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# Food System Resilience Thinking: From Digital to Integral

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## Abstract

The current food system is directly influenced by the increase in environmental problems and nutritional inequality globally. The financial and political collapses, health crises, excessive urbanization, and rapid industrialization are some of the principal factors threatening the food supply's security. The food system needs a profound transformation to avoid ecosystem destabilization and a global food crisis. Concerning this transformation, we are certain that the first step for a successful food system change is global resilience thinking. To reach an integrated food system, we proposed introducing the resilient concept linked with other known concepts such as circular economy and sustainability. A resilient food system can recover over time, ensuring the supply of sustainable and quality food and access to all. This would mean redesigning the value chains in the food system, re-educating the consumers to implement a healthier diet, and introducing technology as digital innovation. Re-evaluating these relevant points, redesigning the focus of the food system, not only for economic efficiency but including significant trade-offs, or valuing other services in the food system, are essential to reaching the desired resilience.

**Keywords:** Circular Economy; Sustainability; Healthy diet; Environmental problems; Nutritional impact

## 1. Introduction

The food system is a socio-ecological system formed by biophysical and social factors linked through feedback mechanisms [1,2]. They include, at a minimum, activities related

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to the production, processing and packaging of food, distribution, retail, and consumption [3]. These activities cover social, economic, political, institutional, and environmental dimensions and processes, called scales (levels of decision-making or management) [3]. The interactions of food system activities can be analyzed across scales and levels, conceiving the food system more broadly as including the determinants and outcomes of its activities. Determinants describe the biogeophysical, social, economic, and political environments that determine how the activities of the food system are carried out (drivers of the food system). These activities lead to various social and environmental outcomes, as well as a certain level of food security: "…when all people at all times have access to sufficient, safe and nutritious food to maintain a healthy and active life", according to the World Summit on Food 1996 [4,5].

In the current world, characterized by an increasingly complex and uncertain matrix of interrelations, many factors become relevant to threatening the security of the food supply. These include sudden and shock phenomena (for example, natural disasters, health crises, financial and political collapses), dynamic phenomena of global impact (for example, ageing of the population, rapid and excessive urbanization, climate change), as well as hitherto unpredictable adaptations and responses of the food system to these events. Consequently, there are more than two billion inhabitants (25.9 per cent of the global population) with hunger or without regular access to nutritious and sufficient food while we produce food in excess (70% more than is necessary for the total global population) [6]. At the current rate of consumption and waste generation, according to the UN, by 2050, we will reach a tipping point that will plunge us into a global food crisis [7]. The intensification of volatility in climate and markets and the increasing complexity of food value chains due to globalization require a robust and optimal response [8]. Therefore, there is an increasing notion of a sustainable food system, understood as "…

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a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition so that future generations are not compromised" [9]. The concept of a sustainable food system entails normative aspects because food systems use resources that typically do not offer absolute levels of sustainability. Therefore, sustainable food systems embody an understanding of sustainability that reflects just an improvement relative to a previous situation. In that respect, the notion of food systems transformation is being considered, given more relevance to a cross-cutting concept, relevant in different fields, including the food system, resilience. This concept refers to the capacity of a food system to achieve food security and nutrition for all "in the face of various and even unforeseen disturbances", including environmental, economic or socio-political shocks [10]. On this matter, the Food Systems Summit 2021 suggests a food system concept that can help establish an action-oriented agenda in support of the United Nations Sustainable Development Goals (SDGs) [11]. This idea encompasses five Actions Tracks, one of which is "Building Resilience to Vulnerabilities, Shocks and Stresses (ensuring the continued functionality of healthy and sustainable food systems)". Thus, the interactions of food system activities can be analyzed across scales and levels, conceiving the food system more broadly as including the determinants and outcomes of its activities [11].

## 2. What is Resilience?

Resilience thinking, originating from ecology, has increasingly been adopted as a generic approach to understanding socio-ecological systems [12]. Resilience is the ability to prepare for, resist, and recover from a crisis or disruption. Resilience thinking presents a new and transcendental framework from which to contribute to the security and sustainability of the food system [13]. This is how several studies have already analyzed

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the food system or its components from a resilience perspective [12]. However, most of them focus on selected components of the food system and often do not consider the complex interactions between scales and levels. This is important "however", as effective planning, development and implementation of policies and management interventions require an understanding of these complex interactions and their implications [14]. Furthermore, this approach must recognize the importance of the dimension of time in resilience. Therefore, in the context of the food system, a suitable conceptual definition of resilience is that a resilient food system can withstand and recover over time from various, even unforeseen disruptions, in a way that ensures a sufficient supply of acceptable food and access for all (Food System Resilience; URL: https://clf.jhsph.edu/projects/food-system-resilience).

