Global Food Security 42 (2024) 100777

Contents lists available at ScienceDirect

Global Food Security

journal homepage: www.elsevier.com/locate/gfs

Insights from systems thinking and complexity science to strengthen food systems frameworks

María Bustamante [a,b,*], Pablo Vidueira [b,c], Lauren Baker [c]

[a] Universidad Politécnica de Madrid. Escuela Superior Agronómica, Alimentaria y de Biosistemas. Departamento de Ingeniería Agroforestal. Unidad de Proyectos, Avenida Puerta del Hierro nº 2-4, 28040, Madrid, Spain

[b] Universidad Pontifica Comillas, Calle Alberto Aguilera nº 23, 28015, Madrid, Spain

[c] Global Alliance for the Future of Food, United States of America

ARTICLE INFO

Keywords:
Food systems
Food systems frameworks
Systems thinking
Complexity science
Principles

1. Introduction

Although hunger and malnutrition have been at the forefront of sustainable development agendas for decades, these issues remain significant challenges for humanity. Current trends support the discouraging fact that by 2030, we will be far from reaching the goal of Zero Hunger, with around 600 million people still facing hunger (FAO et al., 2023). Besides struggling to reduce hunger and malnutrition, the current food regime is questioned for contributing to other socioeconomic and environmental challenges such as poverty (Gassner et al., 2019; Giller et al., 2021; Raza and Soares, 2020), social inequalities and injustices (HLPE, 2020; Leeuwis et al., 2021), and climate change (Crippa et al., 2021).

Global crises like the COVID-19 pandemic and geopolitical conflicts have not only intensified the existing unsustainable trends in our food systems but also brought attention to the synergies and trade-offs between food insecurity and other challenges rooted in how food is produced, processed, traded, and consumed (Béné, 2022; Fanzo, 2021; IFAD, 2021; Ruben et al., 2021).

The growing awareness of the strong interlinkages between challenges traditionally linked to food and agriculture and broader sustainability issues faced by humanity nowadays illustrate the potential of food systems as powerful levers for achieving Sustainable Development Goals (SDGs) and meeting the commitments set for 2030 (Dury et al., 2019; FAO et al., 2023; HLPE, 2020). Furthermore, it supports the global claim for structural changes in food systems in a way that provides food security while fostering the positive and reducing the negative impacts on sustainability (Béné et al., 2019; Dury et al., 2019; Ericksen, 2008; HLPE, 2020; TEEB, 2018).

The idea of food systems that contribute to SDGs is widely used to describe the normative nature of the transformation of food systems (Haddad and Hawkes, 2016; Willett et al., 2019). Nonetheless, it is worth mentioning that systems thinking theory argues there is no single solution or correct answer when dealing with complex systems. Reynolds and Holwell (2010) indicate that defining the values and nature of transformation should involve dialogue and negotiations between stakeholders holding diverse perspectives.

Among the many definitions of sustainable food systems, we adopt the one developed by the HLPE (2020) that states that "sustainable food systems are productive and prosperous, equitable and inclusive, empowering and respectful, resilient to shocks and crisis, regenerative by ensuring sustainability in its three dimensions, and healthy and nutritious" (p. xv).

Significant progress has been made in exploring and comprehending food-and-agriculture-related challenges by acknowledging them as complex issues that require thinking systemically to be addressed (Béné et al., 2019; HLPE, 2020; Walton et al., 2021). As part of this progress, the food security discourse in sustainable development agendas has been

* Corresponding author. Universidad Politécnica de Madrid. Escuela Superior Agronómica, Alimentaria y de Biosistemas. Departamento de Ingeniería Agroforestal. Unidad de Proyectos. Avenida Puerta del Hierro nº 2-4 28040, Madrid, Spain.

E-mail address: maria.bustamante@upm.es (M. Bustamante).

https://doi.org/10.1016/j.gfs.2024.100777
Received 10 January 2024; Received in revised form 2 June 2024; Accepted 12 June 2024
Available online 15 June 2024

evolving over the last 50 years toward more systemic understandings (HLPE, 2020; Westengen and Banik, 2016), hand in hand with the growing adoption of food systems approaches in socio-political, scientific, and technical spheres (Brouwer et al., 2020; HLPE, 2020; IPES--Food, 2021). In September 2021, the first-ever United Nations Food Systems Summit marked a crucial landmark in the adoption of food systems approaches, as it aimed to "deliver progress on all 17 of the Sustainable Development Goals … leveraging the interconnectedness of food systems to global challenges such as hunger, climate change, poverty, and inequality" (United Nations, 2021).

As discourse around food systems evolved, various frameworks have emerged to guide efforts towards sustainability. Developed independently by diverse authors and institutions, these food systems frameworks (FS frameworks) offer practical guidance for exploring and understanding the elements, interrelationships, and dynamics that explain the outcomes and trends of food systems. While this rapid evolution of FS frameworks has undoubtedly advanced our understanding of food systems challenges and behavior, it also presents challenges to leverage contributions and maximize impacts through an enhanced dialogue among the different FS frameworks.

Recent studies reveal FS frameworks' limitations in informing and supporting policy processes and interventions that progress in the transformation toward more sustainable food systems (see, e.g., Brouwer et al., 2020; Zou et al., 2022). Among the research mentioned above, it is worth noting Brouwer et al. (2020) who, besides exploring how FS frameworks address drivers, components, and sustainability-related outcomes, also pay attention to the implications of the focus of the analysis in critical barriers for transformations - such as governance structures, conflicting perspectives, and the identification of leverage points for transformation - calling to harmonize the insights and tools generated in diverse studies under a "commonly agreed food systems approach" (Brouwer et al., 2020, p. 8).

According to Leeuwis et al. (2021), it is essential to acknowledge and embrace the systemic nature of food systems to maximize their contributions to sustainability outcomes. Systems Thinking and Complexity Science (STCS) can be instrumental in this regard, as these disciplines and related literature provide a range of traditions, concepts, approaches, methods, and tools that have been central to the paradigm shift away from linear and reductionist thinking, and towards addressing complex issues and supporting systemic changes (Gates et al., 2021; Walton et al., 2021).

In line with the insights of Leeuwis et al. (2021), we see an opportunity to enhance FS frameworks by fostering dialogue and cross-learning among them and with Systems Thinking and Complexity Science. Building upon this opportunity, our research aims to establish the groundwork for FS frameworks to meaningfully embrace food systems' systemic and complex nature. By facilitating dialogue and cross-learning among FS frameworks and with ideas from Systems Thinking and Complexity Science, we seek to enhance their capacity to support and inform sustainability-oriented transformations.

Section 2 of this article outlines the methodology used to assess 20 FS frameworks developed from 2008 to 2021. This assessment draws on ten STCS principles, which have been designed and tested in previous research to help understand and deal with complex issues. Section 3 presents the insights gained from assessing FS frameworks, showcasing the diverse theoretical and methodological practices they proposed to meaningfully embrace food systems' complex and systemic nature. These findings also reveal gaps and opportunities, underscoring the potential for further dialogue among FS frameworks and with STCS.

Section 4 delves into how FS frameworks, by recognizing and meaningfully embracing the systemic and complex nature of food systems, lay the groundwork to inform ongoing discussions on how to move towards more sustainable food systems. Section 5 concludes by highlighting that STCS principles can play an instrumental role in strengthening FS frameworks to acknowledge and meaningfully embrace the complex, systemic nature of food systems. This paves the way for fostering dialogue and cross-learning within the food systems research field, STCS, and other domains grappling with complex issues.

2. Methodology

This research aims to contribute to the growing body of research and discussions on food systems by delving into whether and to what extent FS frameworks acknowledge and embrace their systemic and complex nature. Gaining insights from a transparent and robust assessment would set the foundations for FS frameworks to dialogue, exchange, and learn from each other and from Systems Thinking and Complexity Science fields of knowledge.

This enhanced understanding and the dialogue and learning between FS frameworks and the ideas, concepts, and instruments offered by STCS will provide food systems researchers, evaluators, and practitioners with actionable ways to strengthen FS frameworks to acknowledge and embrace meaningfully the systemic and complex nature of food systems.

We open this section by detailing the systematic search and selection of FS frameworks made from a review of academic and grey literature that proposes or discusses FS frameworks published from 2008 to 2021.

Next, we introduce the STCS principles synthesized, tested, and validated by Bustamante et al. (2021), illustrating their relevance in current academic discussions and narratives around food systems and the need for their transformation to contribute to sustainability outcomes.

Finally, we present the rubric designed to support a more robust, transparent, and insightful assessment of FS frameworks, based on the core STCS insights provided by Bustamante et al.'s set of principles (2021).

2.1. Selection of publications

Literature on FS frameworks considered for this paper was academic and grey, limited to documents published in English, and published from 2008 – when the food system approach started being broadly used (UNEP, 2016; van Berkum et al., 2018) – to 2021, both years included.

Search engines and databases were explored to identify academic literature. Searches on the Web of Science and Scopus databases were done using the terms "food system*" in the title AND "framework" AND (sustainab* OR "food security" OR "food and nutrition security") in the title, abstract, or specified keywords. The resulting list of academic literature was complemented by a Google Scholar search using the term "food system* framework." Additionally, documents and reports of international agencies and research institutions were identified using the terms "food system," AND "framework," AND "analysis" in the Google search engine.

As a result of these search strategies in scientific databases, 414 publications were retrieved and listed. All their abstracts were reviewed to select those that propose or discuss conceptual and methodological frameworks for analyzing food systems. This second filtering was done using the following exclusion criteria: First, FS frameworks with a partial scope of analysis were excluded -and understood as frameworks focused on exploring certain elements or interrelationships without considering the big picture of food system activities immersed and interrelated with a broader socioeconomic and environmental context. Second, FS frameworks that, being more general in scope, did not delve into the interrelationships and elements within the food system (e.g., the water-energy-food systems frameworks, SDGs focused, and frameworks exclusively dealing with sustainability) were excluded. Third, publications on case studies were excluded if they lacked discussion regarding the FS framework applied. Publications applying a previously designed and discussed framework were also excluded if they did not include decisive changes for its application. Fourth and lastly, FS frameworks limited to specific methods or tools (e.g., Life Cycle Assessment, Multicriteria assessment, Systems Dynamics Models, among others) were excluded if they lacked discussions regarding the definition of food systems and how to improve our understanding of them. As a result, 11 academic publications were selected. For the grey literature, the same selection process led to the identification of 11 international reports published by international agencies – United Nations Food and Agriculture Organization (FAO), United Nations Environmental Program (UNEP), High-Level Panel of Experts on Food Security and Nutrition (HLPE) – policy advocacy networks – International Panel of Experts on Sustainable Food Systems (IPES-Food), Global Alliance for the Future of Food, The National Academies of Science, Engineering, and Medicine – research agencies – Wageningen Economic Research – and consultancy groups – The Institute for Development of Environmental-Economic Accounting (IDEEA Group).

