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Beyond Governance Silos: Socio-Ecological Indicators for Assessing Sustainable Urban Food Systems

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Abstract

Urban food systems are central to addressing today's sustainability challenges. However, their assessment remains fragmented and often detached from broader urban dynamics, limiting the development of integrated approaches to urban food governance. This article advances these efforts by developing a comprehensive indicator set for diagnosing and evaluating urban food systems, grounded in a socio-ecological urban food systems framework that conceptualizes food systems as complex urban systems. The indicator set was developed through a combination of top-down and bottom-up methods. First, a systematic review identified potential indicators from existing urban sustainability and food assessment tools. Second, an applicability test in five cities assessed data availability and feasibility. Third, a modified Delphi process with experts validated the proposed indicators. The process yielded a set of 98 indicators, including 68 core and 30 aspirational indicators, which capture both food-specific and broader urban conditions such as governance, justice, health, and infrastructure. The proposed framework advances existing approaches by offering an indicator-based tool that integrates food and non-food dynamics to elevate the importance of food within urban sustainability, two critical areas to inform a post-2030 sustainability agenda. It complements and strengthens ongoing initiatives with the potential to enable benchmarking, comparability, and embedding of food system considerations within wider urban governance strategies. In doing so, it supports municipalities and actors in recognizing the reciprocal relationship between food and broader urban sustainability agendas, thereby avoiding the creation of a new urban food silo and strengthening pathways toward more resilient, equitable, and sustainable urban food governance.

Keywords
cities; food; indicator set; socio-ecological assessment; urban food governance; urban sustainability; urban systems

1. Introduction

Cities are at the forefront of sustainability challenges and solutions (Angelo & Wachsmuth, 2020). For decades, cities have claimed a role in food systems transformation, as exemplified by the expanding Milan Urban Food Policy Pact (MUFPP), a commitment to developing sustainable, inclusive, resilient, safe, and diverse food systems, now signed by 330 city mayors. In 2025, the Committee on World Food Security of the UN approved policy recommendations to strengthen urban and peri-urban food systems (Committee on World Food Security, 2025), thereby providing global and national recognition of the key role of urban and peri-urban areas in delivering sustainability and food security outcomes.

Despite progress, situating and maintaining the food mandate within urban agendas and developing truly integrated urban food policies remains challenging. Analyses of specific policies point to continuing disconnects across sectors and policy areas (Doernberg et al., 2019; Sibbing et al., 2019), insufficient participation of key actors (Sonnino et al., 2019), weak mechanisms for coherence across governance scales (Parsons & Hawkes, 2019), and a broader failure to assess the material effects of such integrated policies on urban food system challenges, including food insecurity (Moragues-Faus & Battersby, 2021).

Simultaneously, cities have been sidelined in defining global goals, such as the SDGs, whose indicators are geared towards the national level, with only SDG 11 dedicated to cities, thereby obscuring the actual capacities of urban areas to advance multiple sustainability targets simultaneously (Bai, 2024), including food. With fewer than 20% of targets on track for achievement by 2030 (UN, 2020), discussions on the post-2030 agenda increasingly highlight the need for more systematic and systemic approaches that recognize the role of cities as well as the interdependence of social and environmental goals (Rockström et al., 2025), echoing broader calls to conceptualize cities as complex socio-ecological systems (McPhearson et al., 2022).

In this context, recent contributions call for better integration of the urban condition into urban food systems assessments and interventions, as well as better capture of urban food socio-ecological dynamics (High Level Panel of Experts [HLPE], 2024). However, the urbanization and ecologization of urban food system frameworks remain limited in theory and practice, constituting a significant gap that constrains effective responses to the interconnected sustainability challenges facing both cities and food systems (Moragues-Faus et al., 2026). This lack of operationalization can lead to partial food diagnoses and interventions that obscure the actual diversity of cities and limit the prioritization of critical interventions over decontextualized, blanket solutions.

To address this gap, this study aims to operationalize the recently proposed socio-ecological urban food systems (SUFOS) framework by Moragues-Faus et al. (2026), based on a synthesis of indicators for measuring urban sustainability conditions and assessing urban food systems. The SUFOS framework conceptualizes urban food systems as shaped by the dynamic interaction of four interconnected subsystems—social-ecological dynamics, urban infrastructure and form, networked resource flows, and governance dynamics—thereby placing ecological, political, and urban relations at the center of analysis. Based on this premise, the indicator set constitutes an expansion of current efforts focused on food-related indicators to embrace other elements that are usually considered important but rarely measured and analyzed as shaping urban food dynamics. This includes urban infrastructures (LOGIC Africa Team et al., 2024) and other urban subsystems, such as transport, energy, and housing (HLPE, 2024). A significant contribution of this framework is thus the operationalization and characterization of urban socio-ecological dynamics that affect urban food systems, whilst supporting the measurement of progress in addressing urban food system challenges.

The article is structured as follows. It begins with a literature review of the role of indicators in assessment frameworks for urban sustainability and urban food systems, suggesting a more reflexive understanding of indicator-based approaches as active instruments in shaping policy agendas, problem framing, and intervention pathways, as adopted in this study. The following section outlines the SUFOS framework as the conceptual framework for developing the indicator set and the methods utilized. This section is followed by the results, with the discussion situating these findings within the broader literature and policy debates on sustainability indicators and urban food governance. The article concludes by summarizing the main contributions and outlining key implications.

2. Indicator-Based Assessment Frameworks

Since the 2015 launch of the MUFPP, multiple frameworks have emerged to assess urban food system sustainability and inform policymaking. These range from practice-oriented systemic tools, such as FAO's MUFPP monitoring framework (Carey & Cook, 2021) and the City Region Food System Indicator Framework (Carey & Dubbeling, 2017), to academically grounded, action-oriented contributions (Moragues-Faus & Marceau, 2019). While varying in scope and design, these assessment frameworks converge around a sustainability indicator-based logic that is adaptable to diverse local contexts.

