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Time to transform? Sustainability narratives for European food systems

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ABSTRACT

The unsustainable nature of prevailing food systems contributes to drive humanity out of a safe operating space. Despite recognising the need for food systems transformation, its direction diverges into different sustainability narratives and conflicting objectives resulting in disjoint policy agendas and problem definitions. While few studies compared and identified gaps and trade-offs in food systems frameworks, systematic reviews for conceptualising sustainable food systems remain scarce. Focusing on the European context, we investigated how academics framed sustainability narratives and their role in advancing Sustainable Development Goals targets, exploring lock-ins and leverage points for food system transformation. By conducting a PRISMA systematic scoping review and analysing 94 documents, we found disparities in current research with socio-economic and cross-cutting aspects comparatively overlooked to environmental and health ones. Linking sustainability objectives to 55 SDG targets we demonstrated their potential contributions to sustainable development by addressing systemic conceptualisations and acknowledging trade-offs. We identified lack of vision and coordination among stakeholders and institutional framework shortcomings as barriers to change. Analysis of leverage points suggested stakeholder engagement and system transparency as pivotal for transformation. Last, we draw concrete implications for science and policy agendas to shape a food systems transformation grounded in a shared sustainability paradigm forged through collaborative efforts among scientific, policy, and societal domains.

1. Introduction

Advancing the United Nations Sustainable Development Goals (SDG) requires a transformation of food systems (Rockström et al., 2020). Indeed, the current food production and consumption patterns create complex sustainability challenges that are driving humanity out of a safe operating space (HLPE, 2020; SAPEA Science Advice for Policy by European Academies, 2020). These challenges include environmental degradation, food insecurity, socio-economic inequalities, and diet-related health problems (Moragues-Faus et al., 2017; Notarnicola et al., 2017; Penne and Goedemé, 2021; Yumuk et al., 2015).

Effectively addressing the wicked nature of those challenges requires integrated and systemic policy approaches. In 2015, the UN 2030 Agenda pursued to build a tangible sustainability agenda by proposing 17 goals with 169 targets and 233 indicators to advance the interconnectedness of sustainability and touching food systems from multiple perspectives (United Nations, 2015). Attempts to better operationalise such a global sustainable development framework even translated food systems into a transformational pathway through which multiple SDG can be effectively advanced in an integrated way (Sachs et al., 2019; TWI2050 - The World in 2050, 2018).

In Europe, the attempt to respond to cross-cutting societal challenges turned into systemic initiatives such as the European Green Deal (EGD) and its Farm to Fork Strategy (F2F) with the aim of strengthening the coherence in policy design, addressing those inconsistencies having accompanied the agricultural and food sectors for years (Brooks, 2014; Candel and Biesbroek, 2016; F. Galli et al., 2020; Matthews, 2008). Nonetheless, their effectiveness is challenged by food systems complex dynamics in which multiple actors are voluntarily and involuntarily involved and connected through composite relationships shaped by different social, environmental, and economic interests and goals, varying access to resources and diverging degrees of decision-making power (Díaz-Méndez and Lozano-Cabedo, 2020). Further, being food systems embedded in global trade patterns, these relationships encompass not only European but also global dynamics in which policy strategies can create spillover effects outside the EU political and territorial

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context (Fuchs et al., 2020).

Rooted in the agricultural and ecological sciences perspectives, the food system concept was introduced several decades ago (Getz and Gutierrez, 1982; Kneen, 1989) and evolved over time increasingly recognising its interactions with global environmental changes affecting societal outcomes (Ericksen, 2008) and its determinant role for achieving sustainable development (Rockström et al., 2016). First attempts to describe food systems concept date to 1994, when it is defined as "*the way human beings organize themselves across space and time to access and consume their food*" (Malassis, 1994). This definition has since evolved into more comprehensive descriptions, as the one provided by HLPE (2017) which describes food systems as: "*elements and activities that relate to the production, processing, distribution, preparation, consumption and disposal of food, and the outcomes of these activities, including nutritional, food security but also socio-economic and environmental outcomes*". Nonetheless, when defining the sustainability of these outcomes, the food systems narratives depend on the scale of analysis, actors' perspectives, and values (Allen, 2014; Béné et al., 2019a; Eakin et al., 2017; Kanter et al., 2018) resulting in a lack of a comprehensive and agreed-upon definition and conceptualisation of what should be considered 'sustainable'. This plurality of definitions reflects into incoherent policy agendas and hinders efforts to set concrete targets and action plans to operationalise terms such as 'resilient', 'safe' or 'inclusive' (Smaal et al., 2021).

Investigating diverse conceptualisations of food systems dynamics can contribute to prevent miscommunication, inaccurate problem identification (Kelly et al., 2019; Stock and Burton, 2011) and diverging agendas-setting (Kugelberg et al., 2021). The reinvigorated experts' interest in understanding sustainable food systems resulted in an increasing number of conceptual frameworks proposed by international organisations (Bock et al., 2022; SAPEA Science Advice for Policy by European Academies, 2020; Nguyen, 2018), experts' panels (HLPE, 2017; IPES-Food, 2019) and academics (Eakin et al., 2017; Hebinck et al., 2021; Kugelberg et al., 2021; Stefanovic et al., 2020; von Braun et al., 2021). Nonetheless, food systems conceptualisations tend to overlook the dynamics, encompassing feedback loops, nonlinear relationships, and time-dependent behaviours within the system, resulting in static narratives that could misrepresent their real complexity.

While Brouwer et al. (2020) compared different food systems frameworks emerging from grey literature, Zou et al. (2022) explored their gaps and limitations focusing on urban food systems. Béné et al. (2019a) explored how sustainability is included in food systems narratives linking to the questions of healthy diets and focusing on a time frame from 2000 to 2017. However, there still remains a necessity to conduct studies aimed at systematically explore how these sustainable food systems visions and conceptualisations emerge and reflect in academic literature, especially after the publication of UN Agenda 2030. Further, the existing literature lacks a recent thorough review of the existing academic knowledge that attempt to investigate multiple and systemic aspects of food system transformation existing in scientific documents (Table 1).

To fill this gap, this paper aims to understand how academic literature envisages possible systemic pathways for transitioning to sustainable food systems (SFS) in Europe after the UN Agenda 2030 (United Nations, 2015). By adopting a systematic scoping approach, it analyses how the academic literature addresses not only reported food systems sustainability objectives but also their intrinsic trade-offs. Then, it operationalises these outcomes: *a)* by analysing the transformative potential of these aspects in achieving SDG targets and *b)* by identifying the obstacles (lock-ins) and the multipliers (leverage points) that can hamper or boost this transformation. Ultimately, based on the findings of the analysis, it attempts to draw some science-policy implications to shape the food systems transformation.

This article is organised as follow. Section 2 provides the methodological background for the selection of eligible documents, content analysis and SDG mapping. Section 3 reports the sustainability objectives and trade-offs identified in the scientific documents' narratives, their contribution and interactions with SDG targets, and the lock-ins and leverage points for their achievement. Section 4 discusses results and limitations and lists potential implications for the science-policy agendas.

Table 1
Existing reviews addressing the conceptualisation of food system frameworks.

Author	Time horizon	Scope	Nr. of documents	Sources
Béné et al. (2019a)	2000–2017	To explore how sustainability is included in different food system narratives and the link to the question of healthy diets	More than 70	Science Direct, Google Scholar and Grey Literature
Brouwer et al. (2020)	2016–2019	To identify and compare differences in the frameworks used for food systems analysis, and discrepancies in the procedures to identify strategies for and performances of food system transformation	32	Grey Literature
Zou et al. (2022)	N.S.	To discover the current limitation in existing FS frameworks to enhance the development of a new FS/urban food system framework that can tackle the triple burdens of malnutrition and FS unsustainability	50	Web of Science
This review	2015 – 2023	To investigate how academic literature envisages sustainability objective, dynamics, and systemic pathways for transitioning to sustainable food systems	94	Scopus and Web of Science

Source: *Authors own elaboration*

2. Method

We employed a scoping review methodology, which is recognised for its systematic synthesis of diverse findings to address broad topics and has proved being effective for knowledge synthesis and policy contextualisation (Anderson et al., 2008; Tricco et al., 2018). Indeed, the breadth and heterogeneity of the investigated concepts, definitions and methods hinders a quantitative analysis of empirical findings, as well the quantitative assessment of the risk of bias, as in the case of systematic reviews and meta-analysis.