2.2. *Systems thinking and complexity science principles in the food systems discourse*

For several decades, a paradigm shift towards increasingly systemic understandings has reshaped research, debates, and interventions in

Table 1
FS frameworks and publications assessed.

	Publication number	Framework number	Author	Year	Title	Publisher/Journal
Grey Literature	1	1	Bortoletti & Lomax	2019	Collaborative framework for food systems transformation: A multi-stakeholder pathway for sustainable food systems	United Nations Environment Program (UNEP)
	2	2	Dury et al.	2019	Food systems at risk: new trends and challenges	United Nations Food and Agriculture Organization (FAO)
	3	3	Institute of Medicine (IOM) & National Research Council of the National Academies (NRC)	2015	A framework for assessing the effects of the food system	The National Academies Press
	4	4	IPES-Food	2015	The new science of sustainable food systems	International Panel of Experts on Sustainable Food Systems (IPES-Food)
	5	5	Nguyen	2018	Sustainable food systems. Concept and framework	United Nations Food and Agriculture Organization (FAO)
	6	6	The Economics of Ecosystems and Biodiversity (TEEB)	2018	TEEB for agriculture and food. Scientific and Economic Foundations Report	United Nations Environment Program (UNEP)
	7		Eigenraam et al.	2020	Applying the TEEBAgriFood evaluation framework: Overarching implementation guidance	IDEEA Group and Global Alliance for the Future of Food
	8	7	High-Level Panel of Experts on Food Security and Nutrition (HLPE)	2017	Nutrition and food systems	High-Level Panel of Experts on Food Security and Nutrition (HLPE)
	9	8	United Nations Environment Program (UNEP)	2016	Food systems and natural resources	United Nations Environment Program (UNEP)
	10	9	van Berkum et al.	2018	The food systems approach. Sustainable solutions for a sufficient supply of healthy food	Wageningen Economic Research
	11		Posthumus et al.	2018	Food systems: From concept to practice and vice versa	Wageningen Economic Research
Academic Literature	12	10	Allen & Prosperi	2016	Modeling sustainable food systems	Environmental Management
	13	11	Béné et al.	2019	When food systems meet sustainability. Current narratives and implications for actions	World Development
	14	12	Connolly-Boutin & Smit	2016	Climate change, food security, and livelihoods in sub-Saharan Africa	Regional Environmental Change
	15	13	Ericksen	2008	Conceptualizing food systems for global environmental change research	Global Environmental Change-Human and Policy Dimensions
	16	14	Halbe & Adamowski	2019	Modeling sustainability visions: A case study of multi-scale food systems in Southwestern Ontario	Journal of Environmental Management
	17	15	Hubeau et al.	2017	A new agri-food systems sustainability approach to identify shared transformation pathways towards sustainability	Ecological Economics
	18	16	Jackson et al.	2020	System of hunger: Understanding causal disaster vulnerability of indigenous food systems	Journal of Rural Studies
	19	17	Paloviita et al.	2017	Food security Is none of your Business? Food supply chain management in support of a sustainable food system	Operations and Supply Chain Management: An International Journal
	20	18	Raza et al.	2020	Conceptual framework of food systems for children and adolescents	Global Food Security
	21	19	Vallejo-Rojas et al.	2016	Developing an integrated framework to assess agri-food systems and its application in the Ecuadorian Andes	Regional Environmental Change
	22	20	Zurek et al.	2018	Assessing sustainable food and nutrition security of the EU food system: An integrated approach	Sustainability

Note: Two of the listed frameworks were developed through two subsequent publications that we treat as part of the same framework: ([1]) TEEBAgriFood framework (TEEB, 2018), later complemented with an implementation guidance (Eigenraam et al., 2020); ([2]) FSA framework (van Berkum et al., 2018), later complemented with a report that summarizes information about systems thinking and food systems (Posthumus et al., 2018).

diverse fields that explore and address complex issues. This shift is demonstrated by the growing interest in STCS (Gates et al., 2021). To foster engagement with STCS, Bustamante et al. (2021) designed an STCS principles-based framework that comprises ten guiding principles that offer practical guidance to understand and deal with complex issues.

This framework synthesizes the broad array of traditions, theories, concepts, and practices from Systems Thinking and Complexity Science, identifying synergies and complementarities. Drawing on the works of Ramalingam et al. (2008) from complexity science, and of Midgley (2006), Reynolds and Holwell (2010), and Williams and Iman (2006) from systems thinking, we synthesized insights into three considerations for dealing with complex issues: (i) comprehensively exploring the situation of interest; (ii) understanding the dynamic behavior of the system; (iii) and acknowledging the crucial role of agents, governance structures, and power relations in systems performance and transformation.

A relevant clarification on the STCS principles (Bustamante et al., 2021) is that these reflect a methodological pluralism approach (Mingers and Brocklesby, 1997), bringing together worldviews from different STCS paradigms into the same framework (Jackson, 2003) at both ontological and epistemological stances (Bustamante et al., 2021).

Table 2 lists the ten STCS principles mentioned above, including a brief description of the features related to the nature of complex issues for whose understanding and treatment each principle provides guidance.

Lastly, we illustrate the relevance of STCS principles in current discussions and research on transforming food systems towards sustainability. By citing authors focused on making food systems more sustainable, Table 3 links literature on food systems transformation to each STCS principle, highlighting how understanding and embracing food systems' complex and systemic nature lays the groundwork for meaningful and sustainable changes.

2.3. Analysis of FS frameworks

In order to analyze the extent to which FS frameworks acknowledge and embrace the complex and systemic nature of food systems, an evaluation rubric (Davidson, 2004) was designed and applied to the selected FS frameworks. This rubric is based on the STCS principles introduced in section 2.2 (Bustamante et al., 2021).

According to Davidson (2004), a rubric is an assessment tool that enhances transparency, engagement, learning, and adaptation through evaluative processes. Rubrics set out the two fundamental elements for any transparent evaluation: criteria – the dimensions around which the assessment is performed — and standards – the different performance levels aligning with or meeting the criteria. Davidson also stresses that rubrics are especially useful as they describe what performance would look like for each criterion at each level of alignment defined by the standards.

To design the rubric - presented in Table 4 - the ten overarching principles of STCS were incorporated as assessment criteria. In turn, the information provided in Table 2 to describe each principle was used to design levels of alignment that provide clarity and transparency to the assessment of FS frameworks. The rubric consists of four levels of alignment, each indicating a progressively higher level of alignment between FS frameworks and STCS principles. The first level indicates that the principle is absent, while the last three levels are cumulative, meaning each level implies compliance with the previous levels.

Once designed, the rubric was applied to assess the 20 FS frameworks in Table 1. After reviewing their respective document/s, a level of alignment was assigned for each of the ten STCS principles as per the rubric in Table 4.

Our intention in undertaking this assessment is not to render value judgments on FS frameworks. We intentionally avoid ranking and highlighting what might be perceived as weaknesses of the assessed FS

Table 2
STCS principles to understand and address complex issues.

Dimensions	Principles	Brief description of principles
I. Exploring the big picture	1. Acknowledge the multidimensionality and hierarchical structure of complex systems.	Complex systems consist of interrelated elements that operate at various levels of organization, where the lower levels can be themselves systems nested into the embedding multidimensional context (Cornell Office for Research on Evaluation, 2009; Iman et al., 2006; Midgley, 2006). To comprehensively understand complex situations, their hierarchical and multidimensional structure need to be mapped systemically to identify key elements and their interactions (Midgley, 2006; Williams and Hummelbrunner, 2009).
	2. Engage with interrelations and interdependencies.	Linkages between system elements form relationships of causality and dependence, shaping the system as a whole (Midgley, 2006; Williams and Hummelbrunner, 2009). To understand the non-linear nature of these relationships, it is essential to delve into interdependencies and feedback loops that can accelerate or suppress changes in complex systems, leading to unpredictable consequences and outcomes (Foster-Fishman et al., 2007; Reynolds et al., 2012; Reynolds and Holwell, 2010; Williams and Hummelbrunner, 2009).
	3. Explore emergent properties and behavior.	Complex systems exhibit emergent properties (e.g., resilience, self-organization) and behavior arising from their constituent elements' interactions. Exploring these emergent phenomena involves mapping how system elements interact to produce novel behavior and properties that cannot be explained by studying individual elements in isolation (Foster-Fishman et al., 2007; Midgley, 2006; Reynolds et al., 2012; Reynolds and Holwell, 2010).
II. Understanding the dynamics of the system	4. Define the phase space of complex systems to explore their movements through time and identify patterns of change.	The phase space of complex systems provides a conceptual mathematical framework delimited by understanding the possible

(continued on next page)

Table 2 (*continued*)

