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Urbanizing food systems: exploring the interactions of food access dimensions for sustainability

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This paper aims to conceptualize the dimensions of food access to enhance urban food system sustainability by analyzing the cause-effect interactions between the five dimensions and the urban food environment and using spider web diagrams to illustrate their interrelationships in terms of community perception and objectivity. Various studies have conceptualized access as a construct of five dimensions. This new expanded view supports both objective and perceived aspects of access and values the knowledge of residents through community-based participatory research, thereby providing a more complete understanding of access. This study, building on Usher's broader themes of spatiality, objectivity and perception, analyzes the cause-effect interactions between the five dimensions and the urbanizing food environment by expanding and modeling the dimensions of access and their interactions critical to the analysis and decision-making processes of sustainable urbanizing food systems. With the use of spider web diagrams, we demonstrate the degree of interactions among the five dimensions (availability, accessibility, acceptability, accommodation, availability, and affordability), with respect to the community perception and objectivity. We used the DPSIR causal framework to analyze the cause-effect relations between the five dimensions and the DPSIR components: drivers, pressures, state, impact, and response. The five dimensions are further conceptualized for spiderweb and DPSIR for low, medium and high interactivity. The conceptualizations are applied to three case studies from the literature. This paper, additionally, integrates insights from Systems Thinking, which has been pivotal in understanding the complex, interconnected nature of sustainable food systems. Furthermore, ecosystem approaches to health, which emphasize systemic and holistic perspectives, are also considered. These approaches highlight the interdependence between ecological and human health, advocating for integrated strategies that promote both environmental and human well-being.

KEYWORDS

food access, food security, five dimensions of access, DPSIR, spider web diagram, objectivity, perception

1 Introduction

The aim of this paper is to explore the interactions of the dimensions of food access to enhance the sustainability of urban food systems by (a) examining the cause-effect interactions between the five dimensions and the urbanizing food environment, expanding and modeling these dimensions, and (b) using spider web diagrams to demonstrate the degree of interaction among the five dimensions (availability, accessibility, acceptability, accommodation, and affordability) in relation to community perception and objectivity.

In our previous publication, *A conceptualization of the urban food-energy-water nexus sustainability paradigm: Modeling from theory to practice*, under the driver of urbanization, we developed a conceptual model of the urbanizing food-energy-water nexus in the framework of environmental, social and economic sustainability (Gragg et al., 2018). In our second paper on the rapidly transitioning and evolving urban agricultural food and nutrition system we conceptualize, expand and operationalize the Usher (2015) dimensions of food access (Figure 1) in the DPSIR framework (Andress and Fitch, 2016; Penchansky and William Thomas, 1981; Usher, 2015). Usher (2015), reconceptualized food access as a construct with five dimensions: *acceptability, accessibility, accommodation, affordability*, and *availability by applying* the Penchansky and Thomas concept of health access to the concept of food access. This expanded view supported both objective and perceived aspects of access and values the knowledge of residents through community-based participatory action research (Gragg et al., 2015), and thereby provided a more complete understanding of food access and its complexities. In subsequent work by the authors, we sought to conceptually describe the causal chains and feedback loops between the driver variables (e.g., precipitation and temperature) and response variables (e.g., impacts in several ecosystems (Anandhi and Bentley, 2018; Bentley and Anandhi, 2020) as well as describe the urbanizing food energy water nexus in the context of the sustainability paradigm (Gragg et al., 2018).

1.1 Existing food access models and definitions

Access to safe and nutritious food is a basic human right (Lawlis et al., 2018). The World Food Program and FAO's preliminary estimates indicated the COVID-19 pandemic could almost double the number of people suffering acute hunger (Grimaccia and Naccarato, 2022). In fact, the pandemic had global consequences at all levels of life, such as limiting access to food, reducing freedom of movement, and hindering various activities (Salisu et al., 2024). Therefore, applying an integrated system to ensure equitable food access, particularly during crises, is critical and addresses a fundamental aspect of public health (Wopereis et al., 2024) and access to adequate nutrition (Haji and Himpel, 2024). The ripple effects of reduced access to agricultural inputs (fertilizers, interrupted harvesting, and destroyed shipping routes), which caused a shortfall in the global food supply (Alam et al., 2024). Food access is considered as one of the four interdependent dimensions of food security frameworks (Pérez-Escamilla, 2024; FAO, 2006). In the context of food insecurity, food access has economical and physical components (Lawlis et al., 2018) pertaining to economic and physical access to food for households, especially for the poor and vulnerable. The food access dimension received the least amount of attention among the four at both the national and regional levels (Lowitt et al., 2016). Over the last two decades, a surge in systemic approaches and frameworks has endeavored to unravel the complexities of food systems challenges, offering insights to mitigate negative externalities and enhance the well-being of individuals, societies, economies, and the environment (Bustamante et al., 2024; Pérez-Escamilla, 2024).

