



A Case for Clarity: Defining Food System Drivers, Outcomes, and Feedbacks

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Abstract

Food systems frameworks are useful analytical tools for understanding the functioning of a complex set of activities, stakeholders, and system outcomes, and for developing interventions for more desirable futures. Despite the rapid proliferation of food systems framings in recent decades, the field remains under-theorised with inconsistent and ambiguous terminology for core concepts like ‘drivers’, ‘outcomes’, and ‘feedbacks’. This lack of clarity hinders effective communication, research, and intervention design. This paper argues that clarifying these terms is essential for advancing food systems understanding and informing transformative action. We begin by critically examining how these terms are currently used in the food systems literature, highlighting inconsistencies and potential implications. Drawing upon geography literature, which usefully examines spatial dynamics, scale, and human-environment interactions, we then explore how analogous concepts are employed, seeking potential cross-disciplinary learning and enrichment. Geographical perspectives, with their emphasis on spatial dynamics, scale, and human-environment interactions, offer valuable insights for refining our understanding of food system processes. Drawing on this interdisciplinary exploration, we propose that researchers more clearly indicate how the key concepts of ‘drivers’, ‘outcomes’, and ‘feedbacks’ within food systems analyses are being used and offer a distillation of their relationships with each other as key system elements. This will promote more rigorous and consistent approaches to studying food system dynamics, facilitating more effective research, policy development, and practical interventions. Ultimately, this paper underscores the importance of terminological clarity and interdisciplinary collaboration for addressing the complex challenges facing food systems and achieving a more just and sustainable food future.

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Introduction

The global food system faces unprecedented challenges and requires paradigm-shifting transformations toward improved outcomes across all dimensions of the system. These transformations necessitate a comprehensive understanding of the complexity, functioning, and requirements for driving change among a vast range of actors (Godfray et al., 2010; HLPE, 2017). Food systems frameworks offer a valuable lens for analysing these complexities and provide a structured approach for identifying key actors, processes, and interactions within the system. However, the rapid growth in the number and diversity of frameworks has highlighted the need for a stronger theoretical foundation to underpin their application.

The entry point of this work arises from an observation that key concepts in food system dynamics, such as ‘drivers’, ‘outcomes’, and ‘feedbacks’, have been variously depicted and discussed in the food systems literature. Given the increasing calls for quantification and monitoring of the status of food systems, moving away from abstract approaches, such conceptual and definitional confusion becomes more relevant (Béné et al., 2019). These terms were selected due to their foundational role in understanding the dynamics of these systems and their frequent yet inconsistent application across diverse food systems frameworks. They represent core elements necessary for understanding the complex interactions within food systems. Further, due to their definitional confusion, when applying analysis of drivers, outcomes, and feedbacks to food systems research, it is often unclear when these concepts are distinct from each other. For example, when does a factor act as a driver, and when does that factor become a feedback instead of a driver? This paper addresses these concerns by first presenting an overview of the food systems literature through a critical exploration of these terms. We then discuss how these terms relate to one another and how they influence food system transformation debates.

We begin from the position that food systems frameworks aimed at transformational processes, and their visual representations, are not neutral representations of reality. They are inherently political objects, shaped by the worldviews, perspectives, and biases of their creators. The boundary decisions made on what elements and relationships to include and focus on reflect specific priorities and can obscure alternative viewpoints, whether disciplinary, political, or social. This inherent subjectivity introduces potential biases that influence the creation of knowledge about food systems and leads to certain interventions being prioritised over others. This subjectivity also results in certain narratives gaining dominance, even in contexts where they might not be appropriate. On this basis, ‘drivers’, ‘outcomes’, and ‘feedbacks’ were chosen for their direct relevance to policy and intervention design, as these elements are often the targets or consequences of food system transformation interventions. Recognizing this political dimension is essential for critically evaluating these frameworks and understanding their role in shaping research, policy, and practice.

Finally, food systems frameworks are subject to limitations as they are relatively simplistic representations of complex situations and interactions. Despite best intentions, they abstract away from the nuances and complexities of real-world systems. This simplification can lead to particular drivers and outcomes being potentially overemphasised, while overlooking critical feedbacks and emergent properties. Additionally, data availability and constraints on available and acceptable metrics can limit the scope and accuracy of these frames, particularly in contexts of limited resources and where data collection is challenging. Therefore, interpretations resulting from food systems frameworks must be accompanied by caution regarding their limitations and potential for bias, and they should also be supplemented with multiple and diverse forms of knowledge and perspectives.

This paper is structured as follows: we begin with a section on food systems framings, which functions as the literature review, including a detailed examination of ‘drivers’, ‘outcomes’, and ‘feedbacks’. This is followed by a table that summarises these concepts as defined by key authors in the field. Finally, we present a discussion that integrates these findings and offers insights for future research, policy development, and



practical interventions.

Food Systems and Food Systems Framings

Food systems models and frameworks are myriad, and while efforts underpinning the Food Systems Dashboard, Food Systems Countdown Initiative, the High Level Panel of Experts' (HLPE) framing, the Food and Agriculture Organization's (FAO) sustainable food systems map, The Food Systems Economic Commission, and City University's Food Systems framing have been informing research, policy, and programming over recent years, they are all substantially different from each other (Fanzo et al., 2020, 2021; HLPE, 2017; Hanh Nguyen, 2018; Parsons et al., 2019). These differences are not just in terms of representations, but also the selection and combination of elements, relationships between them and interacting systems, and how the context of the food system is handled.

Food systems frameworks acknowledge the intricate relationships between the various activities that take place in the food system. This includes food production, food distribution throughout supply chain processes which include processing and manufacturing, distribution, and storage, environments where food is obtained, individual choices and diets, the drivers affecting these processes, and the resulting nutritional, environmental, and livelihood outcomes that ultimately feedback and influence the overall system.

Food systems frameworks can be categorised according to their primary focus, such as social-ecological frameworks emphasizing the interconnectedness of social and ecological systems (Ericksen, 2008) or political economy frameworks highlighting power dynamics and inequalities within the system (McMichael, 2021). The strength of these frameworks lies in their ability to move beyond linear models and focus on relationships, feedbacks, and complexity. They allow researchers to analyse how different components of the system interact in both intentional and unintentional ways, and how they influence each other (Guptill and Peine, 2021).