In the context of sustainability, indicators are operational representations that provide information on the state of a system and its evolution over time, forewarning the breach of critical thresholds and helping monitor the success of (policy) interventions (González-García et al., 2019; Huang et al., 2015). The development of indicator sets is usually accompanied by the selection and compilation of relevant indicators following an accompanying conceptual framework that disaggregates them into domains, goals, or themes, among others, to capture the different dimensions of the system or to characterize the state of the system being assessed (Halla et al., 2022). Selecting specific indicators to ground concepts, however, is one of the main challenges in developing robust indicator-based assessment frameworks, given the inconsistent use of different concepts (Huang et al., 2015; Janoušková et al., 2018). For example, the selection of sustainability indicators is shaped by the diverse perceptions of sustainability among the experts involved (González-García et al., 2018) and by the definitions mobilized within participatory processes (Moragues-Faus & Marceau, 2019), which are often not explicitly clarified.

In this regard, the blurriness of the sustainability concept has led to a lack of conceptual clarity regarding the different dimensions of sustainability in food systems (Béné et al., 2019) and urban areas (Feleki et al., 2018). Specifically, food system assessment frameworks have been argued to overlook relevant sustainability dimensions (Hebinck et al., 2021), such as social and governance aspects, which are not given equal weight compared to other dimensions (El Bilali et al., 2021). As a result, there is currently no consensus on the indicators considered in urban sustainability (González-García et al., 2018) or food systems (Moragues-Faus & Marceau, 2019). Initiatives such as the Food Systems Dashboard or the EU Food System Monitoring Framework constitute a key step in consolidating fragmented, complex data into a single framework that supports integrated assessment and cross-country comparison (Fanzo et al., 2020). However, they also encounter limitations. These include, for example, the lack of subnational data, which risks hiding large inequalities within countries, reducing their value for local diagnosis and policy targeting (Downs et al., 2020; Herforth et al., 2022), or the reliance on incomplete datasets, particularly in terms of policy and governance, which can make them appear more comprehensive than they really are (Subedi et al., 2025).

Indicator set development has thus been argued to be unsystematic and opaque, relying usually on arbitrary decisions, data availability, and ease of measurement (Khadka & Vacik, 2012). As a result, problems with flexibility and adaptability across different geographical areas while maintaining comparability are common (González-García et al., 2018). Notably, extensive indicator sets are often regarded as difficult to operationalize, prompting an increasing emphasis on prioritizing a limited number of "essential" or core indicators for practical application (Zinkernagel et al., 2018). However, the process for prioritizing what to measure is not neutral. Urban food system assessments are closely linked to political objectives and the actors involved in designing them (Zerbian, Moragues-Faus, et al., 2024).

Recognizing the everyday politics of the use of assessment frameworks and indicators in policymaking is not new, nor is it confined to the realm of food. Science and technology studies (STS), along with more specialized scholarship on science–policy or knowledge–policy interfaces, have long shown that while indicators can function as boundary objects (Star & Griesemer, 1989)—bridging science and policy by being flexible and meaningful enough for both (Turnhout, 2009)—they also carry normative implications. Their uptake is shaped more by the surrounding policy context, power relations, and underlying epistemological and ontological assumptions than by technical robustness alone (Turnhout et al., 2014).

These dynamics invite a more reflexive understanding of the role of indicator-based assessment frameworks in shaping policies, strategies, and interventions. Beyond their role as measurement tools, indicators participate in agenda-setting processes, shape how problems are framed, and influence what is rendered actionable (Forney et al., 2024). Seen in this way, they can be potential leverage points to generate synergies across policy domains, thereby shaping the direction and ambition of urban food system transformations. From this perspective, indicator-based assessments may create opportunities to respond to calls for enhanced policy coherence (Kidd & Reynolds, 2024) and to integrate non-food dimensions into urban food governance processes (HLPE, 2024; Moragues-Faus et al., 2026).

When dealing with this process, however, there needs to be an acknowledgement of the current challenges that cities face in successfully implementing urban food system assessment frameworks. Given the resource constraints already surrounding urban food policy and related initiatives, there is a preference for practical assessment frameworks that are functional enough to provide relevant information or guide discussions (Zerbian, Moragues-Faus, et al., 2024). This process becomes increasingly difficult in the presence of different, at times fragmented, proposals for assessing urban food systems, in conjunction with the diversity of analyses that focus only on specific dynamics, such as urban food flows (Schreiber et al., 2021), urban food infrastructures (Downs et al., 2020), or urban food security (Haysom & Tawodzera, 2018), that need specific tools and resources to conduct them. Considering these challenges, rather than proposing new assessment tools, the focus shifts to synthesizing and organizing existing ones to identify indicators that are both substantively relevant and practically implementable, providing a structured departure point for integrating a socio-ecological and urban perspective into the assessment and governance of urban food systems.

3. Methods

3.1. Conceptual Framework: The SUFOS Framework

Organizing indicators within predefined themes or domains strengthens conceptual validity and analytical robustness (Halla et al., 2022). Given our aim to propose an indicator-based assessment framework that captures the socio-ecological and urban dimensions of urban food systems, we drew from the recently proposed SUFOS framework (Moragues-Faus et al., 2026), which provides an innovative entry point to understanding food systems, compared to existing sustainability and food security-based conceptualizations and associated indicators. The SUFOS framework proposes four interrelated layers to analyze urban food systems, which configure the structure of our indicator-based assessment framework:

- The *governance dynamics* layer comprises the actors, institutions, and decision-making processes that shape urban food systems, including formal policy frameworks, informal networks, power relations, and mechanisms of cross-sector coordination. It provides the basis for assessing actor participation, institutional integration, policy coherence, and accountability structures that influence urban food system outcomes.
- The *infrastructure and form* layer addresses the physical and spatial structures that enable food-related activities, including their distribution across urban space, such as transport systems, markets, storage facilities, processing sites, retail spaces, and green infrastructure. It supports the evaluation of their spatial accessibility, logistical capacity, and equitable spatial distribution, as well as the dynamics between urban planning and design and food.
- The *networked resource flows* layer focuses on the circulation of material and immaterial resources within and beyond the city. It includes food, water, energy, waste, capital, labor, knowledge, and information flows, and how they interact to shape resource use, metabolic patterns, resilience, and distributional food outcomes across the city.
- The *socio-ecological dynamics* layer focuses on the broader environmental and social conditions within which urban food systems operate, including demographic trends, ecosystem services, land use patterns, climate pressures, and social equity dimensions. It provides a contextual baseline for the urban food system, supporting the characterization of cities' profiles and their positioning within broader urban sustainability trajectories.