Regional institutions have a narrower approach to food security than national governments (Lowitt et al., 2016). As food security shifted from larger to smaller spatial scales (e.g., global, national, regional, local, household, and individual); (Ecker and Breisinger, 2012; Hasyimi et al., 2024; Clapp et al., 2022), so did the thinking from food supply to food access (Borch and Kjaernes, 2016; Hussain et al., 2025). Key themes characterizing the food access dimension of food security are monitoring systems access, support rural development and livelihoods, rising food prices and equitable food access (Lowitt et al., 2016). The former two are emphasized in regional food security and the latter three are emphasized at the national level (Lowitt et al., 2016). Short food supply chains facilitate physical and financial accessibility, and allows access to fresh, healthy, pesticide-free, seasonal and local/regional food (Martinelli et al., 2020). Food production must be close to the consumption locations, supporting convenience and a sustainable food system (Martinelli et al., 2020). Strategies such as the delivery of food kits at home have been an important farmers' production outflow, besides providing consumers with fresh food (Martinelli et al., 2020). Street markets facilitate the purchase of healthy and sustainable food with less risk of contamination, because they are operating outdoor, and may be another opportunity for direct sales between producer and consumer (Martinelli et al., 2020). Encouragement to expand urban agriculture and community gardens can also assist in two greater access to fresh food, especially during the pandemic, within an accessible physical boundary of the community's food environment. Exposure to a food environment that offers high ultra-processed foods (UPF) availability and access favors inappropriate food choices, because a greater availability and lower prices increase the chances of such food consumption (Martinelli et al., 2020). Insufficient food access arising from resource constraints is one of the measures of household food insecurity (Loopstra et al., 2015). In a household, food access has three components: physical, financial, and socio-cultural. Nekmahmud et al. (2022) used the World Food Programme definition "food access as a household's ability to regularly gain an adequate amount of food through purchases, barter, borrowings, food help, or gifts."

Food insecurity for individuals is conceptualized as a function of lack of the financial, physical or means of transport to obtain nutritionally adequate and safe foods (Burns, 2015). They associate physical or means of transport with food access because of the convenience to eat at site or the inability to carry grocery (retail or in bulk) from site to home and reduced car access. At the individual level, access to food by gender was modeled by considering several personal and household characteristics (Grimaccia and Naccarato, 2022).

Urban food systems and frameworks influence every human institution and practice (Moores et al., 2025). They influence the economy in terms of labor, capital investment, and productive activities, with implications for the value of surrounding housing and other land uses. Urban food systems impact and guide local ordinances regulating public spaces, public markets, and public health

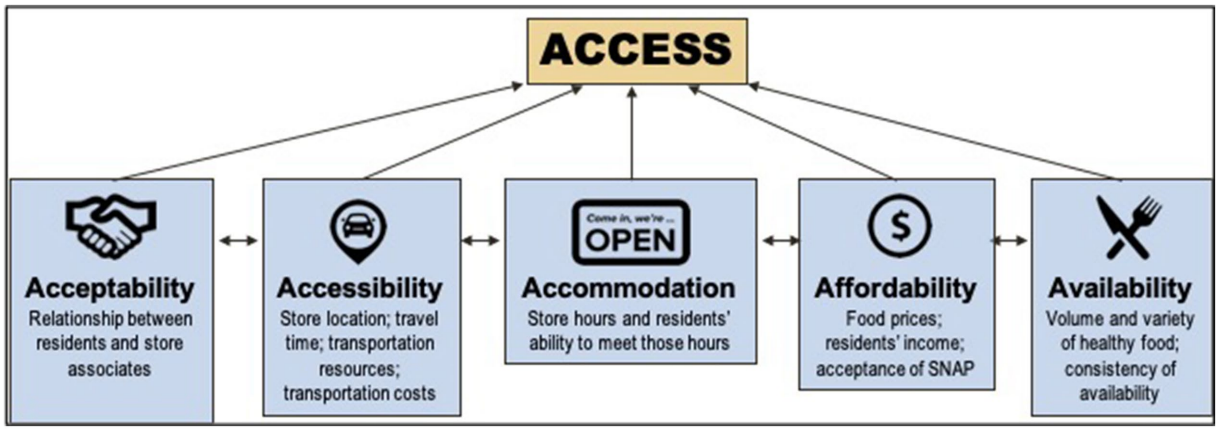

FIGURE 1
Usher (2015) five dimensions of food access.