However, limitations do exist because systems maps are mental constructs (García, 1984). Existing frameworks have tended to lack a strong theoretical foundation, leading to inconsistencies in how drivers and embedded systems are conceptualised and analysed (Béné et al., 2019). Further, system maps (used here to mean 'visualisations of conceptual frameworks') are created by researchers and hence subject to the position, biases, and inherent subjectivities and values of their makers; they should not be portrayed to demonstrate a realist ontology. Definitions of system boundaries for these frameworks can sometimes neglect the dynamic interplay of forces across scales and levels. Finally, feedbacks within the system are often oversimplified, failing to capture the complex and often non-linear nature of change (Gliessman, 2016). Capturing these dynamics over various scales (particularly over various temporal scales) has also proved a challenge for analysing food system dynamics and is rarely addressed in food systems frameworks, such as Stave and Kopainsky (2015). The act of drawing systems maps is inherently political, reflecting the worldview and priorities of the cartographer. The very selection of elements and relationships to represent constitutes a subjective, value-laden decision. The pursuit of an 'objective' system map can inadvertently depoliticise the analysis, masking underlying power dynamics and ideological commitments. This implicit claim to objectivity risks obscuring the fact that systems maps are not neutral representations but rather tools that shape and are shaped by political (or at the very least, subjective) agendas. By acknowledging the inherent subjectivity in systems mapping, we can foster a more transparent and critical dialogue about the choices that shape our understanding of food systems and, consequently, the interventions we prioritise. This reflexive approach is essential for navigating the complex interplay of power, knowledge, and action within food system transformation.

These conceptual differences become particularly concerning given the multiple scales and levels within such frameworks. When analysing relationships in a system, such differences stand out more, particularly given recent efforts to ensure that drivers are quantifiable and can be used in models. Drivers in these global food systems models are again variously shown using a disciplinary lens (e.g., economics and demographics),

subsystems or embedded systems (e.g., human system), or both. A framework visualisation may depict drivers interacting with the system of interest while also depicting that system of interest embedded in other systems. This can be noted, for example, in the Foresight4Food Initiative's visualisation of global food systems (Woodhill, 2019). Outcomes are similarly captured under broad dimensions like food and nutrition security, socio-economic wellbeing, environmental sustainability and will refer to specific elements within them across various levels of food system activity.

The sources of commonalities and differences in these concepts emerge from a range of factors. The disciplinary lenses through which the framework has been constructed is a key influence on the focus. Socio-ecological frameworks emphasise the relationships between environmental pressures and resource dependency on society and economy. A framework designed for addressing nutritional deficiencies highlights the drivers and outcomes ostensibly aimed at drivers that influence diet and consumption habits. These differences are essentially a boundary decision on what factors are brought to the forefront of analysis or problem setting. Furthermore, the scale and level of analysis—local, regional, or global—shapes the selection of relevant drivers and the complexity of feedbacks considered. Contextual factors, such as cultural norms, political structures, and technological advancements, introduce further variation. Finally, the inherent subjectivity of researchers, their values, and their chosen epistemological approaches contribute to the diverse conceptualisations of food systems, resulting in varying interpretations of drivers, outcomes, and the nature of their interconnectedness.

Feedbacks and relationships between the subsystems, drivers, activities, and outcomes are predominantly represented with arrows or connecting lines that do not always consistently identify the nature of the connection or flow: is this an influencing relationship based on human decision-making, or is it a flow of resources as in the systems engineering tradition? Some feedbacks implicitly indicate 'influence' that can cover a myriad of relationships and material flows across multiple scales. For example, arrows between the food system activities of 'production' and 'distribution' presumably include decision-making relationships between actor groups such as farmers and suppliers, while also indicating the transport of physical commodities, and the exchange of money and assets. Frameworks that also incorporate food environments use similar relationships to indicate food behaviour at a household level, with the difference of scale and level represented as either subsystems or as a nested system within a larger system. Of course, these are not intended or claimed to be comprehensive depictions of reality, but questions of such relations and subsystems require greater intellectual investment, particularly when stakeholders are asked to make changes in their mindsets and activities. Therefore, achieving conceptual and definitional clarity is not merely an academic exercise, but a political imperative.

Table I presents a selection of influential, peer-reviewed food systems frameworks that have shaped policy and research aimed at transforming the food system. While a complete review of all existing food system maps is beyond the scope of this paper, the table highlights key policy-relevant examples developed by leading researchers. These frameworks were chosen based on their impact on policy, their comprehensive inclusion of various drivers, interconnected systems, and feedback loops, their interdisciplinary development, their alignment with global goals (like the Sustainable Development Goals), and their applicability to regional and global analyses. It is important to note that this list is not exhaustive and primarily focuses on broad-scale, high-level food system analysis, making it less suitable for examining localised food systems. The table makes a distinction between how the terms are used in the narrative of the document, as compared to the conceptual



framework visualisation, if present.

Table 1. Selected food systems frameworks and how they represent drivers, systems, and feedbacks