2.1. Search strategy and data sources

Adhering to PRISMA extension guidelines, the study adopts a systematic search on two of the most widely used scientific databases for bibliometric analysis (V.K. Singh et al., 2021) - Web of Science and Scopus databases-utilising the following keywords: 'sustainable food systems' or 'food systems' near 'sustainability' and 'concept*', 'element*', 'defin*' and 'framework'. Running searches in January 2023 and updating in January 2024, the review focuses on articles, reviews, book chapters and notes published post-2015, assuming increased relevance after the launch of the UN Agenda 2030 (United Nations, 2015).

2.2. Eligibility criteria and screening process

Obtained records were screened by two independent researchers, reviewing title and abstract for each publication with respect to the eligibility criteria (presented in Table 2), to ensure a consistent and topic-focused set of publications for the content analysis. The eligibility Criteria 1 was defined to narrow down the geographical scope to the European context, stemming on the consideration that food systems outside and within Europe may present different characteristics and dynamics. Secondly, the eligibility Criteria 2, 3 and 4 were defined to limit the analysis to studies that propose overarching and systemic approach to analyse different elements of sustainability, expanding to food systems related aspects, and identified transition pathways. Mendeley Reference Manager facilitated screening and data extraction processes. Documents that did not meet Criteria 1 and Criteria 2 or 3 or 4 were excluded.

Table 2
Inclusion and exclusion criteria for studies' eligibility.

Number	Inclusion	Exclusion
Criteria 1	***1a.*** Address the **European context** or include a case study in the European area (including Switzerland and the UK). ***1b.*** Address the conceptualisation of sustainable food systems **without targeting a specific geographical context** and without reporting results from a specific case study application	Address or include a case study outside the European context and area (excluding Switzerland and the UK)
Criteria 2 *OR* **Criteria 3** *OR* **Criteria 4**	**2.** Attempt to or propose a **framework to conceptualise food systems sustainability** by proposing an overarching and systemic approach (*e.g.,* SFS frameworks) and analysing different elements of sustainability Apply an integrated perspective **on food systems-related aspects** from different conceptual entry points: ***3a.*** Address the conceptualisation of **Alternative Food Networks (AFNs)** as the term covers emerging networks of food systems' actors that propose alternatives (concepts) to the standardised food supply ***3b.*** Address concepts related to **food system governance** (*e.g.,* food democracy) to address the institutional and political context governing food systems and their mechanisms and interconnectedness with the other elements of the systems ***3c.*** Address concepts related to elements affecting **food environments** (*e.g.,* physical, and economic access to food, food safety and quality) and food system **outcomes** (*e.g.,* healthy diets)[1] **4.** Analyse **transition pathways** towards food system sustainability advantaging from the sustainability transition science. This sub-criterion envisages the conceptualisation of barriers and solutions towards SFS	Address specific solutions or interventions (*e.g.,* insects, school canteens), methodological frameworks for sustainability assessments (LCA, indicators), specific food systems (*e.g.,* fisheries, livestock), elements of food systems (*e.g.,* soils, waters) or responses to external shocks (*e.g.,* wars, COVID-19)

1. As illustrated by the food system framewrks proposed by HLPE (2020).
Source*: Authors own elaboration*

2.3. Data extraction and content analysis

To systematically analyse the message characteristics in the documents, we performed a content analysis (Neuendorf, 2020).

2.3.1. Concepts coding

Based on frameworks grounded in food systems and sustainable diets conceptualisations (Ericksen, 2008; HLPE, 2017; Ingram, 2011) we extracted the individual text lines and coded qualitative data from the whole text of the eligible documents. The framework (Supplementary Materials*, Figure B*) captured bibliometric details, geographical scope, methodology and sustainability definitions. Secondly, it attempted to extract the sustainability objectives reported in academic literature, considering the food environment, the food system environmental, social and economic impacts, their nutritional and health outcomes and the synergies and trade-offs among these aspects.

Additionally, it coded information on lock-ins, and leverage points for food system transformation to identify transition pathways and potential feedback loops. Prior data extraction, we agreed on a glossary of terms' definitions for ensuring reproducibility and coherence (Supplementary Materials*, Table D*).

2.3.2. Concepts categorisation

Extracted text lines on food systems impacts, outcomes and environment were grouped in keywords and qualitatively clustered over dimensions and objectives of food system sustainability. Coherently with the paper's objective, this process followed a mixture of inductive, drawing on existing frameworks (Béné et al., 2019a; Bock et al., 2022), and deductive approaches, due to the divergence of values and interests that generated a lack of a shared vision in food systems domain. As the sustainability objectives identified entailed overlapping concepts, each text line was matched to multiple objectives.

On the other hand, an inductive approach was adopted for lock-ins classifications following the systematisation of Geels (2019), as it explains several dimensions of their mechanisms (Weituschat et al., 2022) and includes comprehensive groups that fitted the collected data. Further, we deepened the analysis by complementing lock-ins explanation with system failures classification following Woolthuis et al. (2005) and Weber and Rohracher (2012).

Further, identified solutions were qualitatively mapped to the 12 leverage points for system interventions proposed by Meadows (1997) and systematised by Abson et al. (2017) to identify possible entry points to intervene in different parts of a system (parameters, feedback, design and intent) and the transformational process needed to change the system. Building on this approach, each text line was univocally matched with a type of lock-in, system failure and leverage point.

Finally, having categorised the text lines, results were expressed as frequencies counting the number of scientific documents reporting the specific objectives, lock-in, failure and leverage point identified. Data extraction, coding and classification processes are detailed in the Supplementary Material I, Section 2.

2.4. Mapping of SDG target and interlinkages

We explored the transformative potential of sustainable food systems by qualitatively associating coded elements with the United Nations' 17 Sustainable Development Goals (SDG). Each SDG encompasses targets addressing social, economic, environmental, and governance dimensions, forming a comprehensive framework for global well-being planet (United Nations, 2015). Depending on the level of granularity of the coded elements, we associated one or multiple SDG targets to them.

Adopting an interlinkages perspective, the analysis draws from a database of over 23,724 records (Fronza et al., 2023) examining directed and undirected interlinkages, positive synergies, and negative trade-offs at the goal, target, and indicator levels. To the authors' knowledge, this is to date the most comprehensive database on SDG interactions, synthesising findings of 92 of studies that analysed and revealed interlinkages in various geographical contexts by applying a broad range of diverse methods on different analytical scales and governance levels. Based on the outcomes of the SDG mapping, interlinkages between associated SDG targets were extracted from the database to capture and better understand internal interactions between the system elements.

3. Results

Out of 579 initially identified documents, 94 studies meeting the inclusion criteria were integrated into the analysis (Supplementary Materials*, Figure A*).

3.1. Extent and range of the collected evidence

The database includes mainly scientific articles (n = 71) integrated with reviews (n = 12), book chapters (n = 10) and notes (n = 1). The database covered mainly the European area, while 36% of the studies investigate sustainability concepts without targeting a specific geographical area. Among the studies addressing the European context (n = 60), case studies focused mostly on Western (30%) and Southern Europe (12%), while less documents targeted specifically Northern (7%) and Central and Eastern (5%) Europe.

3.2. Nature of the collected evidence

Qualitative studies prevailed over quantitative ones. Indeed, almost half of the studies (n = 40) employed literature and content analysis to investigate concepts, while one third made use of qualitative methods such as structured and semi-structured interviews, focus groups, workshops (n = 18), and analysis of laws, policy, and strategies (n = 13). The number of studies employing quantitative methods (n = 7) was lower and includes footprinting and modelling approaches. Other methods included Multi-Criteria Decision-Making Analysis (MCDA) (n = 2), Socio-Ecological System (SES) frameworks (n = 2), foresight (n = 1), and participatory spatial planning assessment (n = 1).

3.3. How does the academic literature address the sustainability objectives for transforming EU food systems??

The scientific production trend of the selected studies proves the increasing efforts in investigating sustainable food system frameworks after 2015. The number of scientific documents produced increased steadily from 2015 to 2022 with the highest annual growth rate (+200%) in 2017 (Supplementary Materials*, Figure D*).

Only one-third (n = 32) of the studies examined in this analysis offer explicit definitions of the concepts under investigation. Consensus among scholars is relatively high regarding the definition of food security (n = 7) as established by the World Food Summit in 1996, and sustainable diets (n = 7) as defined by Lang (2012). Higher heterogeneity characterises the definition of sustainable food systems with nine studies reporting six distinct definitions of sustainable food systems. Among these, three studies reference the definition outlined by HLPE (2017). Indeed, there is a broader spectrum of perspectives evident in the literature, with eight studies reporting four different definitions for food systems cited as Ericksen (2008); Nguyen (2018), FAO (2014); HLPE (2017) that draw on other existing definitions (*e.g.,* HLPE, 2014; Ingram, 2011). Additionally, the discourse encompasses other terms connected to various aspects of the food systems sustainability such as 'sustainable bioeconomy systems', 'food governance', 'local food systems', 'alternative food networks', 'food justice', 'food democracy', and 'food sovereignty'.