initiatives associated with producing, processing, distributing, and consuming food. Systems Thinking can be instrumental in this regard, as this discipline and related literature provide a range of traditions, concepts, approaches, methods, and tools that have been central to the paradigm shift away from linear and reductionist thinking, and toward addressing complex issues and supporting systemic changes (Gates et al., 2021).

1.2 Objective

We broadly define food access as a phenomenon that is interpreted and uniquely experienced by the actor given their circumstances and positionality in the globalized food system at any given point in time. While objective attributes, such as food location, cost and availability are necessary to our understanding of the phenomenon, alone, they are insufficient to completely characterize access. The goal of this research is to operationalize the dimensions of food access models in the contexts of their interactions and the societal components of perception and objectivity (Anandhi et al., 2018; Gragg et al., 2018; Usher, 2015). The novelty of the work is its applicability across spatial and temporal scales. We argue that dimensions of access are critical to the analysis and decision making of sustainable food security for vulnerable populations in urbanizing food systems.

2 Methods

2.1 The methodology used in this study is described in the following steps

Step 1: We did an in-depth analysis of food access conceptual models and Usher (2015) Five Dimensions of Food Access and classified the dimension interactions into three levels using two societal components (perception and objectivity).

Step 2: We used the spiderweb diagrams, the interactions between the five dimensions (acceptability, accessibility, accommodation, affordability, availability) and the two societal components of objectivity and perception to explain conditions under the three hypothetical scenarios namely: no interaction, one-way interaction, multiple way interaction.

Step 3: We used the DPSIR framework diagrams, the levels of interactions between the five dimensions and objectivity and perception to explain the three hypothetical scenarios. We use the Driving Forces Pressure State Impacts Response (DPSIR) framework to develop causal chain diagrams for selected case studies (Kristensen, 2004; Patrício et al., 2016; Rodriguez, 2016). The DPSIR, a causal framework for describing the interactions between society and the environment, is utilized to analyze the cause-effect relations between the dimensions of food access utilizing the DPSIR components: drivers, pressures, state, impact and response model of intervention. Essentially, DPSIR converts the complexity of access across the urbanizing demographics and geographies into relatively simple, easily understood, cause and effect diagrams. These diagrams can be subsequently used to develop further analyses to better understand cause and effect in more detail. Accounting for the drivers and pressures that affect food access outcomes, our purpose is to advance a more holistic conceptualization of access to healthy food within urban (metropolitan) areas for utilization in the development of urban food policies and food access-related initiatives, with a particular focus on vulnerable populations.

Step 4: We used three case studies to develop/understand/plot the interactions between the five dimensions and objectivity and perception using spiderweb diagrams. The spider web diagram is utilized to demonstrate the degree of interactions among the five dimensions of food access with respect to the societal components of perception and objectivity. We make that argument by demonstrating the interactions utilizing the spider web diagram and the DISPR Framework—a well-established and utilized decision making tool (Patrício et al., 2016).

Step 5: We also used the three case studies to further elucidate and explain the interactions between the five dimensions and objectivity and perception using DPSIR framework diagrams.

Step 6: We developed an expanded conceptualization of access through the synthesis of the hypothetical cases and case studies. We then developed the descriptions of the five dimensions and objectivity and perception.

3 Results and discussion

3.1 Improved definitions and conceptual model (step 1)

3.1.1 Food access

The use of the word "access" (meaning a means of approaching or entering a place), which by its nature is an individualized notion, yet when used with "food" is often taken to imply a community (or even larger) scale. Past definitions and subsequent measures of food access have cited type and scale of purchasing location and distance to the purchasing locations as essential components of a definition, with most focusing on supermarkets and grocery stores as primary points of food access. But all food purchasing locations are part of the larger picture of food access, and spatial measurements are subject to their own local meanings based on the individual conditions within the community (Andress and Fitch, 2016; Penchansky and William Thomas, 1981; Usher, 2015).