Author(s) and Title	'Drivers' Representation (Narrative)	'Drivers' Representation (Conceptual framework visualisation)	'Outcomes' Representation (Narrative)	'Outcomes' Representation (Conceptual framework visualisation)	'Feedbacks' Representation (Narrative)	'Feedbacks' Outcomes Representation (Conceptual framework visualisation)
Acharya et al., 2014. Centre for Integrated Modeling of Sustainable Agriculture and Nutrition Security (CIMSANS) project	Access, behaviour, business opportunity, nutrition opportunity, fisheries and nutrition policies.	Visualisation of conceptual framework does not label drivers, but shows an enabling environment which leads to system shape and dynamics.	Social outcomes, nutrition and sustainability outcomes, and food system resilience. The overarching 'goal' is to achieve sustainable nutrition security.	Visualisation of conceptual framework does not label outcomes. The system's goal is achieving sustainable nutrition security.	System elements are interconnected through linkages.	Visualisation of conceptual framework does not label feedbacks, but shows how system elements are directly interconnected through linkages. Arrows between consumers/consumption and food chain actors, and food chain actors and producers. Arrow towards system goal of sustainable nutrition security.
Béné et al., 2019. Food systems framework in Understanding food systems drivers: A critical review of the literature	Driver categories of production / supply, distribution / trade, and consumption / demand.	Shown as boxes that interact with each other (production / supply drivers, distribution / supply drivers, consumption / demand drivers). These drivers interact and have a 'durable effect' on food system actors and activities.	Nutrition, food security and health; environment; social; and economic outcomes, and that these different outcomes are characterized by synergies and trade-offs.	Outcomes are shown to arise from food system actors, food environments, and consumers. Outcomes interact with each other through trade-offs and synergies, and additionally, they connect to feedbacks.	Feedbacks are often nonlinear and connect outcomes and drivers.	Feedbacks labelled, showing connections between outcomes and drivers. Different arrows indicating feedback, durable effects, interactions, impacts and influence and trade-offs and synergies.
Brunori et al., 2015. Assessment of the impact of drivers of change on Europe's food and nutrition security (TRANS-MANGO)	Biophysical, socio-cultural, economic, political, technological (depicted outside the overarching system of food regime).	Drivers come from outside the food system regime and are connected to the food system regime through impacting it, and from feedbacks back to the drivers from the regime. Drivers are independent or overlapping, falling under categories of bio-physical, socio-cultural, economic, political, and technological.	Food security, environmental security and other social interests. Outcomes are discussed, particularly with reference to food system vulnerability. Similarly to Ericksen, 2008, outcomes arise from food system activities (their contributions to food security, environmental security, and socio-economic welfare).	Arise as a direct result of food system actors and activities. They fall under categories of food and nutrition security, socio-economic welfare, and environmental security.	Feedbacks and impacts have a delay between drivers and food system regime, arrows indicating coordination, interaction and interconnectedness, flow resources and services, and food system outcomes.	Feedbacks arise from the food system regime and with a one-way arrow, feedback to drivers (with or without delay). Feedbacks also arise from food system outcomes (within the food system regime) and with a one-way arrow, feedback to institutions, assets, and actors/activities (with or without a delay).

Author(s) and Title	'Drivers' Representation (Narrative)	'Drivers' Representation (Conceptual framework visualisation)	'Outcomes' Representation (Narrative)	'Outcomes' Representation (Conceptual framework visualisation)	'Feedbacks' Representation (Narrative)	'Feedbacks' Outcomes Representation (Conceptual framework visualisation)
Ericksen, 2008. Global Environmental Change and Food Systems (GECAFS) Programme	Global environmental change, socio-economic drivers, 'natural' drivers, and driver interactions.	Drivers arise through feedbacks and fall under categories 'global environmental change' drivers and socioeconomic drivers. These interact and influence food system activities and food system outcomes directly. This visual depiction does not show the food system as nested within natural or social systems, so it is unclear whether drivers are endogenous or exogenous to the system, or both.	The three categories of outcomes considered in this framework—food security, environmental security, and social welfare often trade-off with one another across level. Outcomes are also drivers of global environmental change and create feedback loops.	Outcomes contribute to social welfare, food security, and environmental security/natural capital. These outcomes interact with each other with bi-directional arrows and also feedback from outcomes to drivers.	Feedbacks are non-linear and connect outcomes to drivers.	Feedbacks are socio-economic or environmental, arising from food system activities or outcomes and resulting in drivers on the system; feedbacks connect from outcomes to drivers. There are arrows between drivers, activities and outcomes.
Fanzo et al, 2021. Food Systems for 2030 framework	Biophysical, climate, and environment, income growth and distribution, politics and leadership, sociocultural dynamics, population growth, migration, and conflict, globalization and trade, land use and urbanization. Drivers are processes, and the components have feedback loops with each other and with the drivers and outcomes. Drivers can influence the directionality and dynamism of interactions between actors and components, which can help or hinder transformation.	Drivers influence components of the food system, policies, SDGs, and sustainability and resilience. There is no connection in the conceptual framework visualisation between drivers and outcomes.	Outcomes are not explicitly defined but they are grouped into three thematic areas (1) Diets, nutrition, and health; (2) Environment and climate; and (3) Livelihoods, poverty, and equity. Cross-cutting areas focus on (4) Governance and (5) Resilience and sustainability.	Outcomes are depicted to arise from the components of the food system (supply chains, food environments, etc.) and policies, SDGs, and sustainability and resilience. There is no connection in the conceptual framework visualisation between drivers and outcomes.	Components of the food system have feedback loops with each other and with the drivers and outcomes.	Feedbacks are not labelled or the focus of the conceptual framework visualisation, however each element of the system has an outward arrow from it into the rest of the system.
Global Panel on Agriculture and Food Systems for Nutrition (GLOPAN), 2016. Food systems framework	Drivers of food system exist outside of the food system and broadly exert influence on it.	It is unclear in the visual representation if the drivers are completely external to the system. The food supply system appears embedded within the drivers of the food system.	Diet quality as a focal outcome.	The middle (potentially the target) of the system and sub-systems.	Not explicitly discussed.	Double-headed arrows between the four subsystems.