Drawing on these definitions and investigating recurring narratives in the set of scientific documents, results show a pattern of disparities in the sustainability objectives addressed. Resulting from the deductive categorisation, the analysis identified 974 sustainability objectives in the narratives of the 94 studies, grouped into 32 categories, 9 subdimensions and 5 dimensions of sustainability, and across 5 studies' aims, coherently with the criteria outlined in Table 2. The heatmap (Fig. 1) illustrates the percentage of the 974 objectives occurring over 32 categories and 5 studies' aim, identified in the sustainability narratives of the 94 studies. Narratives related to the environmental management of natural resources and food environment prevail over socio-economic and cross-cutting (*e.g.,* democracy, sovereignty) aspects. Indeed, seven of these objectives recurred more frequently (more than 5%) and entail food security, quality and healthy diets delivery, protection and restoration of biodiversity, climate change mitigation and adaptation, management of natural resources use, and equity guarantee.

Despite different studies' objectives, the pattern showed in Fig. 1 replicates across the groups of scientific documents with slight differences in studies conceptualising Alternative Food Networks (AFN) and sustainable governance mechanisms. While narratives in food and nutrition studies remain concentrated around objectives that pursuit sustainable food environment and environmental aspects, guaranteeing food democracy was more frequently addressed (6%) in the set of objectives identified in AFN studies. On the other.

3.3.1. Trade-offs identified in the set of documents

Only a small number of these studies highlights trade-offs and synergies among the sustainability categories they identify. According to those studies, several trade-offs occur among food security and other sustainability aspects especially in terms of land use. Due to limited amount of land, conflicting objectives occur between biodiversity, bioenergy, and food production exacerbated by a potential shift to plant-based diets (Gjerris et al., 2016; Kopainsky et al., 2015; Moragues-Faus et al., 2017; Vicente-Vicente et al., 2021). Further, several studies point out the trade-off in reducing fertilisers and pesticides use which generate lower yields threatening food security and self-sufficiency (Béné et al., 2019a; Gjerris et al., 2016; Kopainsky et al., 2015).

Many of these studies illustrate how shifting to healthy diets generate further trade-offs among healthy food, affordability (*e.g.,* higher costs of diets) but also food safety (*e.g.,* nuts that could be rich in aflatoxins) and cultural acceptability (*e.g.,* cultural accepted diets with high number of calories) (Nicholls and Drewnowski, 2021; Pires et al., 2020). Also, while shifting to plant-based diets could significantly benefit human health and environmental sustainability, reducing meat consumption implies reducing high sources of high-quality protein (Pires et al., 2020) and renouncing the grazing benefits on biodiversity and threatening farmers livelihood (Cué Rio et al., 2022).

Not only environmental concerns incur in trade-offs, but authors also highlight the dilemma of supporting local economy or encouraging small producers (especially in low- and middle-income countries) to gain access to a profitable global market, which can risk imposing unfair trading rules (Boylan et al., 2020; Gjerris et al., 2016). Finally, the identified trade-offs concerned not only system goals but also conflicts among stakeholders' interests and values occurring in the food systems (F. Galli et al., 2020; Scaramuzzi et al., 2021).

3.4. Leveraging a sustainable food system transformation to advance the SDG

3.4.1. Sustainability objectives and SDG target

A transformational pathway towards a sustainable food system provides an operational perspective to advance multiple SDG in an integrated way. This is also emphasised by the numerous links between the sustainability objectives categories identified and the SDG targets of the 2030 Agenda (Fig. 2a). By having qualitatively mapped the 32

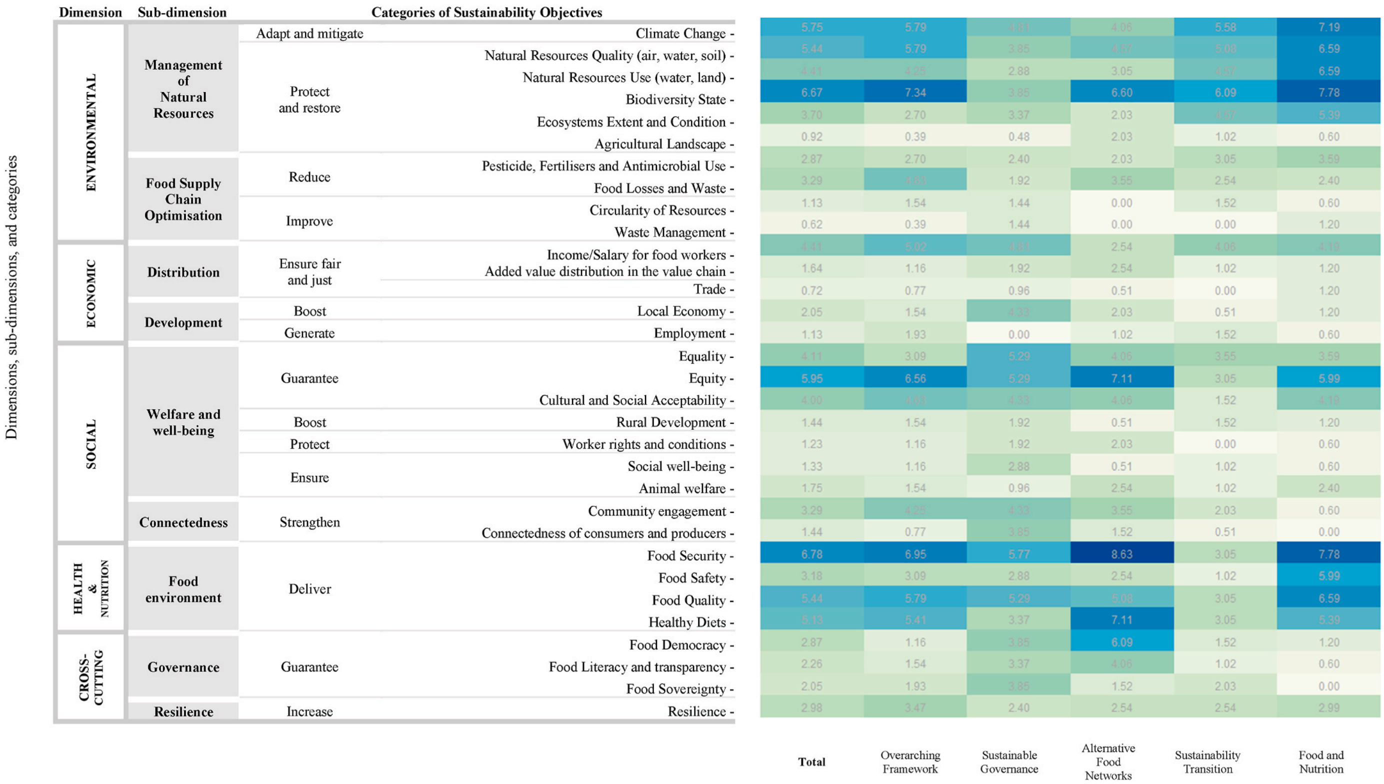

Fig. 1. The percentage of the 974 objectives over 32 categories and 5 studies' aim identified in the sustainability narratives of 94 studies through keywords clustering. The intensity of colours shows the frequency of the objectives across the sustainability categories and studies'aim (color should be used for this figure in print).