3.2. Modified Delphi Method

The proposed indicator-based assessment framework was developed through a combination of top-down and bottom-up methods. For this, we used a modified Delphi method based on the RAND/UCLA appropriateness technique (Fitch et al., 2001)—an iterative survey and consultative process that has been regarded as useful for indicator set development (Khadka & Vacik, 2012). This process followed three phases: (a) a literature review to identify potential indicators; (b) a test of applicability utilizing five cities as cases for indicator selection refinement; (c) a Delphi survey with European experts (panelists) for developing the final validated system of indicators. The use of established indicators to inform the Delphi survey is argued to enhance the efficiency of indicator development and increase their robustness and external validity (Campbell et al., 2002; Khan et al., 2019). Moreover, the applicability test ensures that the proposed indicators in the Delphi survey remain relevant by accounting for data availability. The methods for each phase are summarized below, and Figure 1 provides an overview of the whole process. Supplementary File 1 provides a more detailed explanation of each phase.

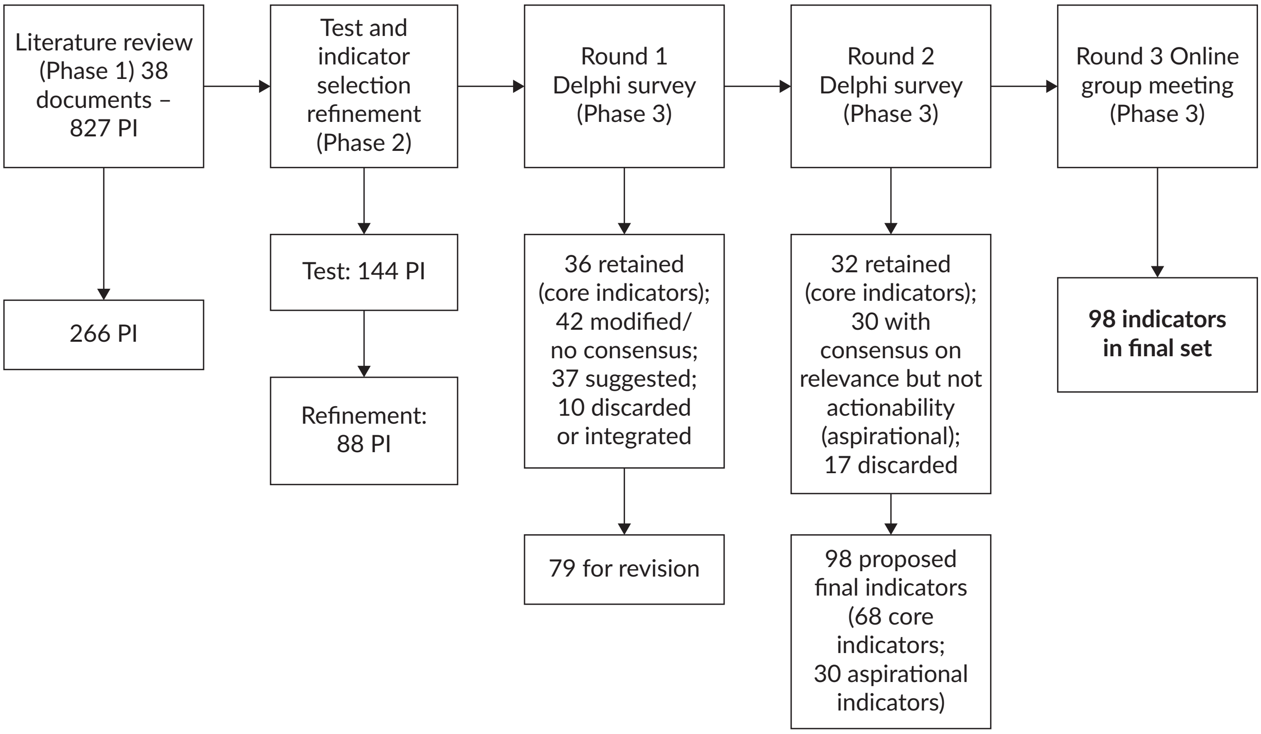

Figure 1. Research design to select and prioritize indicators, including a specification of the actions taken in each phase. The category "Aspirational Indicators" was developed from panelists' feedback, noting the importance of measuring these indicators despite limited data availability, and achieving consensus on their relevance but not on their actionability. Note: PI = potential indicators.

During Phase 1, we conducted a literature review of both scientific and grey literature to identify peer-reviewed articles, documents, and reports proposing or reviewing indicator-based assessment frameworks for urban sustainability and/or urban food system sustainability in Scopus and Google Search. Two Boolean searches were carried out in each case using the keywords "urban sustainability" AND "indicator*" AND ("system*" OR "framework" OR "set") in the title or abstract, and "sustainability" AND "indicator*" AND "urban" AND "food," also searched in the title or abstract, limited to publications from 2015 onwards in English and Spanish, reflecting the post-2015 momentum following the implementation of the MUFPP. These searches were complemented by backward citation tracking of documents and by the authors' previous professional experience and networks. Documents were then filtered based on their ability to propose or synthesize core indicators that enabled comparability, covered a holistic sustainability perspective, and focused on the urban scale. This process resulted in the selection of 38 documents (see Supplementary File 2), from which indicators were identified based on their coherence with the SUFOS framework and their frequency in the identified documents, yielding 266 potential indicators.

These potential indicators were tested for applicability in five Spanish cities during Phase 2, and their availability in potential databases was assessed at the local, regional, national, and European levels. Since the indicator number remained high (144—see Figure 1), another round of refinement was conducted based on more granular criteria, including conceptual relevance and suitability and a clearly defined methodology (see Supplementary File 1), leading to a final set of 88 indicators to use during the modified Delphi survey.