Dimensions	Principles	Brief description of principles
		values that variables and dimensions of the system can theoretically take (Ramalingam et al., 2008). Defining the phase space sets the foundations for tracking and understanding the system's temporal evolution and identifying patterns of change, thus providing valuable insights into the underlying mechanisms driving system behavior (Byrne, 2013).
	5. Explore how and why complex systems change phases and/or states, leading to transformations.	Complex systems, as adaptive and far from equilibrium systems, cannot operate in stability for long periods, being easily disrupted to shift states in response to internal and external influences (Byrne and Callaghan, 2014; Kania et al., 2012). To understand how changes are triggered in the systems and find ways to catalyze them, it is essential to understand and explore the system's control parameters and attractors and their role in driving shifts in system states through time (Byrne and Callaghan, 2014; CECAN, 2019; Ramalingam et al., 2008; Vincent, 2012; Westhorp, 2012). Exploring attractors explains system changes from one equilibrium point to another, understanding attractors as subsets of the phase space that illustrate the states the system reaches after undergoing a perturbation (Burns and Worsley, 2015; Rickles et al., 2007; Vincent, 2012). On the other hand, exploring control parameters implies recognizing that while the state of the system may be described by the values taken by a large number of variables at a given time, only a few determine the actual character of those states: order parameters and control parameters (Byrne and Callaghan, 2014). Order parameters are systemic features that indicate how the system's elements cooperate and compete with each other … Control parameters are external inputs that can be tuned to change the order parameters and thus shift the system from one state to another" (Rickles et al., 2007, p.935). Structural changes or state shifts in the systems occur once a tipping point is reached and if the internal behavior is conductive. A conductive internal behavior implies high connectivity between the system units, achieved when control parameters reach a critical point (Byrne and Callaghan, 2014; Vincent, 2012). To cope with the dynamic behavior of complex systems, evaluation should be designed as an iterative process of learning and adaptation (Cornell Office for Research on Evaluation, 2009; Gates, 2016; Hummelbrunner, 2011; Midgley, 2006; Reynolds et al., 2012; Reynolds et al., 2016; SETIG, 2018).
	6. Acknowledge the path dependence and context sensitivity of complex systems.	Contextual factors and historical trajectories influence the behavior of complex systems (Burns and Worsley, 2015; Byrne and Callaghan, 2014; CECAN, 2019; Kania et al., 2012; Westhorp, 2012). This path dependence means that a decision made at a certain point in time enables a range of possible future states but limits others (Byrne, 2013; Kania et al., 2012; Ramalingam et al., 2008). Recognizing the effects of historical decisions and the influence of contextual factors is essential for tailoring interventions to address specific challenges and leverage opportunities for change in different situations (Burns and Worsley, 2015).
III. Acknowledging the role of agents in complex systems	7. Recognize the role of adaptive agents in the dynamics and behavior patterns of complex systems.	Adaptive agents play a crucial role in shaping complex systems' dynamics and behavior patterns. These agents have their own purposes and perspectives, which influence their behavior and interactions within the system (CECAN, 2019; Kania et al., 2012; Ramalingam et al., 2008). Recognizing that the system's dynamics and the changing context influence and are influenced by the learning, knowledge, and way of acting of agents is essential to understanding processes of co-evolution of adaptation of agents and the self-organizing capacity

(*continued on next page*)

Table 2 (*continued*)

Dimensions	Principles	Brief description of principles
		of complex systems (Kania et al., 2012; Ramalingam et al., 2008).
	8. Engage with the diverse perspectives that are part of the same big reality.	Acknowledging that systems are conceptualizations of complex issues rooted and responding to different worldviews, any systemic inquiry needs to actively engage stakeholders in exploring their motivations, interests, concerns, and values on the situation being explored to identify perspectives on how the system is, how it should be, and potential pathways to reach the desirable state (Cabrera et al., 2008; Hummelbrunner, 2011; SETIG, 2018; Williams and Hummelbrunner, 2009). Actively involving stakeholders with varying perspectives would enrich the analysis of complex issues and develop more inclusive and feasible intervention strategies, fostering collective ownership (Checkland and Poulter, 2010; Cornell Office for Research on Evaluation, 2009; Midgley, 2006; Reynolds and Holwell, 2010).
	9. Promote dialogue and mutual appreciation among perspectives to decide how to frame and address problematic situations.	Promoting meaningful dialogue and exchanges among diverse perspectives is essential to enhance collective awareness of the values and assumptions underlying diverse perspectives, thus encouraging open communication and trust among stakeholders (Cornell Office for Research on Evaluation, 2009; Eppel et al., 2011; Foster-Fishman et al., 2007; Kania et al., 2012; Williams and Hummelbrunner, 2009). Collaborative approaches would enable stakeholders to negotiate from an enhanced trust and awareness and co-create interventions that reflect their shared values, aspirations, and concerns, making sense in practice (Vincent, 2012). When fostering collaborative approaches, it is crucial to draw attention to power relations and governance structures that shape stakeholders' interactions to understand and address their influence on how stakeholders negotiate the framing of the situation, decide the desired future, and identify potential pathways to reach it (Byrne, 2013; Midgley, 2006; Reynolds et al., 2012; SETIG, 2018; Vincent, 2012)
	10. Place boundaries to manage complexity.	Placing boundaries is essential in managing complexity and performing a systemic analysis. Boundary decisions depend on the perspectives adopted; therefore, it is crucial to support stakeholders in being aware and questioning the underlying values and assumptions of different perspectives to build informed arguments when deciding which worldviews and values to prioritize when defining systems' boundaries (Cornell Office for Research on Evaluation, 2009; Gates, 2016; Hummelbrunner, 2011; Iman et al., 2006; Walton, 2014; Williams and Hummelbrunner, 2009). Defining, questioning, and reflecting on boundaries requires careful consideration of the links between power relations, perspective prioritization, boundary decisions, and their ethical and practical implications (Iman et al., 2006; Reynolds et al., 2012; Reynolds et al., 2016; SETIG, 2018; Williams and Hummelbrunner, 2009).

frameworks; instead, we aim to showcase and elevate practices that embrace the systemic and complex nature of food systems. We acknowledge that although the STCS rubric seeks to be a clear and transparent diagnosis tool to find ways to bring SCTS into food systems analysis, our interpretation of how each FS framework accounts for the systemic and complex nature of food systems may be biased as influenced by our perspectives on the documents analyzed.

We aim to create a dialogue and knowledge exchange space among FS frameworks and STCS by showcasing positive examples and practices. We intend to provide a foundation for cross-learning and collaboration among practitioners and researchers to deepen the collective understanding of food systems and inform practice rather than impose a rigid judgment on individual frameworks. Instead, we encourage practitioners to use the STCS principles-based rubric as a tool for self-awareness and reflection, allowing them to analyze and strengthen their frameworks as they see fit (Bustamante et al., 2021), along with the results of this research to inform their practice.

3. Results

This section includes the results of assessing the 20 FS frameworks listed in Table 1. We describe the extent to which the analyzed

Table 3
Relevance of STCS principles in current discussions and research on transforming food systems towards sustainability.

STCS Principles	Current discussions and research on transforming food systems towards sustainability
1. Acknowledge the multidimensionality and hierarchical structure of complex systems. 2. Engage with interrelations and interdependencies.	Understanding the *intricate network of elements and actors that shape food systems' behavior, outcomes, and externalities* is paramount for identifying the drivers and outcomes of food systems (van Bers et al., 2019; Brouwer et al., 2020; TEEB, 2018). This comprehensive understanding enables the management of trade-offs and synergies between competing goals, which is essential for addressing complex challenges such as food insecurity, poverty, inequity, and environmental degradation (Béné, 2022; Caron et al., 2018; Leeuwis et al., 2021; Mausch et al., 2020; Ruben et al., 2021).
3. Explore emergent properties and behavior.	Mapping food systems' complex structure lays the foundation for exploring and understanding the *emergent properties* of the system, which is crucial for maximizing its contributions to advancing sustainability objectives (Béné, 2022; Leeuwis et al., 2021; Ruben et al., 2021).
4. Define the phase space of complex systems to explore their movements through time and identify patterns of change.	Exploring the behavior of food systems over time is crucial for gaining insights into their *patterns of change* and identifying leverage points for the needed transformation (Abson et al., 2017; Leeuwis et al., 2021; Mausch et al., 2020; Meadows, 1999).
5. Explore how and why complex systems change phases and/or states, leading to transformations. 6. Acknowledge the path dependence and context sensitivity of complex systems.	Understanding the *internal and external conditions that shape structural changes*, including governance structures (Huttunen et al., 2022; Leeuwis et al., 2021; Ruben et al., 2021; Vignola et al., 2021), *contextual factors and trends* (Dengerink et al., 2021; Gaitán-Cremaschi et al., 2019), *and historical trajectories* (van Bers et al., 2019; Kuokkanen et al., 2017), is essential for navigating complex challenges. Delving into these conditions sheds light on how food systems can be transformed, highlighting the need for adaptive management and tailor-made solutions that account for their diversity and dynamics (Garbero et al., 2021).
7. Recognize the role of adaptive agents in the dynamics and behavior patterns of complex systems. 8. Engage with the diverse perspectives that are part of the same big reality.	Stakeholders within food systems hold *diverse perspectives* that co-exist, leading to tensions, conflicts, and trade-offs that can hinder the necessary transformations toward sustainability (Béné, 2022; Hubeau et al., 2019). Failure to acknowledge and engage with diverse perspectives underlies *agency and power issues* (van Bers et al., 2019; Zurek et al., 2021), *influencing policies and decision-making processes* that shape the behavior and evolution of food systems (Brouwer et al., 2020; HLPE, 2020; Ruben et al., 2021).
9. Promote dialogue and mutual appreciation among perspectives to decide how to frame and address problematic situations.	Understanding how stakeholders exercise their agency requires recognition of the values, interests, and concerns that drive them (Wojtynia et al., 2021), shaping their worldviews about food systems' challenges and transformations (Béné et al., 2019; van Bers et al., 2019; Garcia-Gonzalez and Eakin, 2019; Zurek et al., 2021). Efforts to address the complexities derived from the diversity of perspectives often involve *creating platforms that bring together and empower stakeholders* with diverse interests, concerns, expectations, and knowledge to engage in dialogue and exchange worldviews until reaching agreements that facilitate a shared directionality (Béné, 2022; Caron et al., 2018; HLPE, 2020; Huttunen et al., 2022; Leeuwis et al., 2021). By fostering a common language among stakeholders based on an enhanced *awareness of values and motivations driving their perspectives*, such platforms facilitate the emergence of realistic and innovative ideas for transforming food systems ((Huttunen et al., 2022; Leeuwis et al., 2021).
10. Place boundaries to manage complexity.	Recognizing and addressing *power imbalances within governance structures* is crucial for strengthening the *agency of stakeholders* in food systems (HLPE, 2020; Huttunen et al., 2022). In that regard, da Costa and McMichael (2007) argue that the market-and-corporate-led regime reinforces the power and authority of dominant players, such as transnational companies, preventing interventions to redirect unsustainable trends in food systems from prospering. This creates a lock-in effect that benefits those aligned with it while excluding the knowledge, interests, and concerns of those on the sidelines of dialogues and negotiations to diagnose problems and propose solutions (Gaitán-Cremaschi et al., 2019; IPES-Food, 2017; Lam et al., 2020; Leeuwis et al., 2021). Moreover, interventions designed within this power-constrained framework often led to undesirable trade-offs, further hindering transformation efforts (Ruben et al., 2021). Recognizing food systems transformation as a political process, as O'Brien (2012) advocates, entails questioning the governance structures that perpetuate the status quo and the values and motivations underlying decisions regarding transformations (Béné, 2022; Huttunen et al., 2022). Questioning governance structures implies questioning the *boundaries* of the current food systems regime (Leeuwis et al., 2021; Vignola et al., 2021).

frameworks acknowledge and embrace the systemic and complex nature of food systems, with the results compiled in Table 5. The table shows the percentage of the analyzed FS frameworks aligned with each STCS principle at varying levels, according to the rubric (Table 4).

