as the linker, can better support food system resilience still needs to be optimised in various aspects.

4.5. Food storage schemes at various geographical scales

Numerous interruptions in the food system have the potential to impede food shipping. As a result, setting up specific food storage schemes by governments or commercial companies at crucial points in the supply chain is considered a good buffer in case the logistics system runs into trouble (Marten and Atalan-Helicke 2015, Paci-Green and Berardi 2015). It is common practice for countries to establish a national food reserve system in case of emergency. For instance, China maintains extensive public inventories of food grain and frozen meat across all provinces as part of a national food stock program. By drawing on reserves during surplus and releasing them during shortages, the food reserve system has the potential to moderate price fluctuations in the food supply (Dev and Zhong 2015).

During the COVID-19 pandemic, groceries and other upstream actors with formal inventory management strategies increased their response to shocks associated with the pandemic (Bender *et al* 2022). At consumer level, a certain amount of household space was redefined as a resilient way to cope with shortages (Benker 2021). Consumers increased the refrigerated food storage capacity during the pandemic by purchasing additional fridges and freezers, and stockpiling raw materials for meal preparation (Bender *et al* 2022). While preparing food storage has been effective in increasing households' and supply chains' resilience during the COVID-19 pandemic, its impact on the resilience of the food system as a whole is controversial. Food storage can be wasteful if not used in a timely manner, and excessive stockpiling can pass feedback up the value chain, thereby increasing volatility at the production end and ultimately undermining the food system resilience (Bajželj *et al* 2020, Benker 2021, Bender *et al* 2022).

4.6. Digital technologies for information sharing

Information technology has improved the supply chain's visibility. For example, traceability solutions built on blockchain can send sensitive information quickly and securely. This helps supply chain actors comprehensively understand their supply chain network and get real-time information about sites, routes, suppliers, and areas where food products are at risk. Blockchain can also improve consumer communication by tracking information, and help companies build consumer trust (Collart and Canales 2022).

The COVID-19 pandemic has acceleratively digitised various sectors of the food system. A growing number of studies report that supply chain actors increasingly use digital technologies to communicate, coordinate and transform within the supply chain (Paganini *et al* 2020, Michel-Villarreal *et al* 2021, Bassett *et al* 2022, Fava *et al* 2022, Mastronardi *et al* 2022). Accessible and affordable internet connections play a central role in digital communication (Paganini *et al* 2020). For example, in a cross-regional study, farmers could sell their crops through apps and digital agricultural marketing during the lockdown (Paganini *et al* 2020). This communication has helped overcome the digital gap that often prevents marginalized groups from participating equally in the food system (Paganini *et al* 2020). Supporting smallholders in meeting market demand and accessing digital marketing is essential in supporting local food systems and shortening food supply chains to adapt to future shocks (Grigorescu *et al* 2022).

Digital technologies such as YouTube, Zoom, Google Meet, and WhatsApp have been used to exchange information between actors, enabling collaboration between customers and suppliers and extending consumer networks (Paganini *et al* 2020, Michel-Villarreal *et al* 2021, Fava *et al* 2022). SFSC actors have been able to communicate directly with each other about stock levels, shop timetables, and consumer orders through WhatsApp, allowing for quick reconfiguration of food supplies during disruptions (Michel-Villarreal *et al* 2021, Bassett *et al* 2022). Therefore, further research and policy efforts to establish and strengthen communication networks are vital to building resilient food systems during crises (O'Connell *et al* 2021).

However, digitisation and e-commerce in agri-food systems as a means of promoting cooperation and rural–urban integration in supply chains are still dependent on facilitating the physical infrastructure of networks as well as storage and delivery (Berkhout *et al* 2023). While digitisation has the potential to compensate for some access inequalities in the current food system, it may also exacerbate such disparities, as the threshold for digitisation can make it more difficult for actors lacking digital skills to compete (Berkhout

et al 2023). The potential damage that such technological thresholds may have on actor diversity deserves greater policy attention.