Phase 3 subjected this indicator set to expert evaluation through a two-round online survey, with a final group meeting to discuss any disagreements and validate the final proposal. Thirty-three European experts were selected as panelists, with consideration given to gender balance, diversity among public and civil society actors, and expertise in urban food system assessment. During Rounds 1 and 2, panelists rated the proposed indicator set for relevance and actionability (for definitions and more explanation, see Supplementary File 1) on a scale of 1 to 9 (1 = *not appropriate on that criterion*; 9 = *extremely appropriate on that criterion*). Consensus in each round was based on the median score for each criterion reaching the top tertile (7–9), with at least 70% in Round 1 and 75% in Round 2 of panel ratings within this range. Open-ended questions allowed us to obtain qualitative feedback on the proposed indicators and elicit suggestions for additional indicators. Indicators from Round 1 with partial or unclear consensus were revised, modified, reclassified as aspirational indicators, or removed when considered unsuitable, redundant, or better integrated into other indicators. The revised, aspirational, and newly suggested indicators were then sent to panelists for re-rating in Round 2. The group discussion meeting was organized after Round 2 to validate and review the final indicator set.

Finally, throughout the process of developing urban food system indicators, the authors have participated in other European processes focused on urban food system assessments and transformations, such as the Food Track of the Urban Agenda of the European Union, as well as panels, meetings, and workshops on indicator development (EUROCITIES, 2025; HLPE, 2024). Participation in these spaces also provides additional insights into challenges and advances in the field of urban food system indicators.

4. Results

4.1. State of the Art on Urban Food System Indicators From a Socio-Ecological Perspective (Phase 1)

The analysis of the 38 documents identified (see Supplementary File 2) revealed that 32 (84%) were specific to urban sustainability and 6 (16%) to the sustainability of urban food systems, indicating greater effort to assess the sustainability of cities. At the same time, many of the indicators proposed for evaluating urban food systems focus on process indicators or the measurement of action implementation rather than impact or performance. For example, while the MUFPP Monitoring Framework proposes quantitative indicators to assess performance and outcomes, 21 of the 44 indicators are self-assessment binary indicators, particularly in governance and policies (Carey & Cook, 2021). Urban sustainability indicator-based frameworks aim to be concise, simple, and comparable (Merino-Saum et al., 2020). In contrast, frameworks for evaluating urban food systems offer more extensive lists of recommendations tailored to specific territories. For example, the City Region Food System indicator framework offers a repertoire of 210 indicators to assess food system sustainability, allowing cities to select those most relevant to their priorities (Carey & Dubbeling, 2017). Finally, urban sustainability frameworks often include the development of indices for benchmarking (e.g., Raedo, 2021), which were not found in the scope of urban food systems.

A total of 827 indicators were identified in the 38 documents that related to the different layers of the SUFOS framework (see associated dataset in Zerbian, Berti, et al., 2024). Within each layer, specific sub-themes were identified and refined, drawing on both the theoretical structure of SUFOS and the categories emerging from the documents analyzed (see Table 1). Following this initial identification, indicators were assessed for their coherence with the SUFOS framework and their frequency of reference in the identified documents. After removing duplicates, 266 potential indicators were selected for the applicability test and the second refinement.

Table 1. Distribution of indicators across SUFOS layers and sub-themes from Phase 1 and Phase 2.

SUFOS Layer	Sub-themes	Identified PI LR	%	1st ref.	%	Applicability test & 2nd ref.	%
Socio-ecological dynamics	Social justice	67	8%	16	6%	4	5%
	Culture & tourism	28	3%	8	3%	2	2%
	Housing	21	3%	8	3%	4	5%
	Education	50	6%	10	4%	2	2%
	Environment	49	6%	7	3%	3	3%
	Biodiversity	15	2%	4	2%	2	2%
	Land use	21	3%	5	2%	4	5%
	Demographics	10	1%	6	2%	3	3%
	Economy	80	10%	26	10%	9	10%
	Health	32	4%	7	3%	3	3%
	Diet	18	2%	5	2%	4	5%
Urban infrastructure and form	Transport networks	27	3%	8	3%	4	5%
	Food infrastructure	74	9%	20	8%	5	6%
	Utilities	32	4%	8	3%	1	1%
	Design & planning	8	1%	2	1%	3	3%
	Green spaces & parks	5	1%	2	1%	1	1%
Networked resource flows	Energy	28	3%	9	3%	3	3%
	Waste	26	3%	7	3%	5	6%
	Food flows	30	4%	10	4%	4	5%
	Water	47	6%	7	3%	3	3%
Governance dynamics	Actors and networks	39	5%	38	14%	5	6%
	Public policies	54	7%	34	13%	9	10%
	Participation, transparency, and inclusion	43	5%	16	6%	4	5%
	Finance	23	3%	3	1%	1	1%
Total		827	100%	266	100%	88	100%

Notes: LR = Literature Review; PI = potential indicators; ref. = refinement and selection of indicators after the initial identification (1st ref.) and after the applicability test (2nd ref.).

The classification of the indicators identified in the literature shows a stronger emphasis on economic indicators (10%) within the socio-ecological dynamics layer, with certain sustainability and urban aspects remaining underrepresented. For example, the indicators retrieved show limited representation in areas such as biodiversity (2%), diet (2%), design and planning (1%), green spaces and parks (1%), and demographics (1%), areas highly relevant for understanding urban and food dynamics (Moragues-Faus et al., 2026). Indeed, in general, more attention is given to broader areas connected to the SDGs, such as emissions, unemployment rates, and life expectancy at birth (see Figure 2), reflecting this framing in urban agendas and a higher representation of urban sustainability indicator sets in the field. The selected 266 indicators also reflect this distribution, in part due to the limited availability of indicator proposals in these underrepresented areas.

Figure 2. Word cloud based on the frequency of the 827 indicators identified in the literature review.

Nevertheless, local food production and food insecurity are indicators that, while not widespread, have been increasingly incorporated into some urban sustainability frameworks, showcasing progress in recognizing food as a key urban issue. Examples of these frameworks include the United for Smart Sustainable Cities Initiative (U4SSC) Key Performance Indicators for Smart Sustainable Cities (U4SSC, 2017), the Urban Sustainability Framework (Global Platform for Sustainable Cities, 2018), or, more recently, the Global Urban Monitoring Framework, including the Food Insecurity Experience Scale (UN Habitat, 2022).