The percentage shown in Table 5 corresponds to the percentage of FS frameworks that meet each level of alignment exclusively. However, the rubric is progressive, meaning higher levels imply compliance with the previous ones. Therefore, to determine the percentage of FS frameworks that meet a certain level of performance as a minimum, it is necessary to sum up the percentages at the higher levels.

Additionally, we highlight exemplary practices proposed by FS frameworks that contribute to meaningfully understanding and coping with food systems' complex and systemic nature. Identifying these practices and the complementarity among frameworks reveals opportunities for dialogue and collaborative efforts within the food system field of research to substantially embrace the systemic and complex nature of food systems.

The following subsections present the assessment results around the three major considerations for addressing complex issues around which the STCS principles were organized.

Table 4
STCS principles-based rubric for FS frameworks assessment.

Levels of alignment and definitions				
STCS Principles	The principle is absent	The principle is acknowledged	The principle is addressed at a theoretical level	The principle is addressed both at theoretical and methodological levels
1. Acknowledge the multidimensionality and hierarchical structure of complex systems	It does not mention that food systems are comprised of several elements from different dimensions and organized hierarchically at different levels/There is not enough information to understand the level to which the multidimensionality and hierarchical structure of food systems are acknowledged.	It acknowledges that food systems are comprised of interrelated elements that operate hierarchically at various levels, with elements in the lower levels nested in the higher ones.	It acknowledges and addresses the multidimensional and hierarchical structure of the food system through a clear description of its components and the way they are interrelated - internally and with the broader socio-political, economic, and environmental context - to achieve the expected outcomes.	It provides theoretical and methodological insights for mapping and describing the structure of food systems and exploring the diversity of elements and interrelations across levels to gain a systemic understanding
2. Recognize and address interrelations and interdependencies	It does not mention the interrelations and interdependencies between food systems elements/There is not enough information to understand the extent to which the relationships of causality and dependence shaping food systems are acknowledged.	It acknowledges the interrelations and interdependencies between food system elements and their non-linear nature.	It describes the main interrelations in the food system, evidencing characteristics such as feedback loops, delays, and multiple causality.	It provides theoretical and methodological insights to explore and understand interrelations, interdependencies, feedback loops and delays, and their role in the non-linear behavior of food systems.
3. Explore emergent properties and behavior	It does not mention the emergent properties and behavior arising from systems' elements relating to each other in non-linear ways/ There is not enough information to understand the extent to which the need for exploring the web of interrelated elements to make sense of food systems' behavior and emergent properties is acknowledged.	It acknowledges the need to explore the web of interrelated elements to make sense of the system's emergent properties and behavior.	It describes how properties and dynamics at the food system's level emerge from interrelations among lower-level elements.	It provides both theoretical and methodological insights to explore emergent properties and behavior arising from between food systems' constituent elements.
4. Define the phase space of complex systems to explore their movements through time and identify patterns of change	It does not mention the importance of defining the space where food systems can theoretically exist to track their movements over time and identify patterns of change./ There is not enough information to understand the extent to which the need to define the phase space to make sense of food systems' temporal evolution is acknowledged.	It acknowledges the importance of defining the space where food systems can theoretically exist – by identifying value ranges for variables that explain the possible states of food systems in their multiple dimensions – to identify patterns of change and gain insights into the underlying mechanism driving food systems' behavior.	It acknowledges and delves into the importance of defining the phase space of food systems to explore their evolution over time and identify patterns of change to shed light on the underlying mechanisms driving systems' behavior.	It provides theoretical and methodological insights to map food systems' movements within the phase space and identify patterns of change to shed light on the underlying mechanisms driving system behavior.
5. Explore how and why complex systems change phases and/or states, leading to transformations.	It does not mention the internal and external conditions behind structural changes in food systems when talking about their dynamic behavior/There is not enough information to understand the extent to which the internal and external conditions shaping food systems' changes are acknowledged.	It acknowledges that changes are triggered in food systems in response to internal and external influences (i.e., attractors, order, and control parameters) that need to be understood and explored in their role of driving shifts in system states through time. Furthermore, it acknowledges the need to design evaluations that are flexible enough to adapt to changes within the food system and in its broader context.	It explores food systems' state shifts, delving into the internal and external conditions (i.e., attractors, order, and control parameters) that allow the system to absorb perturbations or to adapt to them undergoing structural changes.	It provides theoretical and methodological insights to better understand food systems' dynamics behind structural changes to identify leverage points to catalyze changes toward the necessary transformation.
6. Acknowledge the path dependence and context sensitivity of complex systems	It does not mention that contextual factors and historical trajectories influence the behavior of food systems/There is not enough information to understand the extent to which the diversity of food systems and the consequent need to adapt interventions to contextual and/or historical diversity are acknowledged.	It acknowledges the effects of historical trajectories and decisions and contextual factors' influence on food systems' behavior. Consequently, it also recognizes the need for tailoring interventions to contextual and/ or historical diversity in food systems,	It describes how food systems' dynamic is sensitive to the context and historical trajectories and decisions.	It provides theoretical and methodological insights to consider the contextual conditions and historical trajectories of food systems when exploring the system's dynamics and tailoring interventions to address specific challenges and leverage opportunities for change in different situations.
7. Recognize the role of adaptive agents in the dynamics and behavior patterns of complex systems	It does not mention the crucial role that agents play in shaping food systems' dynamics and behavior patterns//There is not enough information to understand the extent to which the role of agents in	It acknowledges that adaptive agents - individuals or institutions - play a crucial role in the food systems' dynamics and behavior patterns.	It evidences the relationships between food systems' agents, their behavior, and the structure and dynamics of the system. In this sense, it recognizes that adaptive agents co-evolve with	It provides theoretical and methodological insights to explore and understand the learning and adaptation processes of adaptive agents and the self-organizing capacity of food

(*continued on next page*)

Table 4 (*continued*)

Levels of alignment and definitions				
STCS Principles	The principle is absent	The principle is acknowledged	The principle is addressed at a theoretical level	The principle is addressed both at theoretical and methodological levels
	food systems' dynamics and behavior patterns is acknowledged.		the food systems through learning and adaptation processes.	systems, which arise from interactions among adaptive agents and other system components.
8. Engage with the diverse perspectives that are part of the same big reality	It does not mention that the same situation could be understood and conceptualized differently, depending on the perspective taken/There is not enough information to understand the extent to which diverse perspectives of a situation are acknowledged/engaged when exploring food systems.	It acknowledges the need to engage with diverse perspectives when exploring food systems since the same situation could be understood and conceptualized differently, depending on the perspective taken.	In addition to acknowledging the need to engage with diverse perspectives, it highlights the need to explore what lies behind each of them (interests, concerns, expectations, etc.) to foster meaningful participation of stakeholders to make sense of the situation and identify feasible and desirable pathways to improve it.	It offers theoretical and methodological insights to identify and explore perspectives concerning the food system and how it ought to be, along with respective feasible and desirable pathways to transform it and how the diverse perspectives privileged condition the systemic analysis.
9. Promote dialogue and mutual appreciation among perspectives to decide how to frame and address problematic situations	It does not mention the importance of promoting dialogue and mutual appreciation between perspectives to decide how to frame and address problematic situations in food systems/There is not enough information to understand the extent to which dialogue and mutual appreciation between perspectives are promoted to decide how to frame and address problematic situations in food systems.	It acknowledges the importance of promoting dialogue and sharing between stakeholders with different perspectives to enhance collective awareness of the underlying values and assumptions, thus encouraging open communication and trust to decide how to frame and address problematic situations in food systems.	It recognizes and explores the influence of power relations and governance structures in stakeholders' interactions to understand and address their influence on how stakeholders negotiate the framing of the problematic situation, decide the desired future, and identify potential pathways to reach it.	It offers theoretical and methodological insights to promote dialogue and exchanges among perspectives while dealing with power issues that emerge from and shape collective decision-making about framing and addressing problematic situations in food systems.
10. Place boundaries to manage complexity	It does not mention boundaries as essential to manage complexity when assessing problematic situations in food systems/There is not enough information to understand the extent to which placing boundaries is acknowledged as an essential activity to justify the decision of what to include and exclude when assessing problematic situations in food systems.	It acknowledges that boundaries are essential to justify the decision of what to include and exclude when assessing problematic situations in food systems.	It acknowledges that decisions about boundaries involve privileging some perspectives at the cost of marginalizing others, which ultimately requires sense-making and deliberation among the values underpinning these perspectives.	It offers theoretical and methodological insights to discuss, reflect on, and question boundary decisions and their ethical and practical consequences.

3.1. *Exploring the big picture*

Almost all the 20 FS frameworks assessed pay attention to the multiple and interrelated dimensions that affect and are affected by the way food is produced, processed, marketed, and consumed. Moreover, they recognize that the way these dimensions relate to each other and with the elements within the value chain is non-linear and could reinforce or balance the effect caused by particular interventions in the system, giving rise to emergent and hard-to-predict properties and behavior. Regarding emergent properties, some authors mention the food systems' capacity to adapt and evolve with changes, which they relate to concepts of resilience and vulnerability (Allen and Prosperi, 2016; Connolly-Boutin and Smit, 2016; Jackson et al., 2020; Vallejo-Rojas et al., 2016).