4.7. Institutional care/support

Undoubtedly, financial and resource support from the public and private sectors has long been proven to facilitate the food system and its actors to navigate crises (Folke *et al* 2010, Jacques 2015). However, many studies have also pointed out that inequalities in support for actors can reinforce existing socio-economic inequalities in the food system. Existing strong retailers received much more support from public policies after the flooding of 2011 in Queensland, while civic organisations were rarely taken into account (Smith and Lawrence 2018). Research by Paganini *et al* (2020) and Zollet *et al* (2021) stated that mainstream food system actors have gained policy favour for their indispensableness in dealing with the COVID-19 pandemic, which has further crowded out the space for smaller actors to survive and operate, hence shadowing the long-term food system resilience. Because of this, the benefits of care and support need to be shared more fairly, including food aid, direct financial assistance, and public policies that support people (Dekkinga *et al* 2022). Receiving support and care can facilitate the adaptation of supply chain actors to the widespread disruptions of the COVID-19 and allow them to continue performing reasonable roles. Support and care are essential, but their effects can vary considerably depending on the type of help given, how well and fairly it is distributed, and the broader economic and social situation (Bassett *et al* 2022).

5. Resilience mechanisms

In this section, we move from actor-specific contributions to a more abstract analysis of cross-cutting mechanisms by which different food system actors influence food system resilience. We note four key issues in particular, all of which are distinguished in being factors that only become apparent, and whose crucial importance becomes understandable, when adopting an actor-system perspective, since they are all specifically system-related features. These mechanisms (e.g. agency, diversity, connectivity, learning) are abstracted patterns that cut across actor types and contexts, and help explain why and how certain actor behaviours or configurations contribute to systemic resilience.

5.1. Actors' capability and agency for resilience

Bene (2020) highlighted the distinction between resilience and resilience capabilities, and the necessity to consider how the latter translates into the former. However, it is also crucial to acknowledge that actors' resilience capabilities and agency to pursue resilience are not always aligned. Physical elements, including finances, education, access to knowledge and infrastructure, and experience, have been emphasised in some research as essential for food system actors' resilience (Bene 2020). Equally essential to these objective considerations is the actor's subjective agency and the extent to which they can proactively employ buffering, coping, and adaptive capability (Dumont *et al* 2020). In other words, actors must be autonomous and willing to use their capabilities to strengthen the food system's resilience to disruptions (Coopmans *et al* 2021). This involves taking proactive steps to build resilience, such as investing in infrastructure or forming partnerships with other actors (Zurek *et al* 2020). However, not all actors have the agency to move towards resilience. Actors prioritising short-term gains over long-term sustainability may not be motivated to invest in resilience-building agency.

By focusing on the subjective agency of actors, we can better understand how their engagement with resilience-building agency can lead to outcomes for the food system. Actors make decisions based on their self-interest, and their engagement with shared knowledge, resources, cooperation, and collective action can be driven by their motivation for robustness, recovery, and reorientation. This means that even if actors have the capabilities and agency to be resilient, they may not necessarily prioritise the optimal outcome of the food system and other actors. In effect, there may be conflicting interests between actors and actors' efforts may not be conducive to food system resilience. For example, emphasising local food production during the COVID-19 pandemic may benefit local farmers but undermine the livelihoods of associated non-local producers, transporters, and retailers (DuPuis *et al* 2022). Actors who hold significant power may use their influence to shape the system in ways that prioritise their interests over the collective resilience of the system (Smith and Lawrence 2018). The actor and system level interest may also be complementary, such as increasing investment in crop diversity and farmers' livelihood resilience (Bailey and Buck 2016). Therefore, it is vital to critically assess the motivations and actions of actors in the food system and to encourage resilience-building agency that benefits the entire system rather than just a select few.

5.2. Diversity of actors and functions

Diversity is widely recognised as a critical strategy for enhancing the resilience of food and even social–ecological systems while mitigating systemic vulnerabilities (James and Friel 2015). Both organisational and functional diversity among actors are vital attributes of resilience (Fletcher *et al* 2021, Merkle *et al* 2021). Organisational diversity can be fostered by including firms of various sizes, as large firms often offer greater reliability, while smaller firms contribute flexibility (Merkle *et al* 2021). A balanced mix of firms sizes is therefore critical for developing resilience across the system.