4.2. Indicator Set Refinement Through City Testing (Phase 2)

During Phase 2, several challenges were identified in measuring indicators at the city level regarding quality and data availability. For example, in the diet sub-theme, consumption data in Spain are typically available only at the provincial level, requiring specialized studies to obtain more localized information. Also, many datasets are only available at the regional (autonomous community) level. Challenges also emerged in analyzing urban conditions, including housing and transport networks. These indicators are often tied to Eurostat's City Statistics or the Urban Audit, which define key metrics but do not always provide data for all cities. Additionally, some indicators in the Urban Audit are outdated, further complicating efforts to obtain current and relevant data.

These limitations create obstacles in both the selection and implementation of proposed indicators, as not all cities have the capacity to generate the necessary or up-to-date data. In this context, data availability and the feasibility of application across geographies were criteria used to select the 88 indicators to be further refined through the modified Delphi process.

4.3. Results of the Delphi Survey (Phase 3)

In this subsection we present the main results of the Delphi survey, where 22 experts participated (see profiles in Table 2).

Table 2. Panelists' characteristics by sector, gender, and region of main residence and work.

Characteristics	*n* (%)
Current Professional Sector	
Public Administration	7 (31.8%)
Civil Society	5 (22.7%)
Academia	10 (45.5%)
Gender	
Woman	11 (50%)
Man	11 (50%)
Other	0
Total	22

Supplementary File 2 provides an overview of the group rating results for each indicator, including the median score, the percentage of panelist agreement according to the criteria outlined in the Methods section for each round, and the action taken for that indicator in each round.

4.3.1. First Round

The response rate for Round 1 was 100%. Of the 88 proposed indicators, 36 were retained after the first round as they achieved 70% agreement on both relevance and actionability, and no modifications were suggested. The remaining indicators lacked clear consensus (40), reached consensus but required minor revisions (2), or were discarded or integrated into revised indicators (10).

Among the 40 indicators that showed unclear consensus, 25 reached consensus on relevance but not actionability, most of which were related to urban food systems' specific activities, such as "#37. Average income of agri-food system workers, including small producers." These were reclassified as "Aspirational Indicators" and submitted for rating in a separate section during Round 2, with some modified according to panelists' comments. Another eight indicators achieved consensus on actionability but not relevance, with the majority relating to general socio-economic characteristics of urban areas, such as "#7. Tourist intensity" or "#58. Car ownership." Seven indicators failed to reach consensus on either criterion but were retained for Round 2, as panelists' comments suggested that they required modification rather than deletion. These were primarily related to environmental sustainability, such as "#22. CO2 total municipality emissions" or "#76. Proportion of renewable energies in final energy consumption." Indicators that lacked consensus on relevance, or on both relevance and actionability, were frequently described by panelists in their comments as more reflective of urban context than as providing pertinent information to assess urban food systems.

Overall, 42 indicators were revised, modified, or reclassified and carried forward to Round 2. Additionally, panelists suggested 37 new indicators, bringing the total to 79 for the Round 2 survey. Modifications to existing indicators or suggestions for new ones often involved calls for greater disaggregation or recognition of the complexity of the topics being measured. For instance, when calculating available urban agricultural area, panelists recommended accounting for potential distortions by municipality type. This change would involve considering population and total surface area, along with specific factors such as the size of the municipal territory relative to its peers in terms of location, administrative significance, and other characteristics.

4.3.2. Second Round

Round 2 of the Delphi study achieved a 73% participation rate, with 16 out of 22 participants completing this stage. Thirty-two indicators were retained after Round 2 ratings since they achieved 75% agreement on both relevance and actionability (median 7–9), with only minor modifications suggested. Thirty indicators achieved consensus on relevance but not actionability. As in Round 1, these indicators were classified as "Aspirational Indicators." Panelists' feedback led to their inclusion in the final set of indicators for validation during the group discussion meeting. Identified as critical for understanding urban food systems, "Aspirational Indicators" were highlighted by panelists as essential to measure, despite limited data availability at the municipal level, underscoring the importance of including them to promote their use.

The remaining indicators either lacked consensus on both criteria (6) or reached consensus on actionability but not relevance (11) and therefore were discarded. All these indicators were non-food specific. This action followed several panelists' comments on their overlap with other indicators or their low relevance for characterizing urban food systems, as scored by the panelists. Examples included: "#7. Tourist intensity (number of tourist beds per 1000 inhabitants)," "#8. Number of same-day visitors per month," "#34. Cultural diversity," or "#58. Car ownership."

In total, 98 indicators were proposed as the final set, based on the results and actions from Rounds 1 and 2 (see Supplementary File 2). Of these, 68 indicators were classified as "Core Indicators," achieving consensus on both relevance and actionability (Figure 3 and Supplementary File 3). In this proposal, zero indicators were included for the Environment and Biodiversity sub-theme, as none reached consensus on both relevance and actionability; the majority fell under the aspirational category. From this list, 43% are non-food-specific indicators and 57% are food-specific, with the Governance Dynamics dimension having 100% food-specific indicators. The remaining 30 indicators were classified as "Aspirational Indicators" (Supplementary File 3), achieving consensus on relevance but scoring low on actionability. Panelists consistently highlighted their importance for assessing urban food systems in their comments, despite limited data availability, and indicated the need to prompt action to measure them. Accordingly, these indicators (of which 80% are specific to food) were retained as a separate category with a future-oriented perspective. In Round 2, only minor modifications were made to the indicators, specifically rephrasing the names of two indicators. While the overall group ratings reached consensus on both criteria for the Core Indicators, panelists' comments did highlight the complexity of measuring them and the potential need to define their meaning further when implemented in practice; issues that were brought to the group discussion meeting.