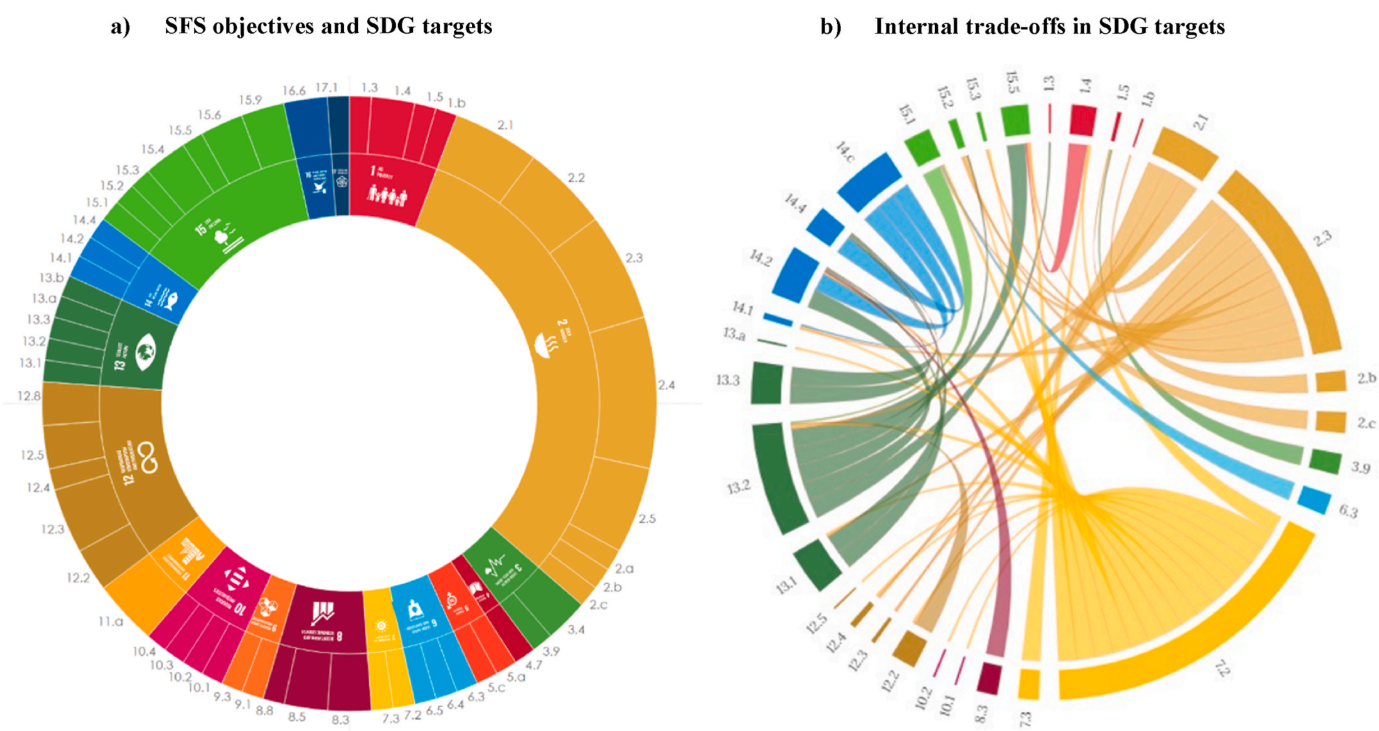

Fig. 2. (2a) Mapping of SDG goals and targets with the 32 objectives for sustainable food systems identified in the scoping review process. (2b) Trade-offs among identified targets as identified by literature (Fronza et al., 2023). The width of the arches indicates the number of targets connected to the 32 objectives and the number of trade-offs among them (color should be used for this figure in print).

sustainability objectives categories to SDG targets, the analysis led to 55 unique targets spanning across all 17 SDG and corresponding to major social, economic, and environmental aspects of sustainable development as envisioned in the 2030 Agenda. Results show that the sustainable food system conceptualisation presented alludes to aspects that are absent in the SDG framework, like animal welfare as well as cultural and social acceptability. SDG 2 on Zero Hunger emerged as the most frequently addressed goal with all its targets being linked to the sustainability objectives. Other frequently addressed goals are SDG 12 on sustainable production and consumption as well as SDG 15 on life on land, but also social (SDG 1 and 10) and economic (SDG 8) goals are well addressed (See *Table* L, *Supplementary Material I* for further details on the specific targets and sustainability objectives linked).

3.4.2. SDG interlinkages

While the numerous links with the SDG framework well reflect the multi-dimensional nature of a sustainable food system, its interconnectedness is strongly underlined when looking at the interlinkages between the associated SDG targets that correspond to the sustainability objectives (Fig. 2a).

Though most interactions tend to be positive, trade-offs need to be considered to carefully manage possible internal conflicts between different sustainable food system objectives when attempting to govern the transition. Capitalising on a database of SDG interlinkages (Fronza et al., 2023) and considering only directed interlinkages between SDG targets associated with the 32 sustainability objectives the analysis reveals a total of 615 relevant interlinkages between the selected SDG targets, out of which 534 interlinkages are considered positive and 81 negative links.

Fig. 2b focuses on the internal trade-offs between the selected SDG targets, highlighting targets belonging to SDG 2 (zero hunger), 7 (clean energy) and 13 (climate change) and environmental goals (14 on life below water, 15 on life on land) as main sources for trade-offs. Concrete examples concern for instance SDG target 7.2 on substantially increasing the share of renewable energy in the global energy mix and its potential negative implications for environmental targets like 15.5 on halting environmental degradation and biodiversity loss, 15.2 on sustainable forest management or 14.1 on marine pollution due to the expansion of renewable energy infrastructures and its possible impacts on the environment which indicates a possible area of friction between a sustainable food system's climate change and adaptation objectives and sustainable resource use and biodiversity protection objectives. Food security objectives as outlined in SDG target 2.3 which envisions a doubling in agricultural productivity may create trade-offs with many other SDG targets, particularly those related to environmental aspects like target 12.2 on sustainable natural resource management or target 15.3 on combatting soil and land degradation and to climate change objectives (*e.g.,* target 13.1 on strengthening climate resilience). These trade-offs also well-reflect and underline the trade-offs identified by the reviewed studies between the identified sustainability categories (*e.g.,* in the context of land use conflicts).

For what concerns synergies, many interlinkages emerge between SDG related to the environmental dimension, for instance between SDG 12 on sustainable production and consumption and SDG 13 and 15 and more specifically between target 12.2 on sustainable resource use and targets 13.1 and 13.2 or 12.8 on promoting and fostering sustainable lifestyles that positively interacts with targets under SDG 13, 14 and 15. When considering the number of interactions with other targets, target 13.1, 14.1, 14.2 (sustainable management and protection of marine ecosystems) as well as 15.5 and 7.2 emerge as those with the highest number of interlinkages (see Supplementary Material, Figure E for full matrix of interactions).

3.5. Which are the lock-ins impeding the transition to sustainable food system?

While enabling a food system transformation could lead to the achievement of multiple and interconnected goals, around 60% of the studies (n = 54) report the existence of self-reinforcing mechanisms that reproduce status quo (lock-ins) and impede the transition to sustainable food systems.

The nature of these lock-ins revealed multifaceted, hiding systemic failures not only at structural level due to inefficacies in formal and informal institutions, but also at transformational level where a lack of directionality for thefood system transformation impede change. Starting from the set of 54 studies reporting the lock-ins, we identified 103 barriers in the set of studies grouping them by nine types of failures (as identified by Weber and Rohracher (2012)). Fig. 3 shows the percentage of the 103 barriers over the nine types of failures grouped in transformational, structural and market failures. These failures originate at structural level due to the shortcomings of current institutional frameworks (22%) (*e.g.,* existence/absence of taxes, subsidies, or regulations) and due to the presence of closely tied networks (15%) that disconnect marginalised actors and reinforce reliance on dominant partners. The lack of physical and knowledge infrastructures (11%) and capabilities to adapt to new circumstances (4%) reinforces these mechanisms. While when transformation occur, the lack of a shared vision (27%) and the consequent policy coordination failures (12%) send conflicting and changing messages to food system actors, whose engagement result disadvantaged by the inability of system to monitor and involve actors in the process of self-governance (6%) and the deficit in anticipating actors' needs (1%). Market failures (3%) related to the externalisation of costs contribute to these failures by leading to innovation that damage the environment and the society.

The systems failures contribute to different extents to generate systemic lock-ins that impede food system transformation. Table 3 groups the nine types of systemic failures by 3 different types of lock-ins proposed by Geels (2019) by providing concrete textual examples from the set of analysed documents. Approximately 50% of the identified barriers, totalling over 103, pertain to institutional and political lock-ins stemming from prevailing regulations, standards, and policy networks. Roughly 30% are attributed to techno-economic lock-ins resulting from inefficient investments and established economies of scale, while the remaining 20% are associated with social-cognitive lock-ins linked to the attitudes, behaviours, and alignments within social groups.

3.6. Which are the leverage points and feedback loops that can boost the transition to sustainable food systems?

To unlock self-reinforcing mechanisms, changing the social structures and institutions governing food systems could leverage a shift to a systemic transformation. Starting from the set of studies reporting a solution for system transformation (n = 71), we have identified 146 solutions grouped by the 12 leverage points identified by Meadows (1997) placed in order of increasing effectiveness and systemic resistance (from 12 to 1) and the associated four system's characteristics identified by Abson et al. (2017). The bar plot in Fig. 4 illustrates the percentage frequency of 146 solutions over the 12 leverage points. Table 4 exemplifies and contextualises the leverage points for transformation in the food systems domain reporting solutions identified in the set of analysed papers.