Functionally, diversified farms play a crucial role in the resilience of food supply chains by increasing income from agricultural production, reducing reliance on a single product or channel, and strengthening relationships with local entrepreneurs, other farms, and consumers (Abson *et al* 2013, de Roest *et al* 2018, Dumont *et al* 2020, Mzyece and Ng'ombe 2020, Helfenstein *et al* 2022, Mastronardi *et al* 2022). Supply chain flexibility can be enhanced by diversifying the network of actors through multi-source sourcing, diverse product mixes, livelihood activities, and distribution strategies. Such diversity can help actors and systems respond to market fluctuations and logistical constraints, thus increasing their ability to withstand shocks (Marten and Atalan-Helicke 2015, Chapot *et al* 2021, Michel-Villarreal *et al* 2021, Bassett *et al* 2022). Conversely, highly efficient networks with greater sensitivity to shocks, low levels of functional diversity, inflexible contracts, and homogeneous processes may increase the vulnerability of supply chains (Voorn *et al* 2020, Merkle *et al* 2021).

As a critical strategy for improving food system resilience, diversity provides functional redundancy, or 'insurance', allowing some components to compensate for the loss of others (Biggs *et al* 2012). The availability of redundant resources and the ability to find alternate producers quickly when needed are essential for achieving system resilience (Michel-Villarreal *et al* 2021). Traditional industrial agri-food systems have tended to eliminate small local farms and businesses that provided redundancy, leaving local food systems without fail-safe mechanisms (Hendrickson 2015). The over-pursuit of efficiency, standardisation, and specialisation in the food system has reduced its functional and organisational diversity, limiting its capability to buffer disruptions and thus reducing resilience (Cabell and Oelofse 2012). While market concentration at some levels can coexist with functional diversity, low enterprise diversity is believed to lead to system vulnerability (Merkle *et al* 2021). To ensure functional redundancy and resilience, it is necessary to retain a varied range of actors with different roles in the food system.

Complementarities can help to achieve the effects of diversity on the food system. Developing local and domestic supply chains that are well-connected, for instance, might lessen reliance on international markets and the accompanying risks while simultaneously enhancing the global trading system. This can make the system and its actors less vulnerable to shocks and better able to cope with or adapt to stresses (Bassett *et al* 2022). Snow *et al* demonstrated that it might be possible to integrate businesses with high degrees of plasticity (e.g. dairy farms), which may adjust their production, processing, and distribution systems, with industries that rely on a constant flow and have little or no storage, such as pork or poultry production. Thus, one or more subsystem(s) can compensate for more vulnerable subsystems, resulting in systemic resilience (2021). To build resilient urban food systems, seeing different food subsystems as complementary rather than conflicting is important (James and Friel 2015).

The literature reveals interesting debates and trade-offs between diversification/redundancy and specialisation/efficiency, identifying crucial thresholds that consider the level of development and geography (Miller 2021). According to Kummu *et al* analysis, global food trade can encourage the specialisation of food production in exporting countries, while also enhance the diversity of food supply at destination and increase their reliance on external food sources (2020). This combination may leave food systems in importing and exporting countries vulnerable to several natural and social-economical disruptions (Kummu *et al* 2020).

However, and crucially, a single diversification or specialisation is neither inherently positive nor negative in itself; nor, therefore, definitively knowable as such in advance of the contingently and uncertainly arising shocks to the system regarding which, it subsequently turns out, it proves beneficial or harmful respectively. The systemic effect can only ever be 'confirmed/verified' post hoc, given the literally infinite—and so uncertain—potential shocks or developments it may need to cope with and prove resilient to. For instance, developing countries with low agricultural and supply chain development levels may advocate for 'sustainable intensification' to increase specialisation in agriculture. This can make farmers more efficient by acquiring specialised production skills and applying the latest production technologies (de Roest *et al* 2018). The question of balance, preserving and actively developing the diversity of such structures, given the particular starting point or context in each location, thus needs to be given explicit consideration. Therefore, too, governance should comprehensively consider and involve many stakeholders in determining whether the development of food systems should focus on diversification or specialisation (de Roest *et al* 2018, Kummu *et al* 2020).