## 3. Resilient Circular Economy

Resilience is often confounded with sustainability. The two concepts are closely related but quite different in scope and time scale. Sustainability is defined as the ability to achieve today's goals without compromising the possibility of achieving them in the future. In contrast, resilience can be defined as the dynamic ability to achieve goals despite disorders and instabilities [12]. Both concepts can be seen as being complementary concepts. Whereas sustainability is the measure of system performance, resilience can be seen as a means of achieving sustainability during disturbance times. The circular economy is an economic concept that is interrelated with sustainability and whose objective is to prolong as much as possible the value contribution of products, materials, and resources and minimize the generation of waste [15]. Therefore, there is a clear need to frame resilience thinking in the circular economy, especially when discussing the food system. The EU established in 2015 an action plan for the transition

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to a circular economy [16]. This plan contemplates the synergistic action of governments, companies, primary producers, retailers, innovators, waste managers and other actors in the food chain to achieve objectives based on circular economy thinking [17]. Circularity not only offers economic benefits and reduces a specific actor's ecological footprint but also increases both business and community resilience by reducing dependence upon scarce resources and long-distance supply chains [18]. Progressive business leaders can implement the concept cost-effectively to improve corporate sustainability and resilience [19]. In this sense, a change in consumer attitudes and behavior is also necessary. It is crucial to identify the economic, social, or psychological factors that determine the degree of consumer participation in the circular economy practices.

## 4. Resilient Value Chains

Within a sustainability framework, the capacity and flexibility of a food system in managing and responding to social and ecological turbulence is essential, not only in primary (agricultural) production but also in value supply chains [4].

The resilience of production is of fundamental importance, so policymakers, development agencies, and even agribusiness and farmers that make part of these stages of the food supply chain must become increasingly involved in exploring and understanding its dynamics and possibilities.

Food supply chains consider the sequences of activities necessary for the creation of value through the conversion of raw materials into final products and the different actors involved in the networks that connect the other production nodes. These chains are an important part of the social structure of the food system, established as a fundamental mediator between the agroecological system, households and markets [2]. In critical situations with a greater need for assistance, value chains must face the storm and

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continue with a certain level of operation. That is why the resilience of the food supply chain is essential for the effective functioning of the food system. Vroegindewey & Hodbod (2018) [20] listed three specific reasons aligned with this idea: i) stable access to markets through value chains by farms and businesses is key to job and income growth; ii) access to diverse and nutritious foods for consumers in the face of shocks; iii) optimization of existing value chains, for greater efficiency of emergency food assistance and development programs. This helps us to visualize in a more practical way the importance of the addressed concepts.

Looking back, the food system was designed just for economic efficiency. Now the focus must be different, having to be re-evaluated or redesigned to achieve the desired resilience. For example, can food systems supply populations enough food while ensuring economic viability, even when international borders are closed, or internal transportation is limited (as was the case during Covid-19)?

Building resilience in the food system and value chain will often involve significant trade-offs, so an accurate understanding of the most valued socio-ecological system services (and for which resilience is sought) is a key part of resilience thinking [20]. The key and the challenge will lie in the structural ease to adapt the business models and regulatory frameworks in which they operate, resulting in more transparent and diversified value chains, changes in consumer preferences and nutritional habits, and the emergence of new consumer groups. That is why innovation and private sector engagement are crucial to enhance future resilient competitiveness.

## 5. Resilient diets and consumption

A diet can be resilient to climate (drought), biotic (pests), market (price), access (value chain disruption), and a host of other stressors. The resilient diets can face these stressors

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and continue to provide nutrition to consumers, but without neglecting that sustainability is inherent to resilience in a world where most stressors are related, at some level, to the lack of sustainability of our activities. Urgent changes are necessary in improving technologies for and the management of the food system [21]. These changes must occur synergistically, focusing on reducing food loss and waste and shifting towards healthier diets.