Core Indicators		
Sociol-ecological dynamics	Social justice	• Population rate at risk of poverty • Gender pay gap • Beneficiaries of social assistance • Beneficiaries of food assistance in cash of kind
	Culture and tourism	• Relative contribution of tourism to the municipality's economy (% of GDP)
	Housing	• Housing costs • Beneficiaries of social housing
	Education	• Educational attainment level of the adult population
	Land use	• Built-up land-use mix • Surface area designated for natural protection
	Demographics	• Population under 16 years old • Population over 65 years old • Immigration rate
	Economy	• Municipality unemployment rate • GDP per capita disaggregated by sector • Distribution of employment by sector in the municipality • Income inequality (Gini coefficient/index) • Employment in the agri-food chain • Average household income
	Health and Diet	• Average life expectancy at birth • Public provision of health promotion programmes • Prevalence of Type 2 diabetes in the adult population • Prevalence of obesity and overweight in adults and children
Networked resource flows	Energy	• Per capita energy consumption • Fuel poverty
	Waste	• Urban solid waste generated • Municipal waste recycling rate • Municipal waste reused as soil conditioner and/or fuel • Number of circular programs and initiatives addressing food loss and waste
	Water	• Per capita water consumption • Drought frequency
Urban infrastructure and form	Transport networks	• Length of bike network • Acces to public transport
	Food infrastructure	• Number of municipal and collective food processing and distribution infrastrucutres • (Potencial) area for agriculture and livestock within the municipality • Proportion of agricultural area under certified organic farming • Number of certified organic farms • Number of community gardens (by type)
	Utilities	• Access to basic services • Access to basic health services
	Design and planning	• Population density • Ratio between land and population growth
	Green spaces and parks	• Green area per capita • Proximity to green areas
Governance dynamics	Actors and networks	• Active multi-stakeholder food planing and policy structure • Level of multi-actor representation and integration in the active food planning and policy structure • Budget for the active multi-actor food planning and policy structure • Sources of funding for the active multi-actor food planning and policy structure • Activity of the active multi-actor food planning and policy structure (I & II) • Active municiapl inter-departmental body of food policy and program decision-making • Inter-jurisdictional collaborations for food policy development
	Policies	• Healthy and sustainable food as a key pillar in the ◦ urban sustainability strategy/climate change adaptaion plan ◦ municipal health strategy ◦ social services strategy ◦ urban planning ◦ sustainable procurement policy ◦ integrated urban strategy • Municipal urban food policy or strategy and/or action plan • Emergency food supply/resilience plan for the municipality • Food policies targeting groups with specific social vulnerabilities
	Participation	• Representation of specific vulnerable groups in food governance bodies • Mechanism for collecting and analysing data on the urban food system
	Finance	• Municipal budget dedicated to healthy and sustainable food • Municipal budget for urban food policy/strategy/action plan • Commitment to sustainable public food procurement • Municipal support for food markets or retail stores providing fresh food • Resources dedicated to urban strategies/plans/policies

Figure 3. Final core indicator set approved by panelists per the SUFOS framework layers and developed sub-themes. Indicator titles have been adapted for presentation in the figure, while the full version, including definitions and measurement details, is provided in Supplementary File 3. For example, labels I and II of the indicator "Activity of the active multi-actor food planning and policy structure" distinguish two distinct ways of measuring it (see Supplementary File 3), presented under a shared title in the figure to improve readability and presentation.

4.3.3. Online Group Discussion

All panelists who responded to Round 2 were invited to the group discussion, with all the results and a detailed description of the process made available to them before the meeting. The group discussion had 11 panelists in attendance, who accepted the proposal of indicators and provided no further comments on rewording or modification. All panelists were invited to provide additional feedback via e-mail if needed.

During the follow-up discussion on the research process and potential steps, panel members agreed on the importance of adopting a comprehensive urban and socio-ecological perspective on food systems, emphasizing its relevance for fostering more transversal food strategies. Participants stressed that introducing the proposed indicators in municipalities could strengthen interdepartmental connections and facilitate collaborative municipal work, as non-food indicators could be used indirectly to evaluate urban food systems. According to panelists, this not only supports the evaluation of system dynamics but also helps to avoid a siloed approach to urban food policy, which experts identified as an increasing challenge across Europe. By promoting linkages with other municipal domains, these indicators can underscore the cross-cutting relevance of food across broader sustainability challenges.

At the same time, participants noted that the linkages between food and non-food elements must be made explicit when applying the framework in practice before selecting indicators and measuring progress. They emphasized that municipalities would need to make deliberate efforts to connect these elements and to prioritize which linkages are most relevant to their specific territories, recognizing that interconnections and the relevance of specific elements vary across contexts.

The translation of the study results into practical tools for municipalities was identified as a key challenge by practitioners. Questions were raised about aspirational indicators, given their importance and how to ensure municipalities are able to consider them when assessing urban food system dynamics, given their difficulty in measuring. Moreover, it was acknowledged that a comprehensive perspective on urban food systems remains lacking in municipalities, along with a lack of resources for monitoring and evaluation. However, some participants also emphasized the need to be "disruptive" by going beyond the easiest or most readily available measures, such as promoting the proposed aspirational indicators, even when these are harder to operationalize or currently lack established data sources. To advance urban food systems assessments, participants underscored the need to advocate at higher governance levels for the collection and provision of relevant municipal-level data.

5. Discussion

The development of the proposed assessment framework further indicates that food remains weakly connected to broader urban dynamics in the understanding, conceptualization, and evaluation of cities, and vice versa. While Moragues-Faus et al. (2026) highlight this disconnection in the literature, our work also shows that indicator sets and urban food experts understate the importance of non-food aspects in shaping urban food system dynamics. As seen in the literature review and initial tests, while a small number of food-related indicators have gradually been introduced into urban sustainability frameworks, most indicator sets rarely include food as a distinct thematic area comparable to domains such as water or energy. At the same time, urban food-specific frameworks rarely integrate non-food dimensions, such as water, transport, or energy, limiting a broader characterization of the urban dynamics that shape the functioning and outcomes of urban food systems. The Delphi process further reinforced this disconnect: Indicators associated with urban dynamics were frequently considered less relevant by participants for assessing urban food systems.

Incorporating a bottom-up phase into the development of the indicator-based assessment framework, however, suggests that indicator selection and prioritization can broaden how urban food systems are understood, with the potential to transcend this division. As shown in the results of Phase 3 of the Delphi process, after rating the proposed indicators and discussing the integration of food and non-food elements into the framework, participants highlighted several potential benefits of this process, including encouraging more transversal perspectives and raising food in the municipal agenda. This finding further reinforces the idea that indicator-based assessment frameworks can play a mobilizing and reflective role in urban food governance beyond their mere use as data-collection tools.