The conceptual basis for exploring food systems is provided by frameworks that organize and present the elements considered relevant to understanding the complex structure of food systems. Here we highlight the use of the multiple capitals framework, usually linked to the broader perspectives of sustainability, human livelihoods, and well-being (Connolly-Boutin and Smit, 2016; Hubeau et al., 2017; TEEB, 2018); the use of the Driver-Pressure-State-Impact-Response framework (Hubeau et al., 2017) and the Structure-Conduct-Performance paradigm (Nguyen, 2018) to illustrate the cause-effect relationship between human activities and the broader and multidimensional environment that trigger societal responses; and the characterization of drivers and outcomes linked with the concepts of vulnerability and adaptation (Allen and Prosperi, 2016; Connolly-Boutin and Smit, 2016).

In addition, around 40% of the assessed FS frameworks propose methods and tools focused on understanding interrelationships, feedback loops, and delays to shed light on emergent properties and behavior. Agent-based Modelling (IOM and NRC, 2015), Causal Loop Diagrams (Eigenraam et al., 2020; TEEB The Economics of Ecosystems and Biodiversity, 2018), Systems Dynamics (Eigenraam et al., 2020; Halbe and Adamowski, 2019; TEEB The Economics of Ecosystems and Biodiversity, 2018), Fuzzy Cognitive Mapping (Halbe and Adamowski, 2019), and a set of output and transition equations (Allen and Prosperi, 2016) are proposed in some of the assessed FS frameworks.

3.2. *Understanding the dynamics of the system*

The assessed FS frameworks, however, do not pay much attention to understanding system dynamics. Even though more than half the frameworks describe the variables delineating the mathematical space within which the food systems display their behavior, only 35% provide theoretical insights to map and make sense of the movements across that space that determine the system's patterns of change. When it comes to providing methodological guidance, about one-third of the assessed FS frameworks propose methods to monitor the behavior of the systems over time, and only 20% delve into the conditions that allow the food system to operate in stability absorbing changes or, on the contrary, to adapt to perturbations by changing state (Allen and Prosperi, 2016; IOM and NRC, 2015; TEEB, 2018; Vallejo-Rojas et al., 2016). Furthermore,

Table 5
Percentage out of the 20 assessed FS frameworks on the four levels of alignment for each of the ten overarching principles as defined in the STCS rubric proposed in this paper.

STCS principles	Levels of alignment with STCS principles			
	The principle is absent.	The principle is acknowledged.	The principle is addressed at a theoretical level	The principle is addressed both at theoretical and methodological levels
(I) Exploring the big picture	3%	22%	35%	40%
1. Acknowledge the multidimensionality and hierarchical structure of complex systems.	0%	5%	45%	50%
2. Engage with interrelations and interdependencies	5%	30%	35%	30%
3. Address emergent properties and unpredictable behavior	5%	30%	25%	40%
(II) Understanding the dynamics of the system	42%	21%	14%	23%
4. Map the system's movements through the phase space to identify underlying patterns of change	30%	60%	30%	30%
5. Understand how a system changes between phases or states	55%	10%	15%	20%
6. Acknowledge the path dependence and context sensitivity of complex systems	40%	25%	15%	20%
(III) Acknowledging the role of agents in framing systems	**38%**	**26%**	**17%**	**19%**
7. Understand adaptive agents and the self-organization capacity that arises from the interactions among them.	40%	30%	20%	10%
8. Acknowledge diverse perspectives as part of the same big reality.	20%	45%	10%	25%
9. Promote dialogue and mutual appreciation among perspectives to decide how to frame the situation-	25%	20%	30%	25%
10. Place boundaries to manage complexity.	65%	10%	10%	15%

Note: Shades of grey are provided to highlight results according to four categories: Less than 25% of the assessed FS frameworks; between 25% and 50%; between 50% and 75%; and above 75%.

very few FS frameworks acknowledge that the present and past states of the system determine which pathways are enabled – and which are not – for future development (Allen and Prosperi, 2016; TEEB, 2018).

To explain the behavior of food systems, Allen and Prosperi (2016) explore the trajectory traced by the system across the phase space over time. For this, they propose a set of equations, known as transition functions, to explore the behavior of state and control variables to map the system's states, with the variables in this last group acting to trigger a change or transformation in the system. Furthermore, by using transition functions, they also acknowledge that a system's trajectory is shaped by its states over time.

Although not always explicit, the concepts of vulnerability and resilience are used in FS frameworks to describe the role of control variables in driving food systems towards stability or transformation (Allen and Prosperi, 2016; Connolly-Boutin and Smit, 2016; Jackson et al., 2020; TEEB, 2018; Vallejo-Rojas et al., 2016; van Berkum et al., 2018). In that sense, IOM Institute of MedicineNRC National Research Council (2015) point out that simulation models allow measuring the probability that a given effect exceeds the threshold from which the system's resilience is affected, thus triggering transformations. Besides the transition functions proposed by Allen and Prosperi (2016), modeling methods like Agent-based Modelling (IOM and NRC, 2015), Causal Loop Diagrams (Eigenraam et al., 2020; TEEB, 2018), Systems Dynamics (Eigenraam et al., 2020; Halbe and Adamowski, 2019; TEEB, 2018) and Fuzzy Cognitive Mapping (Halbe and Adamowski, 2019) are proposed to delve into the conditions determining food systems stability or transformation, as part of exploring the non-linear behavior of food systems.

3.3. *Acknowledging the role of agents in framing systems*

Although more than half of the assessed FS frameworks recognize that agency has a role to play in food systems dynamics, only 30% describe how, thanks to their capacities to learn, adapt, and respond to changes, agents can influence food systems dynamics and co-evolve with them. IOM and NRC (2015) propose using Agent-based Modelling to represent these processes.

Most of the assessed FS frameworks recognize that agents involved in food systems have their perspectives on the situation to be addressed, which translates into different ways of understanding the same situation. Thus, the frameworks proposed by IPES-Food (2015), Béné et al. (2019), Bortoletti and Lomax (2019), and UNEP (2016) acknowledge that the interests and concerns of involved agents determine which dimension – social, economic, or environmental – is prioritized. On the other hand, IOM and NRC (2015) go a step further, highlighting the biases behind the perspectives involved and the need to make them transparent.

The acknowledgment of multiple perspectives results in 80% of the assessed FS frameworks promoting spaces for dialogue and exchange among them. In this sense, Soft Systems Methodology (Hubeau et al., 2017), Vision Design and Assessment (VDA) framework (Halbe and Adamowski, 2019), Causal Loop Diagrams (TEEB, 2018; Posthumus et al., 2018; Halbe and Adamowski, 2019), and Bayesian Belief Networks (Posthumus et al., 2018) are proposed to enable sharing, co-creation, learning, and negotiation processes to build a shared understanding of the situation and desired transformation. Moreover, and to call attention to an under-addressed aspect in FS frameworks, Bortoletti and Lomax (2019) and Posthumus et al. (2018) highlight the need to create spaces to reflect on and understand the values, goals, beliefs, and assumptions behind perspectives to inform mutual understanding between them.

Another critical aspect is the role of power relations when fostering discussion spaces for informed decision-making, described in close to half of the assessed FS frameworks. In this sense, both Nguyen (2018) and UNEP (2016) refer to the need to explore the power relations among stakeholders that underlie governance mechanisms, which finally fed back to the decision-making processes (HLPE, 2017). The assessed FS frameworks propose some methodological insights to control or minimize the hierarchical effect of the most powerful, as well as to ensure the participation of groups that are usually marginalized or have less decision-making power. Thus, IOM and NRC (2015) recommend taking distance from the influence of powerful agents to create spaces for informed decisions, while IPES-Food (2015) bets on engaging them in a way their dominant positions can be constructively challenged. In line with this last idea, Zurek et al. (2018) highlight the importance of transparency in constructing indicators to avoid them becoming a tool for the already powerful. Furthermore, the creation of smaller group discussions (Jackson et al., 2020b), targeted focus groups (Hubeau et al., 2017), and multi-stakeholder platforms (Bortoletti and Lomax, 2019; TEEB, 2018) are proposed to ensure the participation of less powerful and marginalized groups on equal footing.

Although 80% of the FS frameworks recognize that the same situation can be understood differently, only 25% acknowledge that framing the situation and discussing pathways to improve it implies prioritizing some perspectives over others. Thus, Ericksen (2008) understands food systems as "problem-determined systems" that depend on the perspective taken, while IPES-Food (2015) highlights the need for discussion spaces that encompass different perspectives to reflect on which values and preferences to prioritize when framing food systems and proposing transformation pathways. In methodological terms, boundary decisions in FS frameworks are made by reflecting collectively on the dimensions, elements, and agents that are considered important and significant for the analysis from an outcome or impact perspective (Allen and Prosperi, 2016; IOM and NRC, 2015; TEEB, 2018). Interestingly, in the framework proposed by Allen and Prosperi (2016), boundary decisions are linked to the conditions of vulnerability and resilience, asking "vulnerability/resilience to what and for what" (p. 964).

4. Discussions

The STCS principles work as instruments to bring STCS into dialogue with FS frameworks and FS frameworks with each other, thus offering valuable insights to embrace the systemic and complex nature of food systems. Below, we discuss how the 20 assessed FS frameworks, by understanding and embracing food systems' complex and systemic nature, provide valuable insights and guidance to inform current discussions, decisions, and efforts towards their transformation. In addition to highlighting and elevating exemplary practices among FS frameworks, we identify opportunities to strengthen them from a Systems Thinking and Complexity Science perspective.

The comprehensive description of food systems structure made by most FS frameworks sheds light on the drivers, outcomes, and externalities associated with food systems performance, thus providing valuable insights to manage trade-offs and synergies between food systems goals that may hinder their transformation towards sustainability (Béné, 2022; Brouwer et al., 2020; Leeuwis et al., 2021; Mausch et al., 2020). Moreover, by proposing methods and tools that explore the complex network of elements that give rise to food systems properties and results, FS frameworks help comprehend "why, despite the efforts, current food systems configurations contribute to challenges such as food insecurity, malnutrition, poverty, and environmental degradation, instead of moving towards the desired transformation (Leeuwis et al., 2021, p. 762)".