5.3. Connectivity and connections

Food systems are characterized by various linkages and interactions between actors, indicating that pursuing resilience-building activities by individual actors could impact others. On a positive note, restoring degraded farmland and revegetating nearby upstream areas can increase the water available for small-scale irrigation, improving farmers' labour productivity and households' ability to convert assets into income (Bailey and Buck 2016). However, this widespread connectivity also makes it easy for risks to spread. The potential for rapid transmission of disturbances from one landscape scale to another, known as connectivity in ecosystems, is seen as an essential mechanism affecting food system resilience (Rotz and Fraser 2015). Similar concepts, such as 'transmissibility' or 'ripple effects' (Bene 2020) of the supply chain, convey the same meaning.

A phenomenon that spans multiple actors and the entire food system, such as food waste, exemplifies the complex interplay between food system connectivity and resilience. In highly connected food systems, the dynamics of overproduction, oversupply, and overconsumption mutually influence one another (Bajželj *et al* 2020, Bender *et al* 2022). While these dynamics drive food waste, they can also enhance resilience by providing redundancy, regardless of the temporal scale over which resilience operates (Bajželj *et al* 2020). However, the impact of reducing food waste—and consequently reducing redundancy—on resilience is not uniformly positive or negative. For example, unexpected crop losses can have severe consequences for farmers' livelihoods and businesses if redundancy is insufficient (Bajželj *et al* 2020). Conversely, maintaining redundancy, such as through consumer behaviour during the COVID-19 lockdowns—when larger, less frequent purchases were made to expand household food stocks (Benker 2021)—could also increase demand volatility for upstream actors in the food supply chain, potentially posing significant challenges for producers and other supply chain actors (Bender *et al* 2022).

Many studies have argued that high levels of connectivity can make food systems vulnerable to disruptions (Sundstrom and Allen 2019). For example, in the international food trade, the increased connectivity of different regional actors in a heterogeneous global food trade network can make local disturbances more likely to propagate throughout the system, reducing food system resilience (Tu *et al* 2019, Karakoc and Konar 2021). Increased connectivity is often accompanied by reduced diversity, as a few prominent actors provide more services in the food supply chain while smaller actors are eliminated, which is detrimental to the diversity and resilience of the food system (Rotz and Fraser 2015).

This dynamic has led to highly oligopolistic markets, such as the top three American meat processors currently controlling 80% of the US beef market. Commodity concentration in particular can leave supply chains vulnerable to contamination and outbreaks in new ways (Rotz and Fraser 2015). One of the key criticisms of intensive meat production is the spread of zoonotic and drug-resistant pathogens (Chan and Enticott 2019).

More importantly, actors in highly connected food systems may be disproportionately exposed to disturbances or bear a share of the costs for enhancing systemic resilience (Monastyrnaya 2020, Zurek *et al* 2020). For example, in a study of the UK fresh fruit and vegetable sector, Zurek *et al* (2020) found that a diversification strategy to increase supply resilience through flexibility in finding alternative suppliers could undermine resilience at the grower level, while it is the producers who bear more of the cost of investing in agricultural infrastructure to ensure robust production.

In contrast, social connections between actors in food systems, including horizontal and vertical linkages between producers, processors, and retailers, especially across different scales, are recognised as contributing to the resilience of food systems (Leat and Revoredo-Giha 2013, Glaros *et al* 2021). Social connections and networking between actors can facilitate better communications about shared needs and interests to cope with situations of high uncertainty and a lack of clear information, and foster trusting relationships (O'Connell *et al* 2021). Trust is vital in reducing bureaucracy, promoting mobility, and sometimes eliminating accreditation needs (Vieira *et al* 2019). Social connections and networking enable sharing of resources, collaboration, partnership formation, and collective action among food system actors.

Food system actors are encouraged to build social connections and networks with others to share infrastructure, resources, logistics, and knowledge (Merkle *et al* 2021). For instance, when the dairy industry experienced shocks, information sharing and collaboration throughout the supply chain helped maintain a resilient milk supply by ensuring the smooth flow of products from farms to points of sale (Perrin and Martin 2021). For underprivileged communities in Canada, the Food Community Network has become an essential social infrastructure due to its ability to speed up the establishment of community gardens, farmers' markets, and new distribution channels (Glaros *et al* 2021).