Author(s) and Title	'Drivers' Representation (Narrative)	'Drivers' Representation (Conceptual framework visualisation)	'Outcomes' Representation (Narrative)	'Outcomes' Representation (Conceptual framework visualisation)	'Feedbacks' Representation (Narrative)	'Feedbacks' Outcomes Representation (Conceptual framework visualisation)
HLPE, 2017. Nutrition and food systems. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. HLPE Report 12.	Biophysical and environmental, innovation, technology and infrastructure, political and economic, socio-cultural, and demographic	Drivers arise from outcomes via feedbacks. Drivers fall within five categories that act on food supply chains: food environments, and consumer behaviour; Biophysical and environmental drivers; Innovation, technology and infrastructure drivers; Political and economic drivers; Socio-cultural drivers; Demographic drivers.	Outcome areas are: nutrition and health outcomes, environmental outcomes, economic outcomes, and social equity outcomes.	Focus on Nutrition and health outcomes. Other dimensions are captured as impacts: social, economic, and environmental.	There are feedbacks between political, programme and institutional actions and drivers, nutrition and health outcomes, impacts and drivers, impacts and political, programme and institutional actions, and between drivers and the linked systems.	Feedbacks connect outcomes and impacts in a uni-directional arrow back to drivers. There is also a bi-directional connection from food supply chains, food environments, and consumer behaviour with biophysical and environmental drivers and the SDGs through the medium of 'political, programme and institutional actions'.
Nguyen, 2018. Food and Agriculture Organization (FAO) food system	Not explicitly named as drivers. Natural elements (air soils ecosystems and genetics, water, climate) and societal elements (organizations, policies, laws and regulations, infrastructures, socio-cultural norms) as the outer most rings of a nested system.	There are no drivers explicitly named in the conceptual visualisation, however, the core system interacts with natural elements and societal elements through bi-directional arrows.	The food system wheel has goals and 'performance' instead of outcomes. These goals are poverty reduction, food security and nutrition; the performance of the system refers to three dimensions of sustainability: economic, social, and environmental.	Central to the core system are highlighted elements: sustainability performance, and poverty reduction,	Feedbacks connect societal and natural elements between each other and the core food system.	Feedbacks are not explicitly labelled in the visualisation, however, there are bi-directional arrows between natural elements and societal elements with the core system.
Parsons et al., 2019. City, University of London's Centre for Food Policy's food system map	'Dimensions' of economics, politics, the environment, health, and society functioning as drivers and outcomes. Drivers are the factors that 'push or pull' the food supply chain of food system activities.	Drivers and outcomes are the dimensions that shape and are shaped by the food supply chain: health, politics, environment, society, and economy.	Drivers and outcomes are the dimensions that shape the food supply chain: health, politics, environment, society, and economy. While drivers and outcomes are typically portrayed as separate, this approach posits that drivers can also be outcomes, and outcomes, drivers.	Drivers and outcomes are the dimensions that shape and are shaped by the food supply chain: health, politics, environment, society, and economy.	Each dimension feeds into the food chain dimension, which connects back.	As drivers and outcomes are represented by the same part of the figure, there are numerous bi-directional arrows between the driver/ outcome combined dimensions and the food chain.

Author(s) and Title	'Drivers' Representation (Narrative)	'Drivers' Representation (Conceptual framework visualisation)	'Outcomes' Representation (Narrative)	'Outcomes' Representation (Conceptual framework visualisation)	'Feedbacks' Representation (Narrative)	'Feedbacks' Outcomes Representation (Conceptual framework visualisation)
Stefanovic et al., 2020. Food System Outcomes: An Overview and the Contribution to Food Systems Transformation	Drivers are comprised of interactions within and between Bio-geophysical and human environments as well as interactions and feedbacks between them.	No conceptual framework visualisation.	Outcomes arise from food system activities. They note that although the classification of outcomes vary from author to author, regardless of the differences the outcome categories can generally be assigned to four broad groups: food and nutrition security (or health pillar) and the three pillars of sustainability, namely environmental, social and economic.	No conceptual framework visualisation.	Feedbacks are the interactions between all elements of the food system	No conceptual framework visualisation.
Webb et al. 2023. Measurement of diets that are healthy, environmentally sustainable, affordable, and equitable: A scoping review of metrics, findings, and research gaps	Drivers are not the focal area of this paper.	No conceptual framework visualisation.	Categorised as the dimensions of sustainable healthy diets: planetary health, human health, economic, and social outcomes.	No conceptual framework visualisation of the food system, but a chord diagram demonstrating how outcomes are interconnected.	Feedbacks are not the focal point of this paper however they are mentioned as the mediator linking climate and ecology, human health and nutrition, food prices, and social justice.	No conceptual framework visualisation.
Westhoek et al. 2016. United Nations Environment Programme (UNEP) International Resources Panel	Biophysical and socio-economic drivers.	Socio-economic drivers arise from social food system outcomes and in turn impact food system activities ; these interact with natural resources to influence food system activities.	Outcomes related to social factors feedback to social-economic drivers while the outcomes related to environmental factors feedback to natural resources.	Food system outcomes contribute to environmental factors, food security, and societal factors. These feedback with unidirectional arrow to natural resources and socio-economic drivers.	Feedbacks connect drivers, activities, environment, and natural resources.	Depicted as one way arrows between outcomes and natural resources and socio-economic drivers. There are also bi-directional arrows between natural resources and food system activities, food system activities and outcomes, and food system activities and socio-economic drivers.
Woodhill, 2019. Foresight4Food	Demographics and development, consumption, technology, markets, climate and environment, policy and geopolitics.	Drivers are exogenous, acting on the whole natural system and nested human and food systems. Outcomes give rise to drivers through feedbacks.	Economic and social well-being, food and nutrition security, and environmental sustainability.	Economic and social well-being, food and nutrition security, and environmental sustainability. Outcomes arise externally to the natural system and nested human and food systems. Outcomes are in three dimensions: economic and social well-being, food and nutrition security, and environmental sustainability.	Feedbacks (feedback loops) connect the wider interactions between human and natural systems.	Between Food, Human, and Natural Systems, and from Outcomes to Drivers.

Author(s) and Title	'Drivers' Representation (Narrative)	'Drivers' Representation (Conceptual framework visualisation)	'Outcomes' Representation (Narrative)	'Outcomes' Representation (Conceptual framework visualisation)	'Feedbacks' Representation (Narrative)	'Feedbacks' Outcomes Representation (Conceptual framework visualisation)
Zurek et al., 2018. Metrics, Models and Foresight for European Sustainable Food and Nutrition, (SUSFANS)	Indirect and direct drivers and EU policy goals. Drivers influence the different food system actors and their activities.	Drivers are explicitly labelled as direct and indirect. Direct drivers are detailed by supply chain actors, and indirect actors are in the broad categories of economic development, population dynamics, etc.	Nutrition and diet, environmental and economic outcomes together with social equity dimensions. Outcomes arise from actors and activities, with a subsequent arrow to the 'status' of the system.	Captured as a goal, which is to influence the performance of the EU food system.	Feedbacks not explicitly defined or discussed in detail, but are mentioned as interactions and feedback loops between the food system components.	Arrows between indirect drivers (context), policy goals, status of the EU food system, and the EU food system.

Food System Drivers

Drivers represent forces that exert influence on the sustained structure, function, and trajectory of a food system. These forces can be internal (e.g., technological innovations) or external (e.g., climate change) and can operate across various scales and levels. Understanding drivers is crucial for anticipating food system dynamics and identifying potential leverage points for interventions aimed at achieving specific goals (Linnér and Wibeck, 2021). Current scholarship often treats drivers as discrete and independent entities, which overlooks the interconnectedness and potential for synergistic or antagonistic interactions between drivers (Ingram, 2011). The focus on so-called dominant drivers (e.g., globalisation) can overshadow the importance of context-specific and less readily quantifiable drivers (e.g., cultural values).