Despite proposing tools that help explore how interrelationships and feedback loops between elements of food systems shape their outcomes, most of the assessed FS frameworks do not delve into the behavioral patterns that explain what triggers structural changes in food systems. Vulnerability and resilience are adopted as framing concepts in the few frameworks exploring the conditions behind transformation - fostering or preventing it. Through that lens, FS frameworks illustrate how systems' internal sensitivity to stressors and their adaptive and transformation capacities determine whether socioeconomic and environmental drivers trigger changes - or not - in the systems (Allen and Prosperi, 2016; Connolly-Boutin and Smit, 2016; Jackson et al., 2020).

Understanding how internal and external conditions converge to shape the dynamics of food systems is essential to identifying leverage points for transformation (Abson et al., 2017; Leeuwis et al., 2021; Mausch et al., 2020). In this sense, we propose leveraging the insights gained by Allen and Prosperi (2016) - by applying the lens of vulnerability and resilience to model food systems dynamics - to explore the potential of different STCS modeling tools (e.g., systems dynamics models (Sterman, 2000), CDE models (Eoyang, 1996)) to analyze food systems' patterns of change and identify leverage points to move food systems to alternative paths toward sustainability. This represents an interesting opportunity to strengthen FS frameworks by incorporating STCS insights that shed light on systems dynamic behavior.

FS frameworks recognize the importance of engaging with diverse stakeholders and perspectives to deal with food systems challenges from more informed positions. By proposing approaches, methods, and tools that facilitate mutual appreciation and cross-learning between stakeholders (e.g., Soft Systems Methodology, Bayesian Belief Networks, Vision Design and Assessment framework), FS frameworks help decision-makers to be more aware and better equipped to deal with conflicts and trade-offs that result from overlooking other worldviews and ignoring the limitations of our own (Béné, 2022; Hubeau et al., 2019). Additionally, they guide stakeholders in developing a shared understanding of what is failing in food systems, generating insightful discussions on how to support transformation based on realistic assumptions (Huttunen et al., 2022; Leeuwis et al., 2021).

According to Brouwer et al. (2020), engaging stakeholders in the transformation of food systems to contribute to sustainability outcomes is necessary to change the governance structures that limit their agency, allowing groups that have been traditionally marginalized to participate in debates and decision-making. Although the assessed FS frameworks offer some insights into dealing with power imbalances, they provide limited guidance to deal with the lock-in effects generated by powerful agents that, to continue benefiting from the food systems' current regime, use their dominant positions to prevent transformations (Brouwer et al., 2020; IPES-Food, 2015).

To effectively overcome the lock-in generated by power imbalances in food systems, we must challenge the status quo by questioning the boundaries imposed by the current regime and their underlying values (Béné, 2022; Huttunen et al., 2022; Leeuwis et al., 2021; Vignola et al., 2021). One instrument that could support boundary reflection is the materiality assessment proposed by Eigenraam et al. (2020), which illustrates the consequences of privileging certain purposes or perspectives over others through a transparent and systematic process that explores impact pathways. As there is a clear opportunity to strengthen FS frameworks in this regard, we suggest fostering dialogue with STCS ideas and practices to map out power dynamics, foster meaningful participation of vulnerable groups in equitable spaces, and systemically explore and question the boundaries that determine food systems' current situation and trends. A systems approach that could be of help is Critical System Heuristics (Ulrich and Reynolds, 2010), which acknowledges and explores four sources of influence to reflect on boundaries: values and motivations, power structures, the knowledge basis, and the moral basis or legitimacy.

The above confirms that fostering further dialogue between FS frameworks and STCS can help FS frameworks understand and meaningfully embrace the systemic and complex nature of food systems.

5. Conclusions

FS frameworks are intended to play a vital role in facilitating the necessary transformation of food systems to contribute to sustainable outcomes (Brouwer et al., 2020; HLPE, 2020; IPES-Food, 2021). However, their effectiveness could be limited if they fail to recognize and embrace food systems' systemic and complex nature (Leeuwis et al., 2021; Mausch et al., 2020). This research sets the foundation for fostering dialogues, exchanges, and cross-learning among FS frameworks and with STCS ideas and practices to maximize their contributions by substantially embracing the systemic and complex nature of food systems.

To achieve this goal, we developed a rubric based on ten STCS principles that function as a diagnostic tool to identify and leverage exemplary practices proposed by FS frameworks that meaningfully embrace food systems' systemic and complex nature. Our assessment revealed opportunities for improving the contributions of FS frameworks in this regard through dialogue and exchanges among them and with STCS ideas and practices.

The assessment results are also relevant to current academic discussions around food systems. The findings illustrate the potential of FS frameworks to guide debates, decisions, and efforts to make food systems more sustainable, provided that the frameworks acknowledge and meaningfully embrace the systemic and complex nature of food systems.

Understanding and accounting for the inherent complexity of food systems is essential for addressing undesirable trade-offs between food system outcomes (Abson et al., 2017; Béné, 2022; Ruben et al., 2021), identifying leverage points for transformation (Abson et al., 2017; HLPE, 2017; Leeuwis et al., 2021; Mausch et al., 2020), engaging and coping with divergent perspectives among stakeholders (Béné, 2022; Hubeau et al., 2019; Huttunen et al., 2022; Leeuwis et al., 2021), and addressing governance-related issues that constrain the agency of certain groups while enhancing power imbalances (Brouwer et al., 2020; Huttunen et al., 2022; Leeuwis et al., 2021; Ruben et al., 2021; Vignola et al., 2021).

Our research revealed that FS frameworks do not account for the same extent of features related to food systems' systemic and complex nature. Far from being a disadvantage, these differences illustrate complementarities that can be leveraged through dialogue and joint work.

Given that most FS frameworks delve into the structure of food systems but pay less attention to their dynamic behavior and the role of agents in their transformation, we emphasize practices that contribute to the last two dimensions. On the one hand, we propose leveraging practices that improve our understanding of food systems dynamics and patterns of change, such as the use of vulnerability and resilience concepts to identify the variables that shape current and future system states in light of stressful conditions (e.g., Allen and Prosperi, 2016; Connolly-Boutin and Smit, 2016; Jackson et al., 2020; Vallejo-Rojas et al., 2016). On the other hand, we highlight practices that encourage engagement with diverse perspectives, creating awareness of the values underlying them while trying to control or minimize power imbalances that prevent challenging the status quo to foster food systems' transformation (e.g., Soft Systems Methodology with targeted focus groups, Bayesian Belief Networks). As challenging the status quo implies questioning the boundaries upon which the current food regime is built, we propose leveraging the systematic guidance offered by authors such as Eigenraam et al. (2020) and IOM and NRC (2015) to explore how prioritizing certain impacts over others shapes decisions on what to transform and how.

This research also reveals key opportunities to strengthen FS frameworks that could be leveraged by fostering further dialogue with STCS. Specifically, we propose exploring STCS approaches, methods, and tools that shed light on systems' dynamics, address power imbalances, and strengthen the agency of marginalized and vulnerable groups, drawing on their capacities of self-organization and adaptation.

In conclusion, this research highlights opportunities for strengthening the guidance offered by FS frameworks to embrace food systems' complex and systemic nature, fostering dialogue among diverse agents involved in food systems research, and cross-learning between researchers and practitioners from food systems and STCS. We hope to inspire agents engaged in designing and implementing the growing and evolving body of FS frameworks to consider how STCS insights can improve their practices and advocate for including new topics when debating, discussing, and informing decisions about transforming food systems to contribute to sustainable outcomes.

CRediT authorship contribution statement

Lauren Baker: Writing – review & editing, Supervision, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Acknowledgment

This research was supported by the European Union's Framework Programme for Research and Innovation – Horizon 2020 with the ERA-NET Cofund program and Grant Agreement No. 72775, which corresponds to Project "Empowering small-scale farmers (SPEAR): towards the SDGs through participative, innovative, and sustainable livestock and poultry value chains."

References

Abson, D.J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von, Wehrden H., Abernethy, P., Ives, C.D., Jager, N.W., Lang, D.J., 2017. Leverage points for sustainability transformation. AMBIO A J. Hum. Environ. 46 (1), 30–39. https://doi.org/10.1007/s13280-016-0800-y.

Allen, T., Prosperi, P., 2016. Modeling sustainable food systems. Environ. Manag. 57 (5), 956–975. https://doi.org/10.1007/s00267-016-0664-8.

Béné, C., 2022. Why the Great Food Transformation may not happen: a deep-dive into our food systems' political economy, controversies, and politics of evidence. World Dev. 154, 105881 https://doi.org/10.1016/j.worlddev.2022.105881.

Béné, C., Oosterveer, P., Lamotte, L., Brouwer, I.D., de Haan, S., Prager, S.D., Talsma, E. F., Khoury, C.K., 2019. When food systems meet sustainability: current narratives and implications for actions. World Dev. 113, 116–130. https://doi.org/10.1016/j.worlddev.2018.08.011.

Bortoletti, M., Lomax, J., 2019. Collaborative framework for food systems transformation. United Nations Environment Programme. https://www.oneplanetnetwork.org/sites/default/files/un-e_collaborative_framework_for_food_systems_transformation_final.pdf. (Accessed 8 February 2021).

Brouwer, I., McDermott, J., Ruben, R., 2020. Food systems everywhere: improving relevance in practice. Global Food Secur. 26, 100398 https://doi.org/10.1016/j.gfs.2020.100398.

Burns, D., Worsley, S., 2015. Navigating Complexity in International Development. Practical Action Publishing.

Bustamante, M., Vidueira, P., Baker, L., 2021. Systems thinking and complexity science-informed evaluation frameworks: assessment of the economics of ecosystems and biodiversity for agriculture and food. N. Dir. Eval. 170, 81–100. https://doi.org/10.1002/ev.20455.

Byrne, D., 2013. Evaluating complex social interventions in a complex world. Evaluation 19 (3), 217–228. https://doi.org/10.1177/1356389013495617.

Byrne, D., Callaghan, G., 2014. Complexity Theory and the Social Sciences: the State of the Art, first ed. Routledge. https://doi.org/10.4324/9780203519585.

Cabrera, D., Colosi, L., Lobdell, C., 2008. Systems thinking. Eval. Progr. Plann. 31, 299–310. https://doi.org/10.1016/j.evalprogplan.2007.12.001.