The majority of solutions identified in the set of scientific documents leverage on changing the social structures and institutions that manage food systems interactions and parameters (design). These solutions include the restoring information flows and leveraging the power of system actors of changing and self-organising to achieve systemic change, which scientific studies recognize as a powerful solution, despite the high systemic resistance towards targeting this leverage point (*e.g.*, due to power relations dynamics). Solutions leveraging on

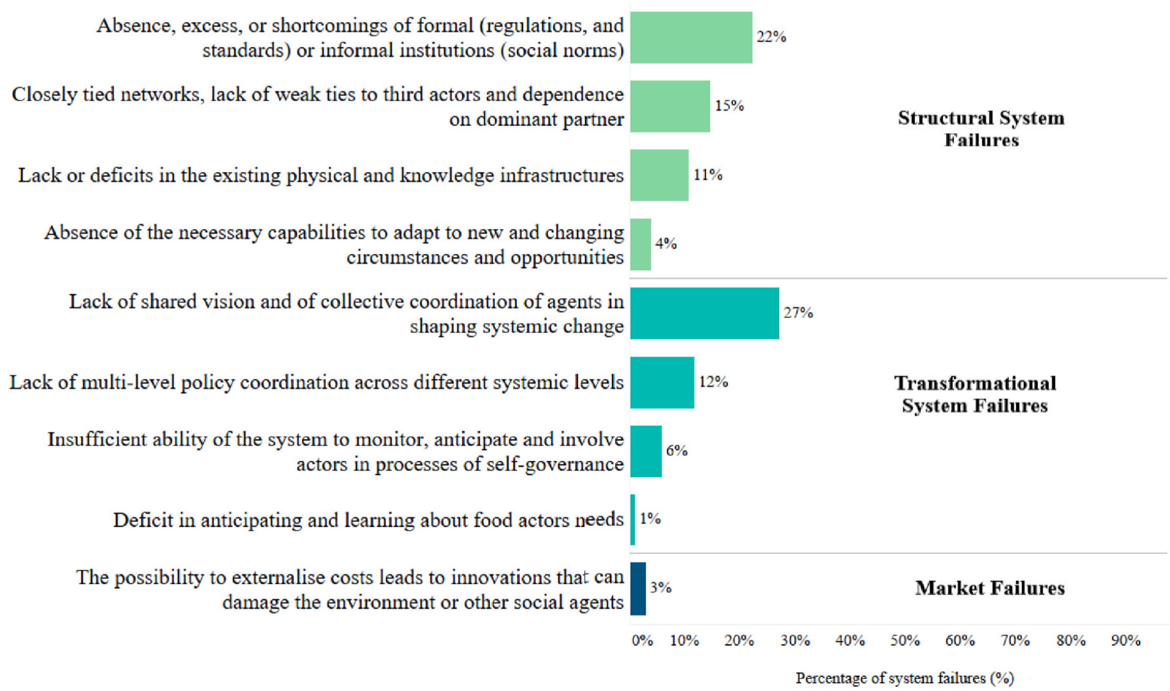

Fig. 3. Percentage of barriers market and structural and transformational system failures identified in the scientific documents. Based on Woolthuis et al. (2005) and Weber and Rohracher (2012) (color should be used for this figure in print). Source: *Authors own elaboration.*

self-organisation, the more frequently addressed in the set (31%), include stakeholders' engagement at multiple governance levels, multi-stakeholders' approach, proactive participation for reflexive and polycentric governance systems, democratisation of food system processes, creation of policy assemblages based on bottom-up approaches. Further, literature report knowledge exchange tools, education, awareness campaigns, labels, or certification and quality schemes (21%) as possible solutions to achieve systemic change by restructuring information flows.

In the set of documents, solutions targeting weaker leverage points tend to be less documented – presumably due to their lower potential for systemic change. Similarly, solutions targeting high leverage points with stronger potential for systemic change were also less documented – most likely due to the higher systemic resistance associated with targeting them which also makes it challenging to even identify, design and implement them effectively. In the first case, these solutions target the mechanistic and physical elements (*parameters*) of the systems (*e.g.,* taxes, infrastructures) and range from 3 to 5% of the whole set; in the second case, they target the underpinning values and goals of actors that shape the system orientation (*e.g.,* shift from the productivist paradigm, shift in beliefs) and range from 2 to 7% of the whole set.

Finally, solutions targeting the interactions occurring between the elements (*feedback*) within the systems show higher variability. Indeed, while the 12% of solutions identified leverage on acting on negative feedback loops (*e.g.,* monitoring frameworks or mechanisms of internalisation of externalities), none of the solution identified target the delays occurring between interventions and their effectiveness in the food systems (*e.g.,* plans for long-term agricultural practices).

4. Discussion

4.1. Summary of evidence

Although various academics attempted to investigate sustainability narratives in food system frameworks, this work represents a first attempt to provide a general overview on the status of academic research on food systems narratives, dynamics, and pathways for systemic transformation in Europe after the launch of Agenda (2030) by conducting a thorough review of academic studies.

Having identified 974 sustainability objectives in the narratives of 94 studies grouped into 32 categories, we found a pattern of disparities in the sustainability objectives addressed. In Europe, sustainability narratives in the academic field tend to focus on environmental, health and nutrition objectives while socio-economic, and crosscutting aspects related to food system governance remain marginal. This connects with the lack of indicators and data at global level on socio-economic (*e.g.*, welfare of food systems workers beyond agriculture) and governance aspects (*e.g.*, lack of indicators for policy coherence) evidenced by researchers (Schneider et al., 2023). This gap might suggest a possible discrepancy between the scientific agenda, shaped by reactions to negative impacts and externalities, and the political agenda, which struggles with socio-economic issues (*e.g.,* the recent protests and strikes of European farming communities). Indeed, as also underlined by Brouwer et al., (2020) who analysed 32 food systems frameworks in international studies, governance aspects and power dynamics between stakeholders tend to be overlooked, underscoring the necessity of systemic approaches that acknowledge and address the existence of competing networks with unequal resources and power (Canfield et al., 2021) in the complexity of food systems governance.

The potential contribution of these 32 sustainability categories to the achievement of 55 SDG targets further highlights the connection between scientific and political spheres. Since the adoption of the Agenda 2030 in 2015, we observed a significant increase in scientific output within food systems science and we identified 5 groups of diverse studies' aims (sustainable food systems frameworks, food system governance, sustainability transition, Alternative Food Networks, food and nutrition). These findings may suggest that the Agenda 2030 could have significantly stimulated scientific engagement with food systems research in Europe (*e.g.*, through a stronger integration of the SDGs into the Horizon Europe Framework Programme, the EU funding programme for research and innovation) and, conversely, that food systems science has contributed to shape policy agendas, as illustrated by the sustainability objectives identified in the studies and their connection to specific SDG targets. Further, this reinforces the crucial role that scientific advancements may play in accelerating the implementation of the

Table 3
Lock-ins mechanisms and associated failures based on Geels (2019), Woolthuis et al. (2005) and Weber and Rohracher (2012).