Drivers operate across different scales and levels, including temporal, spatial, jurisdictional, institutional, and network scales. For instance, global trade policies can influence local food production practices. Similarly, the impacts of a driver can unfold over time, with some effects manifesting immediately and others emerging over millennia. Food systems frameworks also have implicit or explicit boundaries (e.g., national borders, regional watersheds) that can shape the influence or perceived influence of drivers. Understanding these boundaries is critical for effectively analysing how drivers impact different actors and processes within the system (Eakin et al., 2017).

In their review of the literature on food system drivers, Béné et al. observe that, with rare exceptions (Ericksen, 2008; HLPE, 2017; Zurek et al., 2018), drivers are “often simply processes and events that are known (or theoretically expected) to have an impact on food systems” (Béné et al., 2019, p. 150). These drivers can exert influence at various points within the food system, directly affecting production practices, distribution networks, or consumer behaviours. For instance, policy changes, a key driver, can alter agricultural subsidies, thereby reshaping production landscapes and market access. They argue that only processes that infer durable and consistent influences on the system can be considered drivers. This would differentiate a driver from a shock, which would be a more temporally bound process. For the same reason, elements like climate change and price volatility by themselves would not be drivers unless their frequency or recurrence period lasts long enough for adaptations to durably change the system.

The endogeneity, exogeneity, controllability, and accidental nature of drivers is a further area of conceptual concern that stems from boundary definition. Drivers influencing activities outside the determined system boundaries are considered exogenous to the system, and everything within is endogenous. In this narrative, the changes made by consumers are endogenous to a food system, while the increase in frequency and severity of climate change-related extreme weather events are exogenous. This distinction between endogenous and exogenous can be problematic because if food systems are considered to be part of the natural environment,

then changes in climate conditions (which are often considered exogenous) could also be seen as endogenous to the food system. This creates a conceptual challenge in determining the boundaries of the system and identifying which factors should be considered internal or external to it. It is also a cognitive leap to imagine food production as largely embedded in the natural environment in terms of the use of soil, water, and ecosystem services or resources, while keeping the changes in climatic conditions as a result of climate change outside the boundary of interest. Considering the multi-scale and multi-level variations of drivers on activities and actors further complicates the analysis, with the impacts of those drivers being modified by the context of the location and region of interest (Cash et al., 2006).

Food System Outcomes

The term ‘outcomes’ within food systems literature is rarely explicitly defined, and often used interchangeably with related terms. Generally, the literature suggests that outcomes are the ‘impacts’ of food system activities or the performance characteristics of the system itself, spanning scales and levels from the individual to the global. Ingram (2011) succinctly frames them as ‘what we get’ from ‘what we do,’ a seemingly straightforward definition that belies the complexity of its application. Webb et al. (2023) in their scoping review, opt for ‘endpoints,’ measurable variables that document the outcomes across health, environment, social, and economic pillars. Yet, even this seemingly precise definition struggles to capture the full breadth of what has constituted an outcome, as evidenced by the frequent use of proxy terms.

This lack of clarity manifests in the frequent conflation of ‘outcomes’ and ‘impacts’ or ‘performance’ over time. Ambikapathi et al. (2022) exemplify this, using the terms almost synonymously in their analysis of food system transitions, blurring the lines between immediate results and longer-term consequences. The Integrated Food Security Phase Classification attempts to introduce a hierarchy, distinguishing between first-level outcomes—such as changes in food consumption and livelihoods—and second-level outcomes—like nutritional status and mortality (Integrated Food Security Phase Classification Technical Manual Version 3.1. Evidence and Standards for Better Food Security and Nutrition Decisions, 2021). This structured approach, while useful, highlights the inherent challenge of delineating clear boundaries between different types and levels of outcomes within complex systems, and returns us to our early difficulty with boundaries and focus areas of food systems frameworks. Wood et al., (2025) utilizing causal loop diagrams, refer to ‘elements’ in a system, which include actor capacities (in this case, referring to the capacity of organisations to generate profits) and outcomes, illustrating the dynamic and interconnected nature of these concepts. For instance, in their representation of the global ultra-processed food (UPF) system, actor capacities like ‘industry influence’ are linked to outcomes like ‘increased UPF consumption,’ demonstrating the feedbacks inherent in food system analysis. Similarly, Vallejo-Rojas et al. (2016) position outcomes at the centre of ‘focal action situations’ within agri-food systems, using Ostrom’s framework without explicitly defining what constitutes an outcome.

Even when employing methodologies like Life Cycle Assessment (LCA), intended to quantify outcomes, inconsistencies persist. Boundary setting remains a challenge, particularly in capturing non-quantifiable elements that are either referred to generally as a context or the underlying systems of the food system (Webb et al., 2023). This variability points to a fundamental limitation in relying solely on measurable endpoints to capture the multifaceted nature of food system outcomes. Notably, the social dimension remains persistently underrepresented. (Blackstone et al., 2024; Ericksen, 2008; Webb et al., 2023), highlight the tendency to focus on consumer preferences, reflecting a broader conceptual gap and data limitations, especially since this term can be variably discussed as a driver or an outcome, depending on the focus of the analysis. (Blackstone et al., 2024) offer a valuable contribution by delineating social outcomes, distinguishing between measurable aspects like ‘social capital’ and unmeasurable aspects like ‘sense of belonging’. However, the inconsistent use of ‘dimensions’ when also analysing outcomes further muddies the waters.

This discursive ambiguity has significant implications for emerging concepts like resilience and sustainability



assessment. While resilience is often viewed as an intrinsic characteristic of a food system (Tendall et al., 2015), it is also incorporated as a principle of transformation (Stefanovic et al., 2020). Given that resilience is connected to food and nutrition security and environmental sustainability, the lack of clarity regarding outcomes directly impacts the development of relevant metrics and the understanding of driver-feedback relationships. As Stefanovic et al. (2020) emphasise, the emerging discourse on resilience necessitates further attention, particularly in relation to how we define and measure outcomes. Ultimately, a more rigorous and consistent conceptualisation of outcomes, encompassing both quantifiable and qualitative dimensions, is essential for advancing our understanding of food systems and guiding effective interventions.