Caron, P., Ferrero y de Loma-Osorio, G., Nabarro, D., Hainzelin, E., Guillou, M., Andersen, I., Arnold, T., Astralaga, M., Beukeboom, M., Bickersteth, S., Bwalya, M., Caballero, P., Campbell, B., Divine, N., Fan, S., Frick, M., Friis, A., Gallagher, M., Halkin, J., et al., 2018. Food systems for sustainable development: proposals for a profound four-part transformation. Agron. Sustain. Dev. 38 (41), 1–12. https://doi.org/10.1007/s13593-018-0519-1.

CECAN The Centre for the Evaluation of Complexity Across the Nexus, 2019. Complexity Evaluation Framework. CECAN, the Tavistock Institute, and Risk Solutions. http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=220&ProjectID=20401.

Checkland, P., Poulter, J., 2010. Soft systems methodology. In: Reynolds, M., Holwell, S. (Eds.), Systems Approaches to Managing Change: A Practical Guide. Springer, pp. 191–242. https://doi.org/10.1007/978-1-84882-809-4.

Connolly-Boutin, L., Smit, B., 2016. Climate change, food security, and livelihoods in sub-Saharan Africa. Reg. Environ. Change 16 (2), 385–399. https://doi.org/10.1007/s10113-015-0761-x.

Cornell Office for Research on Evaluation, 2009. The Evaluation Facilitator's Guide to Systems Evaluation Protocol. Cornell Digital Print Service. https://core.human.cornell.edu/documents/SEP_I.pdf.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F., Leip, A., 2021. Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food 2, 198–209. https://doi.org/10.1038/s43016-021-00225-9.

da Costa, D., McMichael, P., 2007. The poverty of the global order. Globalizations 4 (4), 588–602. https://doi.org/10.1080/14747730701695851.

Davidson, E.J., 2004. Evaluation Methodology Basics: the Nuts and Bolts of Sound Evaluation. Sage Publications, Beverly Hills, CA.

Dengerink, J., Dirks, F., Likoko, E., Guijt, J., 2021. One size doesn't fit all: regional differences in priorities for food system transformation. Food Secur. 13 (6), 1455–1466. https://doi.org/10.1007/s12571-021-01222-3.
Dury, S., Bendjebbar, P., Hainzelin, É., Giordano, T., Bricas, N., 2019. Food Systems at risk: new trends and challenges. FAO Food and Agriculture Organization of the United Nations, CIRAD le Centre de Coopération Internationale en Recherche Agronomique pour le Développement. EC European Commission, Rome, Montpellier, Brussels. https://doi.org/10.19182/agritrop/00080.
Eppel, E., Matheson, A., Walton, M., 2011. Applying complexity theory to New Zealand public policy principles for practice. Policy Quarterly 7 (1), 48–55.
Eoyang, G., 1996. *Coping With Chaos: Seven Simple Tools.* Lagumo. Circle Pines, Minnesota.
Eigenraam, M., McLeod, R., Kavita, S., Obst, C., Jekums, A., 2020. Applying the TEEBAgriFood evaluation framework: overarching implementation guidance. IDEEA Group and Global Alliance for the Future of Food. https://futureoffood.org/wp-content/uploads/2021/01/GA_TEEBAgriFood_Guidance.pdf.
Ericksen, P., 2008. Conceptualizing food systems for global environmental change research. Global Environ. Change 18 (1), 234–245. https://doi.org/10.1016/j.gloenvcha.2007.09.002.
Fanzo, J., 2021. Achieving food security through a food systems lens. In: Béné, C., Devereux, S. (Eds.), Resilience and Food Security in a Food Systems Context. Palgrave Macmillan, pp. 31–52. https://library.oapen.org/bitstream/handle/20.500.12657/62394/978-3-031-23535-1.pdf?sequence=1#page=48.
FAO Food and Agriculture Organization of the United Nations, IFAD International Fund for Agricultural Development, UNICEF United Nations Children's Fund, WFP World Health Organization, WHO World Health Organization, 2023. Urbanization, Agrifood Systems Transformation and Healthy Diets Across the Rural-Urban Continuum. FAO, Rome. https://doi.org/10.4060/cc0639en.
Foster-Fishman, P.G., Nowell, B., Yang, H., 2007. Putting the system back into systems change: a framework for understanding and changing organizational and community systems. Am. J. Community Psychol. 39 (3–4), 197–215. https://doi.org/10.1007/s10464-007-9109-0.
Gates, E.F., 2016. Making sense of the emerging conversation in evaluation about systems thinking and complexity science. Eval. Progr. Plann. 59, 62–73. https://doi.org/10.1016/j.evalprogplan.2016.08.004.
Gaitán-Cremaschi, D., Klrekx, L., Duncan, J., Trienekens, J.H., Huenchuleo, C., Dogliotti, S., Contesse, M.E., Rossing, W.A.H., 2019. Characterizing diversity of food systems in view of sustainability transitions. A review. Agron. Sustain. Dev. 39 (1) https://doi.org/10.1007/s13593-018-0550-2.
Garbero, A., Resce, G., Carneiro, B., 2021. Spatial dynamics across food systems transformation in IFAD investments: a machine learning approach. Food Secur. 13, 1125–1143. https://doi.org/10.1007/s12571-021-01190-8/Published.
Garcia-Gonzalez, J., Eakin, H., 2019. What can be: stakeholder perspectives for a sustainable food system. Journal of Agriculture, Food Systems, and Community Development 8 (4), 61–82. https://doi.org/10.5304/jafscd.2019.084.010.
Gassner, A., Harris, D., Mausch, K., Terheggen, A., Lopes, C., Finlayson, R., Dobie, P., 2019. Poverty eradication and food security through agriculture in Africa: rethinking objectives and entry points. Outlook Agric. 48 (4), 309–315. https://doi.org/10.1177/0030727019888513.
Gates, E., Walton, M., Vidueira, P., McNall, M., 2021. Introducing systems- and complexity-informed evaluation. N. Dir. Eval. 2021, 13–25. https://doi.org/10.1002/ev.20466.
Giller, K., Delaune, T., Silva, J., van Wijk, M., Hammond, J., Descheemaeker, K., van de Ven, G., Schut, A., Taulya, G., Chikowo, R., Andersson, J., 2021. Small farms and development in sub-Saharan Africa: farming for food, for income or for lack of better options? Food Secur. 13, 1431–1454. https://doi.org/10.1007/s12571-021-01209-0.
Haddad, L., Hawkes, C., 2016. A new global research agenda for food. Nature 540, 30–32. https://doi.org/10.1038/540030a.
Halbe, J., Adamowski, J., 2019. Modeling sustainability visions: a case study of multi-scale food systems in Southwestern Ontario. J. Environ. Manag. 231, 1028–1047. https://doi.org/10.1016/j.jenvman.2018.09.099.
HLPE High-Level Panel of Experts on Food Security and Nutrition, 2017. Nutrition and Food Systems. HLPE, Rome. https://www.fao.org/3/i7846e/i7846e.pdf. (Accessed 8 February 2021).
HLPE High-Level Panel of Experts on Food Security and Nutrition, 2020. Food Security and Nutrition: Building a Global Narrative towards 2030. HLPE, Rome. http://www.fao.org/3/ca9731en/ca9731en.pdf. (Accessed 30 October 2022).
Hubeau, M., Marchand, F., Coteur, I., Mondelaers, K., Debruyne, L., Van Huylenbroeck, G., 2017. A new agri-food systems sustainability approach to identify shared transformation pathways towards sustainability. Ecol. Econ. 131, 52–63. https://doi.org/10.1016/j.ecolecon.2016.08.019.
Hubeau, M., Vanderplanken, K., Vandermoere, F., Rogge, E., Van Huylenbroeck, G., Marchand, F., 2019. Sharing is caring: the role of culture in the transformative capacity and continuation of agri-food networks. Environ. Innov. Soc. Transit. 33, 127–139. https://doi.org/10.1016/j.eist.2019.04.002.
Hummelbrunner, R., 2011. Systems thinking and evaluation. Evaluation 17 (4), 395–403. https://doi.org/10.1177/1356389011421935.
Huttunen, S., Turunen, A., Kaljonen, M., 2022. Participation for just governance of food-system transition. Sustainability: Science, Practice, and Policy 18 (1), 500–514. https://doi.org/10.1080/15487733.2022.2088187.
IFAD, 2021. Rural development report 2021: food systems transformations for rural prosperity. International Fund for Agricultural Development.
Iman, I., LaGoy, A., Williams, B., 2006. Introduction. In: Wiliams, B., Iman, I. (Eds.), Systems Concepts in Evaluation: an Expert Anthology. American Evaluation Association, pp. 3–10. http://www.managingforimpact.org/sites/default/files/resource/system_concepts_in_evaluation.pdf.
IOM Institute of Medicine, NRC National Research Council, 2015. A Framework for Assessing Effects of the Food System. The National Academies Press, Washington D. C. https://doi.org/10.17226/18846.
IPES-Food International Panel of Experts on Sustainable Food Systems, 2015. The new science of sustainable food systems: overcoming barriers to food systems reform. IPES-Food. https://www.ipes-food.org/_img/upload/files/NewScienceofSusFood.pdf. (Accessed 10 January 2021).
IPES-Food International Panel of Experts on Sustainable Food Systems, 2017. Unravelling the Food-Health Nexus: addressing practices, political economy, and power relations to build healthier food systems. The Global Alliance for the Future of Food and IPES-Food.
IPES-Food International Panel of Experts on Sustainable Food Systems, 2021. A Unifying Framework for Food Systems Transformation: a call for governments, private companies & civil society to adopt 13 key principles. https://www.ipes-food.org/_img/upload/files/sfsENhq.pdf. (Accessed 13 January 2023).
Jackson, G., McNamara, K., Witt, B., 2020. "System of hunger": understanding causal disaster vulnerability of indigenous food systems. J. Rural Stud. 73, 163–175. https://doi.org/10.1016/j.jrurstud.2019.10.042.
Jackson, M.C., 2003. The power of multi-methodology: some thoughts for John Mingers. J. Oper. Res. Soc. 54 (12), 1300–1304. https://doi.org/10.1057/palgrave.jors.2601640.
Kania, A., Patel, A.B., Roy, A., Yelland, G.S., Nguyen, D.T.K., Verhoef, M.J., 2012. Capturing the complexity of evaluations of health promotion interventions: a scoping review. Can. J. Progr. Eval. 27 (1), 65–91. https://doi.org/10.3138/cjpe.027.003.
Kuokkanen, A., Mikkilä, M., Kuisma, M., Kahiluoto, H., Linnanen, L., 2017. The need for policy to address the food system lock-in: a case study of the Finnish context. J. Clean. Prod. 140, 933–944. https://doi.org/10.1016/j.jclepro.2016.06.171.
Lam, D.P.M., Hinz, E., Land, D.J., Tengö, M., von Wehrden, H., Martín-López, B., 2020. Indigenous and local knowledge in sustainability transformations research: a literature review. Ecol. Soc. 25 (1), 3. https://doi.org/10.5751/ES-11305-250103.
Leeuwis, C., Boogaard, B., Atta-Krah, K., 2021. How food systems change (or not): governance implications for system transformation processes. Food Secur. 13, 761–780. https://doi.org/10.1007/s12571-021-01178-4/Published.
Mausch, K., Hall, A., Hambloch, C., 2020. Colliding paradigms and trade-offs: Agri-food systems and value chain interventions. Global Food Security 26, 100439. https://doi.org/10.1016/j.gfs.2020.100439.
Meadows, D., 1999. Leverage Points: Places to Intervene in a System. The Sustainability Institute.
Midgley, G., 2006. Systems thinking for evaluation. In: Williams, B., Iman, I. (Eds.), Systems Concepts in Evaluation: an Expert Anthology. American Evaluation Association, pp. 11–34.
Mingers, J., Brocklesby, J., 1997. Multimethodology: towards a framework for mixing methodologies. Omega 25 (5), 489–509. https://doi.org/10.1016/S0305-0483(97)00018-2.
Nguyen, H., 2018. Sustainable Food Systems Concept and Framework. FAO. http://www.fao.org/3/ca2079en/CA2079EN.pdf. (Accessed 8 February 2021).
O'Brien, K., 2012. Global environmental change II: from adaptation to deliberate transformation. Prog. Hum. Geogr. 36 (5), 667–676. https://doi.org/10.1177/0309132511425767.
Paloviita, A., 2017. Food security is none of your business? Food supply chain management in support of a sustainable food system. Operations and Supply Chain Management 10 (2), 100–108. https://doi.org/10.31387/oscm0270183.
Posthumus, H., de Steenhuijsen-Piters, B., Dengerink, J., Vellema, S., 2018. Food Systems: from Concept to Practice and Vice Versa. Wageningen University, & Research, The Hague. https://doi.org/10.5040/9781350044579-ch-002.
Ramalingam, B., Jones, H., Reba, T., Young, J., 2008. Exploring the science of complexity: ideas and implications for development and humanitarian efforts. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/833.pdf.
Raza, A., Fox, E., Morris, S., Kupka, R., Timmer, A., Dalmiya, N., Fanzo, J., 2020. Conceptual framework of food systems for children and adolescents. Global Food Secur. 27, 100436 https://doi.org/10.1016/j.gfs.2020.100436.
Raza, A., Soares, F., 2020. Leveraging food systems to reduce poverty and malnutrition. Policy in Focus. FAO Food and Agriculture Organization of the United Nations and IPC-IG International Policy Centre for Inclusive Growth IPC-IG 46 (1), 1–53. https://doi.org/10.4060/cb2498en. Brasilia.
Reynolds, M., Forss, K., Hummelbrunner, R., Marra, M., Perrin, B., 2012. Complexity, systems thinking and evaluation – an emerging relationship? Evaluation connections: The European Evaluation Society newsletter 7–9. December 2012. http://www.europeanevaluation.org/sites/default/files/ees_newsletter/2012-12-Connections.pdf.
Reynolds, M., Gates, E., Hummelbrunner, R., Marra, M., Williams, B., 2016. Towards systemic evaluation. Syst. Res. Behav. Sci. 33 (5), 662–673. https://doi.org/10.1002/sres.2423.
Reynolds, M., Holwell, S., 2010. Introducing systems approaches. In: Reynolds, R., Holwell, S. (Eds.), Systems Approaches to Managing Change: A Practical Guide. Springer, London, pp. 1–23. https://doi.org/10.1007/978-1-84882-809-4.
Rickles, D., Hawe, P., Shiell, A., 2007. A simple guide to chaos and complexity. J. Epidemiol. Community 61 (11), 933–937. https://doi.org/10.1136/jech.2006.054254.
Ruben, R., Cavatassi, R., Lipper, L., Smaling, E., Winters, P., 2021. Towards food systems transformation—five paradigm shifts for healthy, inclusive, and sustainable food