At the same time, selecting and prioritizing indicators is one of the main challenges in developing sustainability assessment frameworks—a difficulty also identified in this study. This challenge is particularly related to the three tensions for sustainability indicator set development identified by Merino-Saum et al.

(2020): (a) parsimony vs. comprehensiveness (being manageable vs. being able to capture multiple dimensions); (b) general comparability vs. context-specificity (prioritizing standardization and benchmarking vs. adapted to local contexts); and (c) simplicity vs. complexity (remaining understandable and usable for decision-makers vs. balancing robustness and detailed representation). As seen in Phase 1 findings, urban sustainability assessment frameworks tend to rely more on standardized, comparable indicators or indices to support decision-making than do urban food frameworks. These differences reflect the distinct trajectories of the two fields. Urban food system assessment is relatively recent, prompted by initiatives such as the MUFPP. In contrast, urban sustainability assessment is more established, with benchmarking initiatives linked to UN sustainability frameworks emerging in the late 1990s and early 2000s (Sharifi, 2021).

Urban sustainability assessment frameworks have, however, been criticized for relying on highly aggregated metrics that may oversimplify complex urban dynamics (Merino-Saum et al., 2020). Indeed, simple, parsimonious, and standardized indicators can mask the diversity and variability of urban food system conditions and of cities across municipalities (Moragues-Faus & Marceau, 2019), as participants in this study also emphasized. Simultaneously, in policy domains with limited resources and political prioritization, such as food, municipalities are less likely to adopt complex or resource-intensive indicators (Zerbian, Moragues-Faus, et al., 2024). Nevertheless, the inclusion of these types of indicators, such as the aspirational indicators proposed, remains relevant, according to this study's findings. Their presence is considered leverage to legitimize food and encourage its consideration as a cross-cutting issue by prompting action. Figure 4 summarizes these trade-offs, showing how indicator selection and implementation when developing assessment frameworks require balancing feasibility, comparability, and usability with broader coverage, local relevance, and more nuanced representation of system dynamics.

The contribution of the proposed assessment framework for urban food systems relies particularly on this perspective, by attempting to balance these tensions through the proposal of core and aspirational indicators (see Figure 4), potentially serving as an entry point for rethinking how urban food systems are conceptualized and assessed for both knowledge and practice. In the context of ongoing debates on insufficient progress towards the SDGs and the post-2030 agenda, the framework can help municipalities strengthen local monitoring and governance by enabling more context-sensitive responses to food-related challenges. By encouraging cities to first develop a better understanding of their own urban dynamics before devising food-specific strategies or interventions, it can help integrate food more explicitly within broader urban sustainability debates, thus prompting a "food in all policies" approach (Parsons & Hawkes, 2019) or food policy integration beyond "siloisation" (Edwards et al., 2024).

The inclusion of both core and aspirational indicators is particularly relevant in this regard. Rather than proposing entirely new indicators, the framework synthesizes metrics—core indicators—that may already be collected through monitoring systems linked to broader policy initiatives, such as the Urban Agenda or the Urban Audit, while also introducing food-specific—aspirational—indicators intended to stimulate new areas of action, particularly by highlighting areas where data availability and operational measurement tools are still needed. This synthesis effort is particularly relevant in a context where progress is hindered by fragmented indicator initiatives and weak harmonization of concepts, limited local capacity, unclear priorities on what to measure from different sectors and levels of government, major data gaps including difficulty in accessing private sector data, difficulties integrating datasets, and the challenge of capturing qualitative governance and participation outcomes (EUROCITIES, 2025).