Food System Feedbacks

Feedbacks are extremely important in the food systems literature, particularly for analysing the dynamics of these systems. Ericksen's (2008) seminal work on food systems defines feedbacks as "when a process interacts with a system component and the response then produces another reaction," further stating that "feedbacks can reinforce or counterbalance the original process" (Ericksen, 2008). Ericksen encourages that food systems "analysis must trace cross-scale interactions, especially the feedbacks," and notes that a holistic approach to understanding food systems interactions requires feedbacks and interactions to be analysed along with drivers and outcomes (Ericksen, 2008). Investigating the dynamics of feedbacks is central to food systems analysis and toward transforming these systems.

While the food systems literature has broadly demonstrated the importance of feedbacks (e.g., Serraj and Pingali, 2018), beyond Ericksen (2008), feedbacks have seldom been the subject of theoretical inquiry. Most often, feedbacks are described alongside linkages between focal elements of the food system, such as outcomes and drivers, or as the result of system interactions (Brouwer et al., 2020; Hahn Nguyen, 2018; Ruben et al., 2021). Occasionally, some food system conceptualisations omit the use of feedbacks altogether in their narrative (HLPE, 2017). Also, when feedbacks are used in conceptual narratives, they frequently remain unlabelled in food system conceptual maps such as in Ruben et al. (2021) and FAO Sustainable Food Systems Concept and Framework (2018).

The interactions between system elements (inclusive of feedbacks), rather than assessment of system elements as distinct pieces, are crucial for taking a food systems approach (Béné et al., 2019; Chase and Grubinger, 2014; Grant, 2015; Pinstrup-Andersen and Watson II, 2011). While feedbacks link outcomes to drivers and can reinforce or counterbalance the original process, outcome, or driver, feedbacks warrant analysis as processes *sui generis*. They can be negative or positive and need to be contextualised in system scales (Béné et al., 2019; Dalin and Rodríguez-Iturbe, 2016; Zimmerer, 2013). For instance, considering feedbacks across the analytical scale of time during reinforcement and counterbalancing processes: they can occur instantaneously or slowly, which have significant impacts on the dynamics of the whole system. Thus, to achieve a shift toward a sustainable food systems approach, feedback analysis can act as a vital entry point for change (Béné et al., 2019).

While it is important to explicitly define and analyse what constitutes a feedback, this clarity is also essential for distinguishing what is important about feedbacks for food systems transformation. Feedbacks are vital for assessing the performance of systems and the nature of outcomes and drivers, particularly as systems change and evolve over time (Hanh Nguyen, 2018). Further, assessing the food systems' complex and systemic nature, which feedbacks aim to address, enables improved analysis aimed at transformation (Bustamante et al., 2024). Feedbacks are important to analyse because, by their nature, they determine the dynamics of a system or how systems may change. Hence, where there are objectives to shift systems or improve their function (or undergo food systems transformation), feedbacks are an important focal area to address and analyse.

Insights from Geography

Geographical perspectives, particularly within food and commodity geographies, offer valuable insights by emphasizing spatial dynamics, scale, and human-environment interactions. While the specific term ‘outcome’ is less prevalent, the broader concept of ‘impacts’ is central, encompassing environmental, social, and economic dimensions. This aligns with the food systems focus on multifaceted outcomes and trade-offs between outcome areas. Geographical analyses illuminate how socio-spatial drivers shape food systems. These drivers extend beyond traditional geographical concepts to include the crucial dynamics of territorial development as follows. These include globalisation and trade, where commodity geographies underscore the influence of global trade networks and power dynamics on food production and distribution (Morris and Kirwan, 2011). Urbanisation, as explored in urban geography, alters food demand, land use, and access. Environmental geography highlights climate change as a critical driver, impacting agricultural productivity and food security (Morales-Muñoz et al., 2020). Furthermore, political geography examines how policies, land tenure, and regulations shape food systems, while the uneven distribution of technological advancements also plays a key role (Robinson, 2018). This broader lens, which encompasses territorial development, is crucial for understanding the link between food and the social and economic vitality of a region. The concept of territorial food systems views food production and consumption as deeply embedded within specific places, focusing on the interactions between diverse actors, activities, and governance mechanisms within a defined territory. This perspective moves beyond a purely spatial analysis to consider how actors like farmers, institutions, and consumers, through their activities and strategies, influence regional development and contribute to outcomes like food and nutrition security (Lamine et al., 2012; Galli et al., 2020).

Geographical perspectives have also tended to emphasise localisation and regionalisation, highlighting the importance of understanding food systems not just on a global scale, but also through the lens of specific places and regions (Hinrichs, 2003). This focus on local, regional, and place-based food systems analyses how proximity, cultural ties, and community networks shape food production, distribution, and consumption, offering alternatives to globalised models. This body of work examines the practice and politics of creating more localised and place-based food systems and also questions whether localisation alone is sufficient to address systemic issues (Clancy and Ruhf, 2010).

Geographical analyses often focus on the spatially-related distribution of impacts, revealing disparities and inequalities. Food and commodity geographies document the environmental consequences of food production, such as deforestation and pollution, often mapped spatially. Food environment studies explore the spatial distribution of food access and its relationship to health outcomes. Geographical perspectives also highlight the uneven distribution of economic benefits and social costs associated with food systems, and the specific impacts on specific places. Also, geographical approaches illuminate the complex feedbacks that shape food systems. Land use change, for example, can alter local climate patterns, affecting agricultural productivity. Urban food environments demonstrate how the concentration of unhealthy food options can lead to increased diet-related diseases. Similarly, climate change and agriculture interact through feedbacks, with rising temperatures reducing crop yields and increasing pressure for land expansion. Global commodity markets generate price signals that influence production decisions, and can result in feedbacks that either stabilise or destabilise food systems.

Research on food environments within geography (discussed below) provides valuable insights into the spatially-related dimensions of food access and health. This research emphasises the importance of considering multiple scales and levels, from the individual to the regional level, when analysing food access and health outcomes. These studies utilise spatial analysis techniques, such as GIS, to map food access and identify food deserts, providing valuable tools for understanding the spatial distribution of food system outcomes. They also examine the accessibility and affordability of healthy food options, shedding light on the social and economic factors that shape food choices. They can inform food systems thinking by providing empirical evidence on



the spatial distribution of food system outcomes, highlighting the importance of place-based interventions, and offering methodological tools for spatial analysis.