The World Resources Institute published the Reducing Food Loss and Waste report, which lays out a Global Action Agenda that will help reduce food loss and waste [22]. This action agenda includes a Target-Measure-Act approach, an actor-specific "to-do" list, and 10 "scaling interventions" designed to take the approach and to-do list to scale. In line with this, more aggressive but science-based action is urgently needed to reduce food loss and waste [23]. This requires the participation of everyone throughout the food supply chain, including policymakers, producers, suppliers, and consumers.

Regarding healthier diets, the EAT-Lancet Commission report proposed a “planetary health diet”, in which adults consume 2,500 calories per day, and most of these foods are obtained from plants [24]. Specifically, animal-based proteins were targeted for a significant reduction because the terrestrial animal production system is inefficient in terms of protein input: output production ratios and contributes to climate change directly (methane emissions) and indirectly (deforestation). Yet animal-based food products provide livelihoods for millions of people, providing essential protein and micronutrients to the world’s poor, and are key in reducing stunting and wasting around the world [25]. For this reason, the production of animal protein for human consumption is under rethinking, which will lead to a radical reconfiguration [26].

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Another way of rethinking the diet is the use of unicellular proteins [27] (such as yeast, microalgae [28], or bacteria) as well as insects [29]. These new protein sources are also increasingly positioning themselves as new protein sources for food due to their generally high protein content and favourable amino acid profiles. This hyper-specialized food has much greater potential to disrupt the system as a resilient diet if it is in line with the social and political processes that impede or catalyze system innovation. This innovation is part of the process of food system transformation. At the heart of this process is a form of innovation that involves significant changes in the parts of the food system (technologies, infrastructure, skills, and capacity) and a fundamental reformatting of the values, regulations, policies, markets, and governance that surround it. This view of transformation as a complex and systemic process implies that novel technologies alone are not sufficient to drive food system transformations; instead, they must be accompanied by a wide range of social and institutional factors that enable their deployment. In practice, this means building alliances, dialogue and trust around food system development pathways and ensuring governance and regulator regimes to safeguard desired food system outcomes. Additionally, to provide optimal nutrition for a growing population while decreasing the consumption of terrestrial animals, aquaculture and agriculture systems must work together to meet the challenge of operating resiliently within planetary boundaries [30].

## Digital Innovations for Resilience

The resilience for the world to address such challenges cannot be achieved overnight. In a difficult and low-margin market, where a small number of players struggle to retain share, it is up to innovators and disruptive market players to leverage digital tools to drive

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that change. So, a resilient and modern food system cannot escape the tools of the digital age.

When it comes to tackling the key challenges related to how we grow, distribute and consume food, the digitization of the food system offers many opportunities [31]. The main of these digital technologies is the Internet of Things (IoT), which is a concept that can be defined as a network that interconnects physical objects using the Internet, which acts as a promising platform for the integration of artificial intelligence and robotics throughout the production and supply chain [32]. IoT allows the systematic use of objects that function as sensors and/or perform active actions, interacting with each other, without the fundamental need for human intervention. In the context of the food chain, IoT refers to a variety of devices and activities related to intelligent tracking and monitoring (for example, animals, products, services) and the active control of indoor or outdoor production processes.

There are already successful cases of IoT application, mainly concerning the supply chain, but also in primary agricultural production, installation of smart factories, efficient retail stores, and in the home itself. An abrupt catalyst for the increasing implementation of digital technology in the supply chain revolution has been the coronavirus outbreak [33]. Thanks to digitization, many of the logistic services could provide acceptable compliance, within what is necessary, for food distribution during COVID-19 lockdowns. What's more, the pandemic organically accelerated the incorporation of new channels into everyday life, such as online platforms for the provision of food. However, its current implementation is barely embryonic. There are still many challenges ahead to achieve greater socio-environmental benefits (for example, improving public and animal health, reducing food waste, and controlling climate change).

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Considering all this, it is key to expand the incorporation of IoT into the food production supply chain and propose digital strategies consistent with the new trends that arise from specialized scientific-technical interest in the area [32]. In this way, we will be able to establish a solid network that digitally interrelates: logistics management (security, temperature control and travel tracking); the availability of crops linked to producers and control of the supply chain; the application of Industry 4.0 concepts applied to food production; the use of IoT to improve food-related health outcomes; IoT applications to minimize food waste; IoT devices for the food supply chain; 5G solutions and challenges for the food supply chain; cybersecurity related to the food supply chain.