Lock-ins/System Failures			Examples	Source
Institutional/ Political (50)	**Structural**	**Institutional**	**Labelling, standards and regulatory barriers** (*e.g.,* seeds, safety regulations) marginalising small-scale producers; **Lack of monitoring and control** of measures effectiveness; Inefficacy of voluntary initiatives; Monitoring frameworks often **lack standardised indicators** covering the whole food system; **Lack of financial and temporal resources** for collaboration and **excessive bureaucracy**; **Historical regulatory frameworks** locking farmers in the dependency from retail and catering corporates and EU subsidies; Unfavourable trade policies (EU trade agreement with duty free protein based imports).	Anderson et al., 2019; Báldi et al., 2023; Baldy and Kruse, 2019; Blumberg et al., 2020; Cifuentes and Gugerell, 2021; Connolly et al., 2022; F. Galli et al., 2020; Gliessman et al., 2019; Jarzebowski et al., 2020; Kugelberg et al., 2021; Lang and Mason, 2018; Marsden et al., 2018; Scaramuzzi et al., 2021; Triboulet et al., 2019; Weituschat et al., 2022; Zawalińska et al., 2022
		Capabilities	**Capacity gaps** of the local institutions to implement their responsibility; **Lacking** progressive **dynamic change** in administration settings; **Slow adaptation** of institutions to new opportunities; Low institutional **capacity** to solve **wicked problems**;	A. Galli et al., 2020; Moragues-Faus et al., 2017; Säumel et al., 2022; Zawalińska et al., 2022
		Interaction/ Network	Local production and supply networks **are not integrated into the corporate food regime,** building relationships that depart from the **hegemonic socio-technical script** and its institutional framework;	Báldi et al., 2023; González De Molina and Lopez-Garcia, 2021; Scaramuzzi et al., 2021
	Transformational	**Policy Coordination**	**Sectorial policies** creating silos between different approaches and actor groups; EU and national policies sending **conflicting objectives** to promote health and to support sustainable development objectives; CAP income support logic (Pillar 1) in contrast to the provision of public good (Pillar 2); Exclusion of local food system and urban based initiatives from CAP support; **Lack of food policy councils** and urban food policy planning; **Lack of integration** among trade-offs of sustainability outcomes which hinder reflexive thinking among current and detrimental practices; **Lack of coordination** among municipal, national and European food security goals and actions.	Anderson et al., 2019; De Schutter et al., 2020; de Vries et al., 2021; de Vries et al., 2022123AD; Fesenfeld et al., 2023; A. Galli et al., 2020; F. Galli et al., 2020; Kennedy et al., 2020; Kugelberg et al., 2021; Minotti et al., 2022; Moragues-Faus et al., 2017; Moragues-Faus and Carroll, 2018; Säumel et al., 2022
		Directionality	Historic **focus on mass production** for food security (historic prioritisation of EU policies on cereals lead to marginalisation of legumes); Policies that tend to **support the status quo** of largely specialised, animal-based and export-oriented primary production; Unbalanced geometries of power inside the food chain and in the broader political spheres which **impose a dominant discourse on consumerism, free trade and neoliberalism**; Agenda setting of food security policies focuses **on quantity of production** and crops and less attention to food availability, access, utilisation and stability; The **lack of agreement over a shared vision** at the provincial level.	Biesbroek et al., 2023; Cué Rio et al., 2022; De Schutter et al., 2020; F. Galli et al., 2020; Kugelberg et al., 2021; Maughan et al., 2020; Minotti et al., 2022; Moragues-Faus et al., 2017; Moragues-Faus and Carroll, 2018; Säumel et al., 2022; Venn and Burbi, 2023; Weituschat et al., 2022; Zollet and Maharjan, 2021
		Reflexivity	The **heterogeneity of groups negatively affected** by dynamics in food systems (especially food workers, migrant labour, and the urban and rural poor) is **underrepresented** in policy processes.	Maughan et al., 2020; Minotti et al., 2022
Techno-economic (30)	**Market**	**Externalisation Costs**	**Nutrient rich food is costly than more energy dense ultra-processed food** with lower nutritional value; The intensification and specialisation efforts are linked to attempts to compensate falls in agricultural income and employment creating a disproportionate increase in the technical means of production and deterioration of the land's environmental quality and its associated resources.	Biesbroek et al., 2023; Fanzo et al., 2020; González De Molina and Lopez-Garcia, 2021
	Structural	**Institutional**	Lack of **subsidies** (previously effective); Investment on cereals and red meat (even if their supply exceeds the global need); Tools that aim to **sustainability performance** (*e.g.,* direct payments); Food **taxation only at national level** and contested; **Complexity of certification schemes** for organic product; Economic viability with **low financial incentives** (*e.g.,* lock-ins contracts); **Lack of public funds** invested for supporting the organisational structure; The dominant regime's interrelated **market incentives** and policies lock many farmers into individual path-dependencies towards large scale, high-external input dependent agriculture.	Anderson et al., 2019; Béné et al., 2019a; De Schutter et al., 2020; Díaz-Méndez and Lozano-Cabedo, 2020; F. Galli et al., 2020; Weituschat et al., 2022; Zawalińska et al., 2022
		Infrastructural	Lack/inadequacy of risk management tools; Vulnerabilities of food assistance systems; Poor access to standardisation and global value chains for small	Anderson et al., 2019; Boylan et al., 2020; Díaz-Méndez and Lozano-Cabedo, 2020; Fanzo et al., 2020; F. Galli et al., 2020; Gliessman et al., 2019;

(*continued on next page*)

Table 3 (*continued*)

Lock-ins/System Failures			Examples	Source
			farmers; Knowledge barriers (*e.g.,* unequal access to intellectual property); Weak infrastructure of farming or food systems; Lack of human capital (*e.g.,* skills required for a new technique); Cost of technology adoption, lack of IT and accountancy skills, lack of expertise in branding; Lack of knowledge on how persuading consumers to buy more nutritious food; **Agro-industrial monoculture systems** disrupting resource cycles, making farmers dependent on external inputs, undermining their knowledge and distancing consumers from agri-production.	Jarzebowski et al., 2020; Küchler and Herzig, 2021; Levidow, 2015; Weituschat et al., 2022; Zawalińska et al., 2022
		Interaction/ Network	**By imposing certain criteria** on the upstream part of the food chain (*e.g.,* homogeneity standards) **corporate retailers exclude** a significant part of the foods that are most **sustainably produced** and **force farmers to use more chemical inputs**; **Primary producers and manufacturers are put under commercial pressure** to reduce prices **by a highly concentrated retail sector,** which is expanding aggressively. **Power of corporations** is now deeply embedded in the debt cycle that locks in farmers and governments to vicious cycles of debt, chemical dependence, and unequal diets.	Biesbroek et al., 2023; Bui et al., 2019; Gliessman et al., 2019; Paloviita, 2017
	Transformational	**Directionality**	Lack of agricultural production diversity due to **region's focus on monocultural livestock production**; Retailers want to manage local food production as a **niche market** separated from the conventional supply chain and favour the reproduction of the incumbent system. 'Bioeconomy' and 'sustainable intensification' **agendas reinforce corporate power** to extract more market value from agri-food value chains.	Bui et al., 2019; Díaz-Méndez and Lozano-Cabedo, 2020; Levidow, 2015; Moragues-Faus and Carroll, 2018
		Demand articulation	**Expensive for consumers** as exclude less affluent consumers and, as consequence, these SFSCs may remain **niches** in the food market.	Vittersø et al. (2019)
Social/ Cognitive (23)	**Structural**	**Interaction/ Network**	Dichotomy between corporate industry and local/trans-local alternative food networks create **fragmented food landscapes**; Marginalisation of Food Self-Provisioning in the research debate respect to Alternative Food Networks which are the dominant narrative in Western Europe (mostly accessible for privileged groups); **Individualistic**, **self-enhancing orientation**; Lack of **transparency** (especially from retailers food industry and restaurateurs); Lack of **trust** due to failed past cooperative experiences and difficulties in maintaining the **actors' engagement** with the biodistrict's goals.	Anderson et al., 2019; Cifuentes and Gugerell, 2021; Daněk et al., 2022; Goszczyński, 2020; Marsden et al., 2018; Moragues-Faus et al., 2017; Scaramuzzi et al., 2021
	Transformational	**Directionality**	Lack of appropriate **knowledge** and **information** due to constantly **changing and conflicting discourses** on sustainable consumption; Divergences of actors opinion on legitimacy to participate in the process and credibility (*e.g.,* presence of hidden goals or values); Alternative Food Organisations are not united **under common and transformative goals** and share a common understanding of sustainability, **foster citizens' confusion** about what to do in light of the multiple challenges that they face; **Consumers** may in these instances face a **normative dilemma between** the ethical issue of "fair price" and the moral issue of acting economically sensible	Baldy and Kruse, 2019; Daněk et al., 2022; de Vries et al., 2022; Díaz-Méndez and Lozano-Cabedo, 2020; Fanzo et al., 2020; F. Galli et al., 2020; Gjerris et al., 2016; González and Lorenzini, 2021; Goszczyński, 2020; Moragues-Faus et al., 2017; Vittersø et al., 2019
		Reflexivity	Dominant regimes **ignore** the roles, **knowledge** and **perspectives** of **women and marginalised actors** in rural communities; Discursive frames on high-tech or reductionistic approaches that **trivialise smallholders**; **Separation of consumers/citizens from nature** that discourages positive attitude and emotions towards the environment and creates a cycle of disaffection; Lack of knowledge about the local food system that **hinders actors from participating in transformation processes.**	Anderson et al., 2019; Báldi et al., 2023; Baldy and Kruse, 2019; Mehrabi et al., 2022

Agenda 2030; Herrero et al. (2021), as well as the relevance played by current and future Science Policy Interfaces (SPIs) (*e.g.*, HLPE, IPCC) and political initiatives mobilizing science (*e.g.*, UNFSS) in advancing food systems transformation, as highlighted by B.K. Singh et al. (2021).