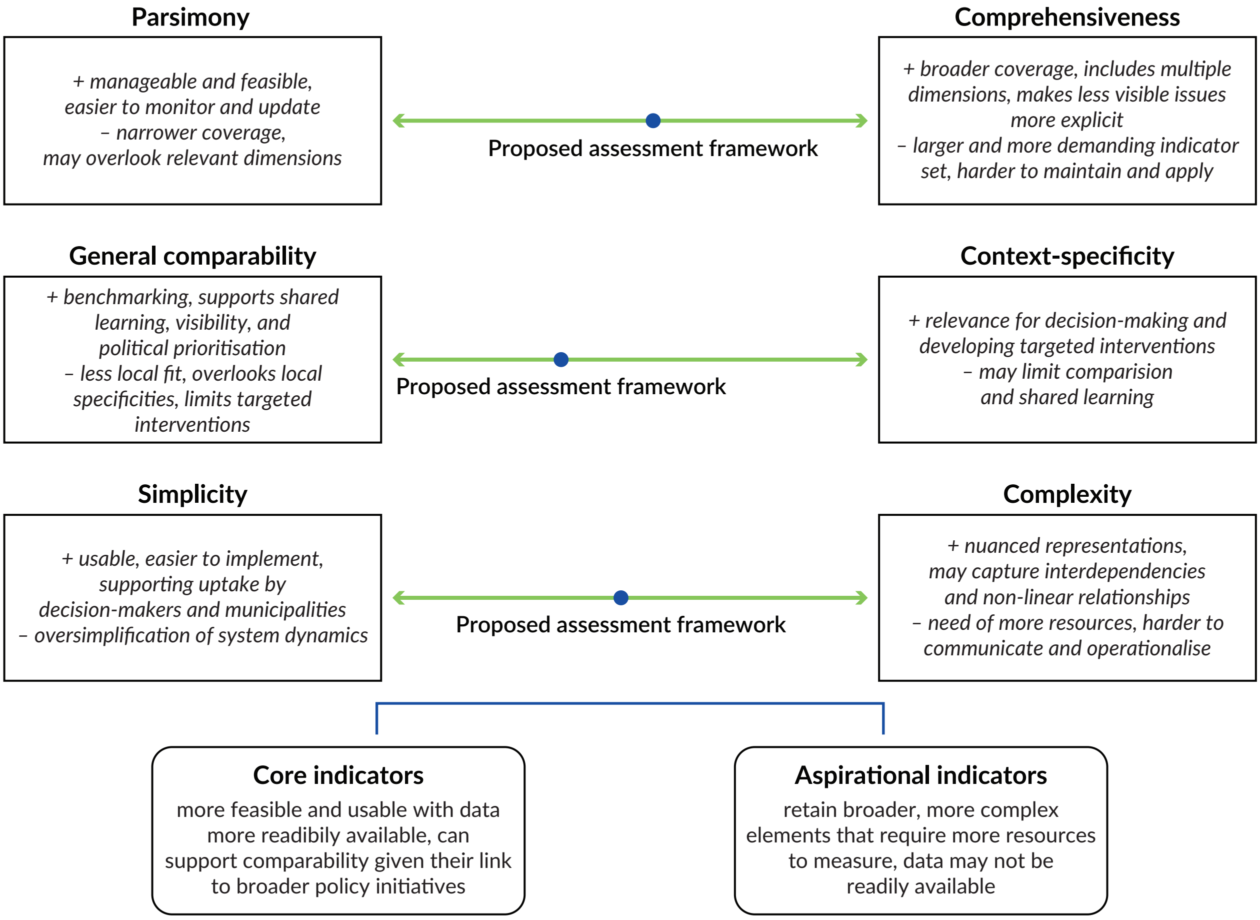

Figure 4. Key trade-offs in designing indicator-based assessment frameworks. The figure also indicates where the proposed assessment framework is positioned within these trade-offs due to its proposal of core and aspirational indicators.

In participatory spaces, such as the Urban Agenda or MUFPP 2025 workshops, cities specifically highlighted the difficulty of communicating evidence in ways that resonate with policymakers, as well as the importance of aligning indicators with local priorities. This creates a tension with the selection of a fixed set of common European-wide indicators for benchmarking, as indicators that lack local relevance are unlikely to receive strong political backing from cities or contribute meaningfully to urban agendas. The proposed indicator-based assessment framework, therefore, constitutes a first step towards embedding food within mainstream urban monitoring and governance frameworks and vice versa. It does not only make food systems more legible to urban decision-makers but also creates the conditions for stronger cross-sectoral alignment, more coherent priority-setting, and greater political recognition of food as a core urban policy issue. However, we also note that its applicability beyond European contexts should be treated with caution. Figure 4 highlights this potential limitation, particularly regarding context-specificity and applicability in other contexts, given its European focus. In this respect, its application beyond this context should be adapted to local data realities, institutional capacities, and locally defined urban food system challenges.

At the same time, the exercise of developing the proposed assessment framework illustrates that indicator selection and implementation are not only technical tasks but also socio-political and governance processes (Forney et al., 2024; Zerbian, Moragues-Faus, et al., 2024). In this case, these processes involved making decisions and negotiating tensions around the operational feasibility and relevance of indicators to support more resilient, equitable, and sustainable urban food governance. However, as Kitchin et al. (2015) note, urban indicator and benchmarking initiatives can be driven by politics and economics. Indicator selection may serve to advance or defend particular agendas. At the same time, the development of assessment tools may also benefit actors with commercial interests in their adoption and promotion, such as corporations creating them and then selling related data, software, or analytical services. In this sense, indicators do not simply represent urban realities but actively shape what is made visible, comparable, and governable, in ways that may not always align with sustainability objectives. Given the non-neutral character of evidence uptake in urban food governance, as shown by Zerbian, Moragues-Faus, et al. (2024), applying the framework will thus also require attention to who is involved in its use, what forms of knowledge are legitimized, and how municipal capacities, data availability, and political prioritization shape whether it becomes actionable and how—issues that might be exacerbated as food concerns become increasingly integrated into urban agendas.

6. Conclusion

This study aimed to develop an indicator-based framework to assess urban food systems from a socio-ecological and urban perspective, to support more integrated approaches to urban food governance and transformation. In doing so, the findings illustrate how the development of such a framework inevitably involves trade-offs between maintaining operational, manageable frameworks in underprioritized municipal domains and ensuring that the multiple dimensions of urban food systems and cities are adequately captured.

At the same time, the results suggest that the process of designing and prioritizing indicators can itself stimulate new ways of thinking about the role of food within urban systems. Rather than introducing an entirely new set of indicators, this study synthesized and classified existing measures in urban policy and urban food governance contexts, using top-down and bottom-up methods. By building on indicators already embedded in these policy processes, the framework seeks to enhance coherence and usability rather than impose new reporting burdens. The underlying rationale is that cities can first build a clearer understanding of their socio-ecological dynamics using available data and then use this knowledge to guide context-specific food strategies and interventions, using adapted, more complex or resource-intensive indicators.

Beyond its practical application as an assessment tool, the proposed indicator-based framework aims to contribute to a broader shift in how food is understood within urban sustainability agendas—not as a sectoral concern, but as a cross-cutting lens through which social, ecological, and governance challenges can be addressed in a truly integrated manner. As cities navigate the uncertainties of the post-2030 sustainability landscape, making food more visible within urban decision-making may help unlock new pathways towards more resilient, equitable, and regenerative urban futures. For that purpose, further research could delve deeper into the tensions, transferability, and usefulness of the framework in diverse urban settings and expand the potential of food as a catalyst for urban sustainability transformations.

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Conflict of Interests

In this article, editorial decisions were undertaken by Anna R. Davies (Trinity College Dublin), Dean Phelan (University College Dublin), and Yuliya Voytenko Palgan (Lund University).

Data Availability

The research data associated with this article are available in DIGITAL.CSIC under the dataset "A review of indicators for the characterization of urban food systems using a socio-ecological and urban indicator framework." The dataset includes the list of reviewed documents, the Atlas.ti analysis results, and the first iteration of the indicator framework after the literature review, before the applicability test and the Delphi process. DOI: https://doi.org/10.20350/digitalCSIC/16685

LLMs Disclosure

ChatGPT, version GPT-5.5, was used for language improvement, particularly to refine sentence structure and grammar, considering that the authors are non-native English speakers. All changes were reviewed and validated by the authors and a native English proofreader. The original ideas and arguments presented in this work are the authors' own.

Supplementary Material

Supplementary material for this article is available online in the format provided by the authors (unedited).

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