Many of these food system technologies focus on horticulture and logistics efficiency to maintain the quality and freshness of food products while reducing cost and time during transport within the supply chain [34]. However, it is necessary to move away from "business as usual", develop new solutions, and implement innovative technologies in all food supplies [9]. Along these lines, a digitalized supply chain allows companies to monitor material flows in real-time, making potential risks visible and develop plans to face them. The support of each technology to different data chain activities lets us envisage that the true potential of the data comes from the combination and integration of these technologies. Indeed, each one will improve some of the following basic functions of agri-food supply chains: sensing, monitoring, control, analysis (descriptive capabilities), prediction (predictive capabilities), decision-making (prescriptive capabilities) and adaptive learning. Through sensing, monitoring, control and analysis, it is possible to detect early and accurate problems and even predict them before occurring, making better decisions and learning of them, improving the sustainability and resilience of agri-food supply chains [35].

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Beyond all the promise of digitization, it is important to note that applying these technologies soon is only likely in certain regions of the world, the most developed countries. Meanwhile, although digital systems are online in less developed regions like Africa, local food systems are unlikely to become more resilient to shocks due to digitization, at least not in short/medium term.

## 6. Integrated food system

The growing complexity of the food system is closely related to the rapid change in the level of industrialization and market segmentation. The current food system is directly related to the increase in environmental problems. It is estimated that by the year 2050, due to the expected changes in food consumption and production of the food system, environmental impacts could increase by 50-90%, exceeding planetary boundaries to the extent that crucial ecosystem processes could become at risk of being destabilized [36]. The SDGs provide a common foundation for overcoming the great interconnected challenges of food supply, water scarcity, human health and nutrition, pollution, biodiversity loss, and climate change [37,38], but achieving the SDGs is an ambitious and complex task [39,40]. Actions that lead to progress on one SDG can harm another, and it is essential to find common denominators to unify them into coherent policy instruments.

It is crucial to carry out management that optimizes the food system triple bottom line — social, environmental and economic — sustainability [41]. On this basis, the Food and Agriculture Organisation of the United Nations (FAO) argues in its principles for a sustainable food system that "…greater resilience of people, communities and ecosystems is key to sustainable agriculture" [42]. This is because resilience allows the balance between human needs and desires and the long-term survival of agricultural areas without negatively impacting their productivity or ecology [43]. Furthermore, It is more urgent to

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understand the food system's resilience as a whole for the contexts of developing countries, where vulnerability is greater in the face of challenges that undermine food and nutritional security, which are already weak at baseline [44]. Also, these countries have economies that are more rooted in primary sectors and, therefore, more dependent on the agri-food sector for employment, family income and economic growth [45].

Systemic innovation is essential for the deep transformation that the food system needs. We have the necessary technology to achieve that goal. What is missing is to achieve a paradigm shift that must come through a cultural change. We know that any change of this magnitude is gradual, but the transition to a more sustainable food system needs to be accelerated. This depends not only on social incentives, regulations, and licenses but, in turn, requires a constructive dialogue between producers, governments, researchers and consumers [46]. It is essential to understand that scientists research and warn, while governments must analyze, plan, and manage remarkable change processes. To do this, they must consider the economic and social base of the region for inclusive work where the most nutritionally impoverished countries can find a balance in their diets. The consumer must be informed, introducing healthy changes in their diets, always considering the regional food culture, and thus forcing the producer to generate innovations in their products. This on-chain, synergistic, and enhanced concept of resilience can help decentralize the industry by bringing food production to cities and increasing their autonomy. Similarly, the communities furthest from the major commercial routes/agri-industrial regions will no longer be entirely dependent on imported food but could more easily and reliably be self-sustaining.

## 7. Future challenges

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As final thoughts, we can talk about the imperative need to integrate different food system components in a cross-learning approach that capitalizes on existing initiatives, projects, and disciplines to deliver Resilient European Food Systems. There are already the capacity, the resources, and the knowledge to build multi-level resources for the food system to be ready to adapt and face European and global threats: climate changes, soils, resources scarcity, new biological and chemical hazards, increase of chronic diseases, demographic changes, new human diseases (e.g. COVID-19). Thus, through a multi-stakeholder approach to increase the scientific knowledge base in key areas in an inclusive and lasting way, which allow us to have innovations and digital tools focused on the development of sensors and robotics; understand consumer engagement and its multivariate importance in the food system; develop new models of value chains; and finally, but not less important, achieve integrated food systems, with greater sustainability and resilience.

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