Social connections and networking are also crucial in regional food systems (McDaniel *et al* 2021). For example, connecting growers in Florida with buyers made it easier to deal with public health emergencies and natural disasters (Campbell and McAvoy 2020). Local food councils in North Carolina increased data collection and public messaging to share concerns from various sectors, identify solutions, and build resilience in the local food system during the COVID-19 pandemic (Cruz *et al* 2021). Adaptation and

resilience in Australia's intricate food system require open lines of communication between the private sector, the government, and enterprises that are typically seen as rivals (Jones *et al* 2022).

Collective action is viewed as an opportunity to collaborate across scales, such as producer and distributor networks, and share knowledge in the Canadian Maritimes food system (Tu *et al* 2019). Farmers' associations commercialise fresh produce in Nicaragua for local consumption, developing new niche markets through a network of trusted producer communities (Starobin 2021). Collective action has knock-on effects beyond direct benefits, such as developing and maintaining market positioning, reducing farm risks and vulnerabilities, gaining official acknowledgement and legitimacy, and consolidating a body of knowledge and best practices (Tu *et al* 2019). It is important to approach collective action with a degree of caution, as if such measures going too far—for instance, the formation of monopolistic cartels by large industry players to manipulate the production and pricing of certain foods—could marginalize smaller, less competitive actors (Rotz and Fraser 2015). This, in turn, risks undermining the diversity of the food system and threatening its overall resilience.

Overall, the food system resilience depends on a complex web of connections and interactions between different actors. However, this research has found that the critical factor affecting the impact of these connections on resilience is whether they are based on diversity. Connections of actors could complement diversity by activating different components innovatively (Jones *et al* 2022), i.e. in novel and newly productive arrangements, combinations and relations. For example, food trade networks can increase diversity and resilience by targeting the elimination of essential large-scale exporters, thus ensuring that the system is not overly reliant on a few dominant actors (Karakoc and Konar 2021). However, increased connectivity can lead to concentration in the food system. To ensure that connectivity contributes to resilience, it is crucial to balance it with diversity.

5.4. Learning and knowledge

The fourth key issue emerges from, and is manifest in and regarding, both diversity and connectivity, namely learning. Most obviously, learning is essential for building food system resilience by enhancing the adaptability of the actors involved (Walker *et al* 2004, Paloviita *et al* 2017, Smith and Lawrence 2018, Bassett *et al* 2022). This is because learning allows actors to respond accurately, or at least receptively and appropriately, to socio-ecological feedback (de Roest *et al* 2018). Tendall *et al* stated explicitly that building food system resilience is a long-term, continual cycle of action and learning (2015).

Perrin and Martin showed that reflective and shared learning to build human capital, i.e. learning from past experiences and sharing this knowledge, is a vital strategy for building resilience on farms and that farm resilience underpins food system resilience (2021). Fletcher *et al* also suggested that increasing knowledge exchange between stakeholders and actors in existing and new value chains is a crucial resilience mechanism (2021). Knowledge and learning can link food production systems and consumers, helping local or regional food systems compensate for mainstream food system deficiencies (Marten and Atalan-Helicke 2015, Skog *et al* 2018). Milestad's research found that feedback between consumers and farmers provided the potential for learning, which helped to improve their adaptive capacity to each other, and thus became a driver of increased food system resilience (2010).

Such considerations clearly thus invoke issues of both diversity and connectivity. The sharing of insights and learning amongst food system actors clearly is conditional upon the connectivity amongst that food system; while the diversity of actors, and the flourishing of that diversity, also likewise manifests the extent, pace and depth of learning by actors, spotting opportunities for collaborative and/or competitive advantage and innovation, not least in their own activities and forms. But equally, diversity and connectivity are themselves key dimensions of learning here too. Flagging this explicitly, as here in this review, thus, we would hope, could contribute indirectly to alerting food system actors to otherwise neglected and untapped opportunities for learning that is productive for the resilience of both them as actors and the system as a whole.

6. Conclusion

This review has highlighted the importance of adopting an actor-based systems lens to understand how food system resilience is generated, maintained, or compromised through the actions and interactions of diverse actors. By synthesising empirical evidence across producers, intermediaries, and consumers, the review identifies four cross-cutting mechanisms-actors' agency, diversity, connectivity and learning—as central to how food system actors influence resilience outcomes. This approach moves beyond a static or structural understanding of resilience to one that recognises dynamic agency embedded within systems of interdependence.