The analysis of interlinkages highlights 81 negative links among the 55 SDG targets identified confirming that fostering sustainable food systems transformation requires a careful analysis of systemic trade-offs, competing objectives, and conflicting values and interests in food systems actors, as highlighted by other scholars (Béné et al., 2019b; Brouwer et al., 2020; Herrero et al., 2021). We found that most trade-offs occur in advancing SDG 2 (zero hunger), SDG 7 (clean energy) and SDG 13 (climate change), as also shown by potential incoherences

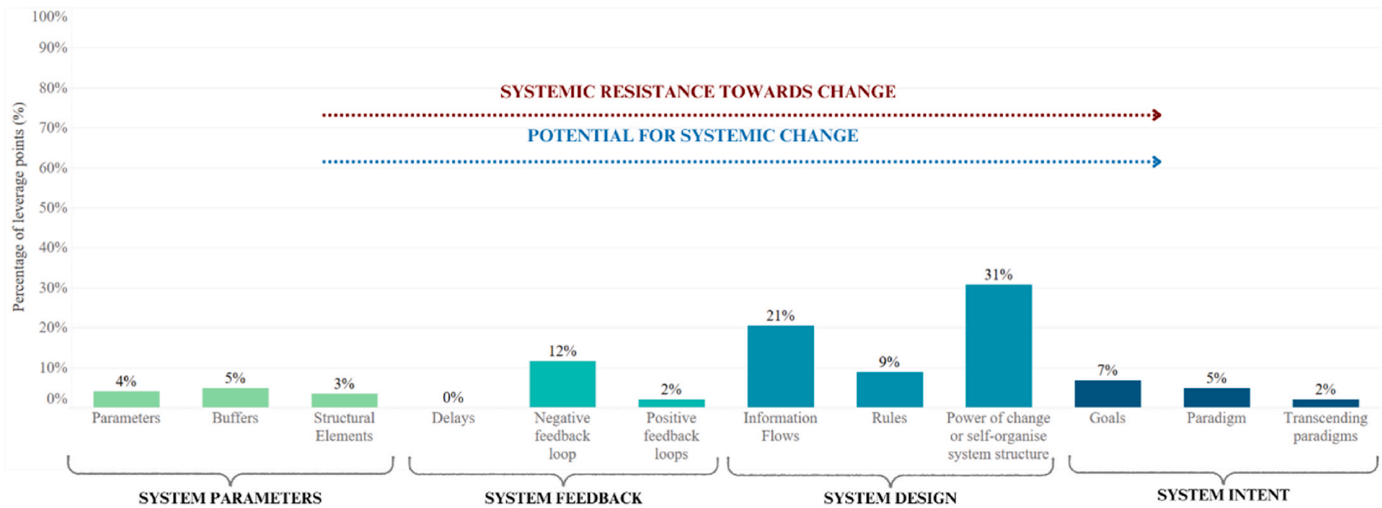

Fig. 4. Percentage of solutions identified in the database mapped against 12 leverage points for systemic change (from 1 to 12). The arrows show leverage points placed in increasing order of effectiveness (Blue arrow) and increasing order of resistance (Red arrow) in changing the system. Based on Abson et al. (2017) and Meadows (1997) (color should be used for this figure in print). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Leverage Points description and examples extracted from the database. Based on Abson et al. (2017) and Meadows (1997).

Characteristics	Leverage Points	Examples
INTENT	1. The power to **transcend paradigms**	Self-transcending sustainability, ethical system changes, shift in values and beliefs;
	2. The mindset or **paradigm** out of which the system arises	Shift from corporate-environmental food regime, 'food as a common';
	3. The **goals** of the system	Common food policy, shift to a food system perspective;
DESIGN	4. The power to add, change, evolve, or **self-organise** system structure	Multistakeholder engagement in food governance, reflexive governance;
	5. The **rules** of the system	Food public procurement strategies and programmes, legal frameworks;
	6. The structure **of information flows**	Labels, certification, education and awareness campaigns, knowledge exchange tools;
FEEDBACK	7. The gain around driving **positive feedback loops**	Sustainability rewards, investments, or progress income taxes to boost or slow multiplier effect;
	8. The strength of **negative feedback loops**, relative to the impacts they are trying to correct against	Evaluation and Monitoring frameworks, mechanisms for externalities internalisation;
	9. The lengths of **delays**, relative to the rate of system change	Plan for long-term sustainable agricultural practices;
PARAMETERS	10. The **structure** of material stocks and flows	Regional food hubs, alternative distribution chains, infrastructures;
	11. The sizes of **buffers** and other stabilising stocks, relative to their flows.	Crop diversification to increase system resilience;
	12. Constants, **parameters**, numbers	Market-based (taxes) or command and controls instruments (standards).

Source: *Authors own elaboration*

existing between current EU environmental policies (*e.g.,* Water Framework Directive, Nitrates Directive) and policy frameworks that promote large-scale commodity production (*e.g.,* CAP or biofuel incentives under Renewable Energy Directive) (IPES-Food, 2019) highlighting areas of improvement to promote better policy integration in the food system domain (OECD, 2021).

Our investigation of major barriers hampering food systems transformation pointed to 103 barriers hindering transformative change that we categorised into three main types of lock-ins (according to Geels (2019) further discussed below:

- *Institutional/political lock-ins.* Half of the studies report how ineffective institutional frameworks, policy networks and vested interests reinforce the status quo and impede food system transformation. The studies reported that these structural lock-ins are attributed to ineffective institutional frameworks, lack of policy coordination and directionality that leads to a lack of a common vision at institutional level. Hence, academic studies highlight the great potential residing in re-designing EU current policy instruments and institutional frameworks. For instance, several scholars argue that existing EU schemes lack sufficient incentives for a shift towards more sustainable production and consumption patterns (Kortleve et al., 2024; Pe'er et al., 2020). Indeed, while agricultural subsidies have become progressively decoupled from production, a substantial portion still takes the form of commodity-specific support measures through direct coupling or market price support (Springmann and Freund, 2022). Research suggests that repurposing these subsidies within Europe to align with environmental and health goals, by supporting sustainable production and consumption practices and acknowledging the potential trade-offs associated with different repurposing options, could significantly contribute to the transition towards sustainable food systems (FAO; UNDP and UNEP, 2021; Gautam et al., 2019).
- *Techno-economic lock-ins.* The ineffective institutional frameworks identified in the set of documents, the weak physical and knowledge infrastructures, and the market power dynamics further create barriers for food systems transformation driven by sunk investments in R&D and dominance of low costs and high-performance technologies (*e.g.,* due to ignorance of externalities). Scholars report how grassroots and social innovations (*e.g.,* alternative food networks) remain a niche in the market separated from conventional supply chains (Vittersø et al., 2019) which are shaped by corporate retailers' power. This gap highlights the need of incentives and investment in innovation (*e.g.* by introducing new support schemes as shown in Gautam et al. (2019)) by ensuring financial support and knowledge access to climate-smart or social innovations (Dinesh et al., 2021) as

well to propose new business models and strategies for sustainable food systems (Long et al., 2018) that target and reshape current power relationships and dynamics.

- *Social-cognitive lock-ins.* Only 23 barriers report that routines, mindset, and social groups alignments and lifestyles impede food systems transformation due to interaction failures (*e.g.*, fragmented foodscapes), directionality failures (*e.g.*, consumers' confusion about sustainability choices), and to the marginalisation of certain social groups in food systems policy. The emphasis on techno-economic and political drivers in existing studies suggests a need for increased attention to the behavioural aspects influencing, for instance, dietary choices (Higgs, 2015; Hoek et al., 2017) or household food waste (Vittuari et al., 2023), as their integration can provide a more comprehensive understanding of the factors that facilitate or hinder the transition towards sustainable food systems also at individual level.

These findings are consistent with those from similar systematic reviews. For example, Conti et al. (2021) conducted a review of 122 scientific documents to explore lock-ins that generate resistance to change within agri-food systems. Their analysis identifies several major barriers occurring due to shifts in directionality, including the entrenched nature of dominant technologies, institutional and policy frameworks that design inefficient incentives, attitudes and cultures resistant to change, existing power dynamics influencing the political economy of food systems, and misaligned sustainability narratives in the research agenda.

Having integrated the identified potential solutions for food system transformation into a framework of system intervention, our analysis identified 146 potential leverage points with varying transformational potential and systemic resistance. They encompass strategies for creating new social structures and behaviours (*e.g.*, democratising food systems and fostering reflexive governance), enhancing information transparency, implementing effective monitoring frameworks, and developing new legal structures. While policymakers tend to target shallow leverage points like food systems' stock and flow structures or parameters of different food system elements (*e.g.*, taxes, regulations) (Abson et al., 2017), the research agenda acknowledges the potential impacts of altering social structures and institutions that govern food systems and the interactions among elements that drive internal dynamics (*system design*) to rebuild assemblages embedded in a more reflexive governance configuration (Marsden et al., 2018). Nonetheless, the success of these reconfigurations depends on and results from power relationship dynamics in policy arrangements. Harnessing feedback loops to drive change in system's behaviour is another powerful intervention area where solutions can be deployed to foster a food system transformation like well-designed subsidies incentivising sustainable agricultural practices (Gautam et al., 2019). On the other hand, higher leverage points that could address the underlying values, goals, and perspectives of actors shaping the direction of food systems (*system intent)* are less frequently reported. This indicates that the research agenda is not adequately focused on challenging the current paradigms underpinning European food production and consumption (Béné, 2022; Jackson et al., 2021). Nonetheless, changes in parameters (*e.g.*, agri-environmental payments) or feedback mechanisms (*e.g.*, true price labels) may induce a shift in the mindset of food system actors and contribute to targeting higher leverage points. This highlights the need for further exploration of the interactions between different types of solutions at various systemic levels to implement effective combinations of interventions as the interplay between systemic resistance and potential for change associated with targeting different leverage points suggests that a well-balanced mix of solutions targeting different system parts and leverage points might be the most effective approach for fostering a food system transformation (Abson et al., 2017).