Geographical approaches enhance food systems analysis by providing a spatial lens for understanding the distribution of drivers, outcomes, and feedbacks, highlighting the importance of scale and place, and offering tools for mapping and analysing food system processes. This is relevant across levels for several spatially-related analytical scales, including spatial, management, network, and institutional scales (Cash et al., 2006). By using the concept of spatial justice, understood here as the “fair and equitable distribution in space of socially valued resources and opportunities to use them” (Soja, 2009, p. 2), we can better analyse the uneven distribution of food system burdens and benefits. Integrating geographical perspectives enables a more nuanced and comprehensive understanding of food systems, leading to more effective interventions for achieving a just and sustainable food future. Clarifying and consistently applying the concepts of ‘drivers,’ ‘outcomes,’ and ‘feedbacks’ within this interdisciplinary framework is crucial for advancing food systems research and action.

Food Environments and Food Systems Framing

Food environments, which synthesise food systems and geographical approaches, serve as the interface between consumers and the broader food system, encompassing the multifaceted physical, economic, political, social, and cultural settings that shape food-related practices, from food purchase planning to disposal. This includes a range of settings ranging from hospitality services and household kitchens to digital platforms like social media. Dimensions of a food environment span individual factors such as accessibility, affordability, convenience, and desirability, to external factors like availability, prices, product placement, neighbourhood characteristics, food composition, marketing, labelling, information, and the social environment. These dimensions have been highlighted in the health and nutrition perspectives as well in efforts of understanding drivers of health outcomes such as obesity and other non-communicable diseases. Nutrition and health is crucial for understanding how food environments influence diet quality and public health. This emphasis is supported by a significant body of research which demonstrate a link between the characteristics of a local food environment and dietary outcomes (Caspi et al. 2012). Studies demonstrate that factors like the proximity and density of supermarkets versus fast-food outlets, as well as the variety and price of healthy foods available, can significantly shape an individual’s food choices and overall diet (Holsten 2009). These dimensions are, in turn, influenced by policy instruments and biophysical factors. Contemporary definitions and descriptions, as articulated by Downs et al. (2020), further integrate sustainability and nutritional security, conceptualizing food environments as the consumer interface with the food system that encompasses the availability, affordability, convenience, promotion and quality, and sustainability of foods and beverages in wild, cultivated, and built spaces that are influenced by the socio-cultural and political environment and ecosystems within which they are embedded.

The food environment literature, rich in its exploration of consumer-food system interactions, provides insights into the micro-level spaces where food consumption decisions are made. However, the inherent complexity of food environments, which encompass a wide array of external drivers and active consumer agency, can create conceptual challenges when contextualised within broader food systems frameworks. Recent models, like that of Downs et al. (2020), attempt to clarify this by positioning food environments within a nested structure, with outer layers representing sectors of influence (agriculture, media, labour, etc.), socio-cultural and political environments, and ecosystems, and inner layers representing individual factors and diets. This hierarchical approach underscores the interconnectedness of various scales and influences, a concept that resonates with geographical perspectives on embeddedness.

Indeed, the conceptualisation of food environments as embedded systems within larger food systems aligns closely with geographical approaches to embeddedness (Hinrichs 2000, Sonnino 2007, Brinkley 2017).

Geographical literature emphasises the interconnectedness of social, economic, and ecological systems at different scales and levels, highlighting the importance of considering both local and global factors. Just as geographical analysis examines the spatial distribution of food system impacts, food environment research investigates the spatial dimensions of food access and consumption. For instance, studies on food deserts, a prominent area within food environment research, demonstrate the spatial inequalities in access to healthy food, reflecting broader systemic drivers. This spatial lens, informed by geographical methodologies, provides a crucial understanding of how factors like location, accessibility, and cultural influences shape food system outcomes.

Furthermore, the food environment framework reveals crucial feedbacks within food systems. While the assumption that healthy food environments promote healthier consumer choices is prevalent, research indicates that this link is not deterministic (Turner et al., 2018). Consumers are not passive recipients of their food environments but actively shape them through their choices and demands. This active role of consumers highlights the feedback mechanisms where consumer behaviour influences food availability and quality, which in turn influences future behaviours. For example, consumer demand, as demonstrated by Fuentes and Fuentes (2022), can significantly impact food availability, illustrating direct feedback. This aligns with the broader food systems concept of feedbacks, where changes in one component can trigger cascading effects throughout the system.

The typology of food environments, such as the natural and built food environments proposed by Downs (2020), also shares similarities with food system typologies, highlighting the interplay between the 'form' of environment and consumer access. However, the primary distinction lies in scale and level, with food environments focusing on sites of direct consumer access, while food systems encompass the broader interconnected network of activities and actors. This emphasis on scale and level, a core concern in geographical analysis, allows for a more nuanced understanding of how micro-level consumer decisions are shaped by and contribute to macro-level food system dynamics. By integrating geographical perspectives and food environments approaches, and by clarifying the concepts of drivers, outcomes, and feedbacks within food environment research, we can enhance our understanding of the complex interactions that shape food consumption and health outcomes, ultimately contributing to more effective interventions for a just and sustainable food future. With this conceptual clarity, the food environment lens helps bridge macro-level food system processes with broader interventions aimed at transforming food systems.