Despite the growing body of research on food system resilience, this review has several limitations. First, in terms of literature selection, it excludes studies that focus solely on individual actors or subsystems—such as farmers or agricultural systems—without adopting a food system lens. Only studies that explicitly explore cross-actor or cross-level dynamics were included. As a result, some research that may have broader system-level relevance was not considered, simply because the original authors did not frame their work within a systemic perspective. Consequently, certain relevant insights may have been overlooked. In addition, while much attention has been paid to producers and consumers, midstream actors such as processors and wholesalers remain underrepresented in the literature, despite their critical role in shaping value flows and mediating between upstream and downstream segments of the food system. The food service sector, including restaurants and catering services, is also largely absent from food system resilience research, despite the importance of out-of-home eating in shaping dietary patterns and value chain dynamics. Furthermore, studies examining how actors influence resilience are predominantly based on observations from single crisis events, offering limited insight into how strategies evolve over time or contribute to resilience in more sustained, system-level ways. Longitudinal research on these dynamics remains scarce, making it difficult to establish clear causal links between actor behaviour and systemic outcomes. These gaps point to important opportunities for future research that is both geographically inclusive and temporally attuned.

From a methodological view, a majority of reviewed studies rely on case-based qualitative approaches, which are rich in contextual detail but limited in generalisability. There is considerable scope for advancing the field through greater use of mixed-methods designs—such as comparative case studies, agent-based modelling, and social network analysis—which can better capture cross-level dynamics, feedback loops, and emergent properties within complex systems. Participatory and co-produced research methods also hold significant potential, particularly for uncovering actors' lived experiences and perspectives, and for exploring processes of learning, agency, and collaboration under conditions of uncertainty.

This paper has seen how both large and smaller actors, long and short supply chains, and diverse forms of organisation each offer particular strengths and expose particular weaknesses—revealing unavoidable trade-offs rather than clear-cut solutions. For instance, large-scale food producers may benefit from economies of scale but struggle with flexibility, while smaller actors can be more adaptable but face challenges in meeting high demand. Similarly, long food supply chains may offer greater efficiency and reach, yet are more vulnerable to disruptions, while shorter chains can be more resilient but may have higher costs or limited in scale. No single configuration can be deemed optimal in advance. Rather, it is precisely this diversity—across actors, scales, and strategies—that generates a context of continual novelty and innovation, hence a dynamic background and an uncertainly moving target.

This complexity poses profound challenges for research and governance alike. As already noted, it proves to be extremely challenging to identify a clear and definitive optimal policy or strategy for food system resilience ex ante, but that *no such optimal actually exists* (i.e. 'out there', awaiting identification). Instead, food system resilience must be approached as an ongoing, adaptive process—one that resists linear planning and definitive prescriptions. From the perspective of appropriate intervention in food system resilience, it is in principle never definitively knowable whether a specific intervention will benefit or harm that goal across contexts or over time. Key to all this, though, is the underlying paradigm shift: from the search for optimality to a commitment to responsive experimentation and continual adjustment.

Within this framing, learning—rather than fixed 'knowledge' (let alone 'information' or 'data') that is of such central importance, viz. in terms of the still-crucial application of knowledge to improving food system resilience as explicitly a never-ending and constantly improving process to be sustained through reflexivity, openness, and inclusive engagement, *and* at both the level of individual actors and the collective emergent level of the system as whole.

This has significant implications for both future research agenda and policy. In addition to an enhanced focus on actors that are currently under-researched, scholars must embrace modes of inquiry that are iterative, situated, and responsive, and that account for the asymmetric power relations shaping whose resilience is supported and whose is neglected. Policy efforts should shift from seeking to design perfect interventions toward supporting diverse actors with the capacities, networks, and institutional space to adapt, collaborate, and innovate under uncertainty. Building resilient food systems is not about finding the right cipher. And instead, a different and new approach is needed, in which the goal is explicitly reoriented towards the live and responsive ongoing experimental attempt to govern and balance the food system ever more wisely and justly to respond to what cannot be fully predicted.

Data availability statement

No new data were created or analysed in this study.

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