4.2. Limits and strengths of current research

Although scoping reviews inherently accommodate diverse study designs (Tricco et al., 2018), we acknowledge the qualitative nature of the investigated topic as a potential limitation to the reproducibility of the selection process, emphasizing the need for nuanced consideration in interpreting the findings. However, we considered the heterogeneity of the methods employed in the scientific documents analysed and their qualitative nature as enriching sources for our analysis, even if we acknowledge the weaknesses and limitations of such an approach.

The complexity and the wider systemic nature of the topic overlooked the granularity and the context specific characteristics of the diverse food systems across Europe, including the stakeholders' interaction in those systems. For instance, the interlinkages dataset (Fronza et al., 2023) contained scientific documents identifying synergies and trade-offs through different methodologies and in different geographic contexts (also outside Europe). Also, the numerous links between targets indicate some level of ambiguity in the type of interaction (either positive or negative) underlining the importance to contextualise interlinkages within the specific scope and context of such an analysis. Nonetheless, the sheer number of interlinkages emphasizes the strong interconnectedness of the SDG framework in general, but also of the food system elements, which articulates a high degree of complexity for sustainable food system governance.

Despite the benefit of integrating a stronger systemic perspective through the notion of leverage points for system intervention, we acknowledge the potential biases and imperfection of this mapping due to its qualitative nature. Further, as the results are based on an analysis of scientific literature, findings interpretation should consider that academic research may overlook certain processes within food systems and may not necessarily or accurately reflect their effective processes and dynamics.

4.3. Science-policy implications

The analysis highlights the complexity inherent in food system governance, the divergent visions, values, and interests of stakeholders, and the inherently wicked nature of sustainability challenges. These factors collectively underscore the significant difficulty faced by food systems in converging on a unified vision and set of objectives. However, the findings and discussions derived from our analysis provide several key implications for both scientific research and policy agendas:

a. *Understanding and strengthening the role of Science Policy Interfaces (SPIs) in shaping food system transformation.* The analysis of scientific literature and its alignment with Agenda 2030 illustrates how the scientific and policy agendas may have affected each other in shaping their respective pathways after 2015 showing not only the pivotal role that SPIs may play in the food systems transformation, but also the role of science in shaping and framing sustainability narratives that can contribute to achieving multiple interconnected sustainability objectives (Fig. 2a). The new science-policy reconfigurations explicated in the *United Nations Food Systems Summit* (*UNFSS*) organised by UN Secretary General in which the weight given to the Scientific Group and the multi-stakeholder structure were considered unprecedented compared to other summits. The UNFSS can be considered a powerful accelerator for science-policy agendas, nonetheless, understanding the possible impacts of such an initiative and the role of power configuration in its governance architecture remains essential to achieve the food systems transformation (Canfield et al., 2021).
b. *Promote policy coherence in the food systems domain.* Our analysis highlights significant trade-offs in achieving the Agenda 2030 goals (Fig. 2b), underscoring the necessity for systemic policy approaches in Europe. These approaches must recognize the synergies and trade-offs among various policy areas, as well as the diverse values and

perspectives of food system stakeholders that influence political priorities. Over the past decade, the scientific agenda has prioritised environmental and nutritional challenges (as depicted in Fig. 1) while in the policy arena, more systemic approaches, such as the Farm to Fork strategy, have emerged, in which an increasing influence of environmental agencies and climate activists occurred. This shift has led to discontent among farmers (Matthews, 2024), further emphasizing the need to consider the side effects of food system transitions and to design political strategies that mitigate potential negative impacts of new policy configurations in Europe across all sustainability dimensions equally.

c. *Re-design policy instruments for a common objective.* To overcome the diverse types of lock-ins that impede food system transformation, new policy mixes and strategic toolkits are essential. This necessitates revisiting and repurposing some detrimental policy instruments currently in place (OECD, 2021), mobilizing multiple innovations across different sectors and stakeholders, and understanding the socio-cultural drivers that influence actors' behaviour in the food environments. Furthermore, implementing 'mission-oriented policies' (Mazzucato, 2018) for food system transition can be an effective approach to achieve a common policy goal. This involves exploring inclusive narratives that reconcile various values towards shared objectives (*e.g.*, One Health approach).

d. *Co-create a more inclusive and participative governance style.* Greater emphasis should be placed on the role of European society in the transformation of the food system. Changes in social structures and behaviours are influencing European food policy, with consumers increasingly engaging in citizenship through their consumption choices and the growing prevalence of Alternative Food Networks movements contributing to urban food policy agendas (Petruzzelli et al., 2023). Societal efforts to shape EU food policies are evidenced by the scientific agenda's recognition of these structures (Fig. 4) as crucial leverage points for altering the underlying paradigms of production and consumption. These efforts open new avenues for establishing effective and inclusive science-policy-society interfaces (SPSIs). These interfaces facilitate stakeholder dialogues and participation, increase transparency and knowledge access, ensure the availability of robust data, and enhance the participation of traditionally excluded groups (European Commission, Directorate-General for Research and Innovation, 2022; van den Hove, 2007). In this context, participation needs to move beyond the usual information and consultation processes towards co-ownership that will eventually also challenge existing power relationships and asymmetries.

5. Concluding remarks

In this study we reviewed how academic studies envisaged possible systemic pathways for transitioning to sustainable food systems in Europe post-Agenda 2030. By identifying 974 sustainability objectives across 94 studies, we first showed that scientific agenda focuses on environmental, health, and nutrition goals, while comparatively overlooks socio-economic and governance aspects, emphasizing the need for systemic approaches to handle governance and power dynamics that affect food systems actors. Further, we linked sustainability categories to 55 SDG targets revealing sources of major trade-offs in the achievement of sustainable food systems and illustrating potential entry points to promote better policy coherence. Future research should be focused on contextualising these synergies and trade-offs at local level to promote granular horizontal and vertical integration of European food policies.

We investigated how food system science mainly identifies institutional/political barriers as hampering factors to achieve food system sustainability, while less studies document techno-economic and behavioural drivers that can thrive the food system transformation. Among these barriers the lack of a shared vision and collective coordination, exacerbated by ineffective institutional frameworks are the most cited impediments in scientific studies. When identifying potential leverage points for transformation, our analysis illustrates that scientific studies emphasizes the role of changing system design (*e.g.*, social structures, information flows), and system feedback (*e.g.*, negative feedback loop) as well the importance of exploring interactions between solutions at various systemic levels to identify combinations that can foster sustainable food systems transformation.

Finally, we argued how these findings illustrate the increasing mutual influence of science and policy agendas after 2015 highlighting the crucial role of SPIs in advancing food system transformation towards common global sustainability goals. Nonetheless, while scientific sustainability narratives tend to focus on environmental and health externalities, food systems governance face complex challenges due to diverging interests, goals and degrees of decision-making power impeding the construction of a common vision towards a sustainable food system and generating conflicts in food system domain (e.g, as shown by the recent farmers protests). Establishing a common vision allows to repurpose existing policy instruments (*e.g.*, subsidies) while designing new policy mixes that could tackle lack of innovations and social/cognitive drivers of food consumption.

Finally, the emphasis on higher leverage points illustrates an increasing effort of academic studies in recognising the powerful role of changing underlying social structures in food systems domain. Although power asymmetries may challenge their effectiveness, these bottom-up policy reconfiguration (*e.g.*, AFN) could leverage a significant systemic change and illustrate the potential impact of co-designing more inclusive and participative governance in European food policy. Hence, although this work attempted to systematise food system research in system thinking perspectives further studies are needed to explore the effects of food system interventions at different systemic level as well the factors affecting their power to change and challenge underpinning food systems paradigm.

CRediT authorship contribution statement

V. Guerrieri: Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **S. Borchardt:** Writing – original draft, Visualization, Validation, Methodology, Conceptualization. **G. Listorti:** Writing – review & editing, Validation, Supervision, Conceptualization. **L. Marelli:** Writing – review & editing, Validation, Supervision, Conceptualization. **M. Vittuari:** Writing – review & editing, Validation, Supervision, Resources, 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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gfs.2025.100831.

Data availability

Data will be made available on request.

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