Discussion

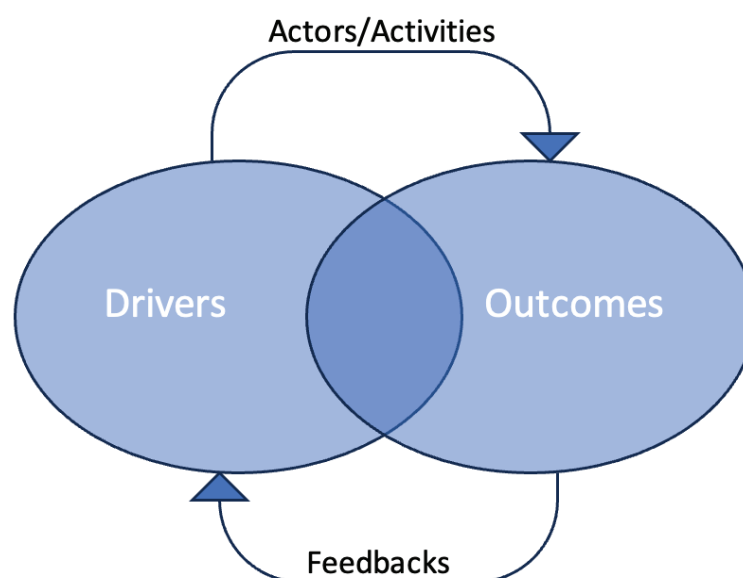
This paper has demonstrated the persistent ambiguity surrounding the core concepts of 'drivers,' 'outcomes,' and 'feedbacks' within food systems literature. Through a critical examination of existing frameworks and an interdisciplinary lens incorporating geographical insights and food environment studies, we have highlighted the inconsistencies that hinder effective communication, research, and intervention design. Table 2 resulting from our analysis, illustrates the intricate overlaps and divergences between these terms. For instance, a policy decision might act as a driver, leading to an outcome of altered market prices, which then feeds back into further policy adjustments. This demonstrates that the categorisation of these elements is often context-dependent and scale and level-sensitive. Determining when a driver is strictly a driver; when an outcome is an outcome, and when feedback is feedback requires a clear articulation of the system boundaries and scales under consideration.



Table 2. Designation and clarification of key food systems concepts and their relationship to each other.

Food System Element	Element in Context of System (in relation to other key elements)
Drivers	Drivers give rise to outcomes mediated by actors/activities within the system, across scales and levels. Drivers can be endogenous or exogenous to the food system.
Outcomes	Outcomes become drivers when they are mediated by feedbacks , which are subject to dynamics of the system across scales and levels. Outcomes can be endogenous or exogenous to the food system.
Feedbacks	Feedbacks are the mediator between outcomes and drivers . Feedbacks capture the dynamics of the system across scales and levels. Feedbacks can link endogenous or exogenous drivers and outcomes .
Actors/Activities	Actors (that undertake activities) are the mediators between drivers and outcomes . Actors can be human, non-human, or institutional and the activities they undertake are subject to drivers . Actors exist across levels and undertake activities across scales. These activities result in outcomes across scales. Food system actors are by definition endogenous to the system.

Figure 1. Simplified illustration of key food system terms and their relationships with each other.



The clarification of terminology is crucial for robustly analysing food system dynamics. While we acknowledge and value the diversity of descriptions and definitions, we propose that researchers explicitly define their use of these terms within each study. This ensures transparency and facilitates comparative analysis across different contexts and scales. By providing a theoretical basis for understanding food system dynamics and drawing upon relevant geographical literatures which have more robustly addressed challenges such as scope and scale, we can better contextualise the interactions between drivers, outcomes, and feedbacks, leading to more effective and targeted interventions. However, this call for clarity is not merely a technical exercise; it is also a political one.

The choices made in defining these terms and delineating system boundaries inevitably reflect particular worldviews and priorities, shaping the very understanding of food system problems and solutions. Recognizing this, we must approach the task of conceptual clarification with a critical awareness of the power dynamics inherent in knowledge production.

The synergy between food systems frameworks and geographical perspectives offers a powerful tool for understanding the dimensions of food system challenges relating to spatial, scale, and human-environment interactions. Geographical analysis, particularly through food environment studies, reveals how socio-spatial and spatially-relevant drivers and feedbacks shape food access, health outcomes, and environmental impacts, as well as the dynamics of the food system. By incorporating these factors and integrating the dynamics of systems, researchers and practitioners can better assess food system transformation interventions. The concept of embeddedness, central to geographical literature, aligns with the nested structure of food environments within broader food systems, emphasizing the importance of considering multi-scale and multi-level interactions. This integration allows for a more nuanced understanding of how local food consumption patterns are influenced by global drivers and how micro-level decisions contribute to macro-level outcomes.

Ultimately, developing a theoretical basis for sustainability transformations in food systems requires a rigorous and consistent application of these core concepts. This clarity enhances our ability to identify leverage points for change and design interventions that address the complex and interconnected challenges facing food systems. By explicitly defining drivers, outcomes, and feedbacks in relation to one another, and by integrating interdisciplinary insights, we can move towards more effective and equitable food system transformations. The 'so what' of this theoretical grounding lies in its potential to inform improved food system transformation processes, ensuring that interventions are grounded in a comprehensive understanding of the system's dynamics. Therefore, the pursuit of conceptual clarity must be accompanied by a critical reflection on the political implications of our analytical choices, ensuring that food system interventions are not only technically sound but also ethically informed and socially just.

Conclusion

Defining drivers, outcomes, and feedbacks with precision is essential for establishing robust metrics and monitoring progress towards food system transformation. The findings of this paper underscore the need for a more consistent and rigorous approach to these concepts, summarizing the inconsistencies and ambiguities present in current literature, and further supporting this by drawing on geography literatures. Returning to the key thesis of this study, which addresses the challenges posed by the special issue brief, we have demonstrated that conceptual clarity is paramount for effective food systems analysis.

However, this study has limitations. Our literature review, while comprehensive, may not have captured every nuanced definition or application of these terms. Furthermore, the complexity of food systems necessitates interdisciplinary and transdisciplinary approaches that extend beyond the scope of this paper. Future research should focus on developing standardised methodologies for defining and measuring drivers, outcomes, and feedbacks across diverse food system contexts.

The need for interdisciplinary collaboration is evident. Integrating geographical perspectives, food environment studies, and other relevant disciplines can provide a more holistic understanding of food system dynamics. Transdisciplinary approaches, involving stakeholders from various sectors, are also crucial for ensuring that research findings are translated into practical and effective interventions.

This paper serves as a call to action for food system scientists, policymakers, and practitioners to adopt a more rigorous and consistent approach to defining and analysing drivers, outcomes, and feedbacks. By doing so, we can enhance our understanding of food system dynamics and facilitate more effective interventions for achieving a just and sustainable food future. Ultimately, the clarity and consistency we advocate for will contribute to more impactful research, policy development, and practical actions that address the complex challenges facing global food systems.



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