systems. Food Secur. 13, 1423–1430. https://doi.org/10.1007/s12571-021-01221-4.
SETIG Systems in Evaluation Topical Interest Group of the American Evaluation Association, 2018. Principles for effective use of systems thinking in evaluation. https://www.systemsinevaluation.com/wp-content/uploads/2018/10/SETIG-Principles-FINAL-DRAFT-2018-9-9.pdf.
Sterman, J.D., 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World. McGraw-Hill, Irwin, Boston.
TEEB The Economics of Ecosystems and Biodiversity, 2018. TEEB for Agriculture & Food: Scientific and Economic Foundations. UN Environment, Geneva. http://teebweb.org/wp-content/uploads/2018/11/Foundations_Report_Final_October.pdf. (Accessed 30 January 2021).
Ulrich, W., Reynolds, M., 2010. Critical systems heuristics. In: Reynolds, R., Holwell, S. (Eds.), Systems Approaches to Managing Change: A Practical Guide. Springer, London, pp. 243–292. https://doi.org/10.1007/978-1-84882-809-4.
United Nations, 2021. Nearly 200 commitments from civil society, farmers, youth, and Indigenous Peoples and Member States highlight Summit's inclusive process to accelerate action [Press release]. https://www.un.org/en/food-systems-summit/news/nearly-300-commitments-civil-society-farmers-youth-and-indigenous-peoples-and. (Accessed 11 March 2022).
UNEP United Nations Environment Program, 2016. Food systems and natural resources. United Nations Environment Program. https://wedocs.unep.org/handle/20.500.11822/7592. (Accessed 30 January 2021).
Vallejo-Rojas, V., Ravera, F., Rivera-Ferre, M., 2016. Developing an integrated framework to assess agri-food systems and their application in the Ecuadorian Andes. Reg. Environ. Change 16 (8), 2171–2185. https://doi.org/10.1007/s10113-015-0887-x.
van Berkum, S., Dengerink, J., Ruben, R., 2018. The Food Systems Approach: Sustainable Solutions for a Sufficient Supply of Healthy Food. Wageningen Economic Research, Wageningen. https://library.wur.nl/WebQuery/wurpubs/538076. (Accessed 30 January 2021).
van Bers, C., Delaney, A., Eakin, H., Cramer, L., Purdon, M., Oberlack, C., Evans, T., Pahl-Wostl, C., Eriksen, S., Jones, L., Korhonen-Kurki, K., Vasileiou, I., 2019. Advancing the research agenda on food systems governance and transformation. Curr. Opin. Environ. Sustain. 39, 94–102. https://doi.org/10.1016/j.cosust.2019.08.003.
Vignola, R., Oosterveer, P., Béné, C., 2021. Conceptualizing food system governance and its present challenges. Wageningen University. https://edepot.wur.nl/561830.
Vincent, R., 2012. Insights from complexity theory for evaluation of development action: recognizing the two faces of complexity. PANOS/IKM Emergent Research Program 14. https://www.emergentworks.net/sites/default/files/ikmemergent_archive/1203-IKM_Emergent_Working_Paper_14-Complexity_Theory-March_2012.pdf.
Walton, M., 2014. Applying complexity theory: a review to inform evaluation design. Eval. Progr. Plann. 45, 119–126. https://doi.org/10.1016/j.evalprogplan.2014.04.002.
Walton, M., Gates, E., Vidueira, P., 2021. Insights and future directions for systems and complexity-informed evaluation. N. Dir. Eval. 159–171. https://doi.org/10.1002/ev.20459, 2021.
Westengen, O., Banik, D., 2016. The state of food security: from availability, access and rights to food systems approaches. Forum Dev. Stud. 43 (1), 113–134. https://doi.org/10.1080/08039410.2015.1134644.
Westhorp, G., 2012. Using complexity-consistent theory for evaluating complex systems. Evaluation 18 (4), 405–420. https://doi.org/10.1177/1356389012460963.
Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., Vermeulen, S., Garnett, T., Tilman, D., DeClerck, F., Wood, A., Jonell, M., Clark, M., Gordon, L., Fanzo, J., Hawkes, C., Zurayk, R., Rivera, J., De Vries, W., Sibanda, L., et al., 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 393, 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4.
Williams, B., Hummelbrunner, R., 2009. Systems Concepts in Action: A Practitioner's Toolkit. Stanford University Press.
Williams, B., Iman, I. (Eds.), 2006. Systems Concepts in Evaluation: an Expert Anthology. American Evaluation Association. http://www.managingforimpact.org/sites/default/files/resource/system_concepts_in_evaluation.pdf.
Wojtynia, N., van Dijk, J., Derks, M., Groot Koerkamp, P., Hekkerts, M.P., 2021. A new green revolution or agribusiness as usual? Uncovering alignment issues and potential transition complications in agri-food system transitions. Agron. Sustain. Dev. 41 (77) https://doi.org/10.1007/s13593-021-00734-8.
Zou, T., Dawodu, A., Mangi, E., Cheshmehzangi, A., 2022. General limitations of the current approach in developing sustainable food system frameworks. Global Food Secur. 29, 100546 https://doi.org/10.1016/j.gfs.2021.100546.
Zurek, M., Hebinck, A., Selomane, O., 2021. Looking across diverse food systems futures: implications for climate change and the environment. QOpen 1, 1–39. https://doi.org/10.1093/qopen/qoaa001.
Zurek, M., Hebinck, A., Leip, A., Vervoort, J., Kuiper, M., Garrone, M., Havlík, P., Heckelei, T., Hornborg, S., Ingram, J., Kuijsten, A., Shutes, L., Geleijnse, J., Terluin, I., van't Veer, P., Wijnands, J., Zimmermann, A., Achterbosch, T., 2018. Assessing sustainable food and nutrition security of the EU food system – an integrated approach. Sustainability 10, 4271. https://doi.org/10.3390/su10114271.