Measures of objectivity are material facts in the food environment that can be quantified and measured directly. They are not influenced by personal feelings or opinions in considering and representing facts. Some examples are the number and type of food stores, location/distance, sidewalks, street lighting, cost of fruits and vegetables, income of customer (e.g., SNAP, EBT, farmers' market "bucks"), availability of fruits and vegetables speaks to volume and variety, transportation: mode, distance, time and costs (Andress and Fitch, 2016; Caspi et al., 2012; Dubowitz et al., 2015; Lytle and Sokol, 2017; Rahkovsky and Snyder, 2015; Sharkey et al., 2010).

Measures of perception are influenced by personal feelings, attitudes, or opinions in considering and representing facts. They can be quantified indirectly. Some examples include, personal feelings and attitudes toward existing objective, culturally relevant foods, ideas/feelings about a store, cleanliness, food quality, store workers. Perception incorporates the notion of *Accommodation: store hours, acceptance of EBT and SNAP, store credit*. This might be seen as Objective, but the customer's Perception of the store's measures of accommodation is what we are pointing toward. Lastly, one's perception of crime in an area impacts their food-buying decision (Andress and Fitch, 2016; Caspi et al., 2012; Cummins et al., 2014; Freedman and Bell, 2009; Hilbert et al., 2014; Motoyama and Usher, 2020; Penchansky and William Thomas, 1981).

Measures of interaction are characterized as None, One-way and Multi-way levels of interactions among the five dimensions of food access and the social components of objectivity and perception.

3.2 The interactivity framework

Existing models lack the interactivity among dimensions of access as well as the societal components: "Perception" and "Objectivity." In the adaptation (Figure 2), the gray triangle and the two circles are added to the original model to capture the view with respect to perception and objectivity.

To clearly describe/demonstrate the interaction, we are presenting it below with all the dimensions of access along with perception and objectivity. As a result of our analyses of the five dimensions of food access described by Usher (2015) and analysis of potential types of interactions described by Anandhi and Bentley (2018) and Bentley and Anandhi (2020) we derived the following interactions (Figure 3).

The interactivity framework which describes the interactions between the five dimensions of access in the contexts of objectivity and perception is illustrated (Figure 3). The first column in Figure 3, shows results from Usher (2015) where the five dimensions and objectivity and perception are seen as individual silos with no interactions among them. The second and third columns are this paper's reconceptualization of Usher (2015) and suggests one-way and multi-way interactions between the dimensions influenced by objectivity and perception.

This conceptualized framework is first visualized and described hypothetically using spiderweb diagrams (section 3.3) and the DPSIR frameworks (section 3.4). Next, to further explain the interactivity, they were applied to real-world problems using three case studies (sections 3.5) obtained from published literature using what we refer to as the "Interaction Analysis" (steps 1 - 3) process.

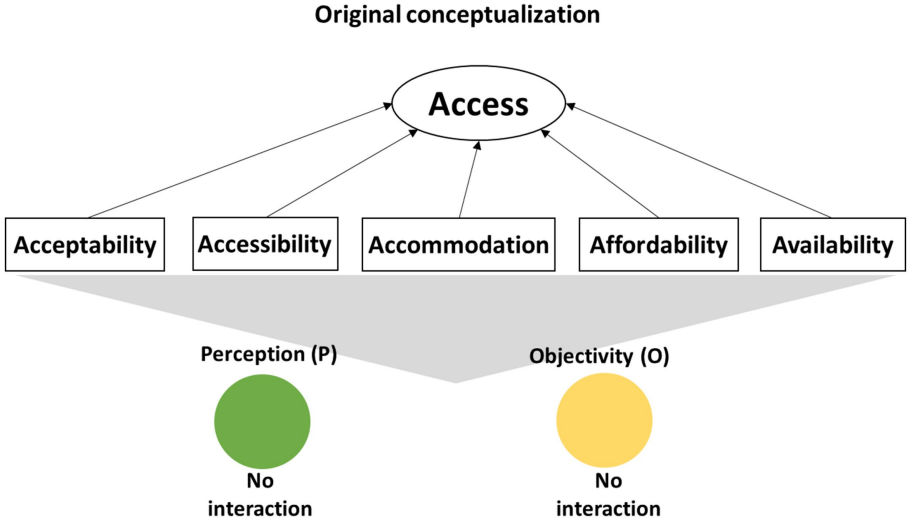

FIGURE 2
Starting model, adapted from Usher (2015) conceptual model.

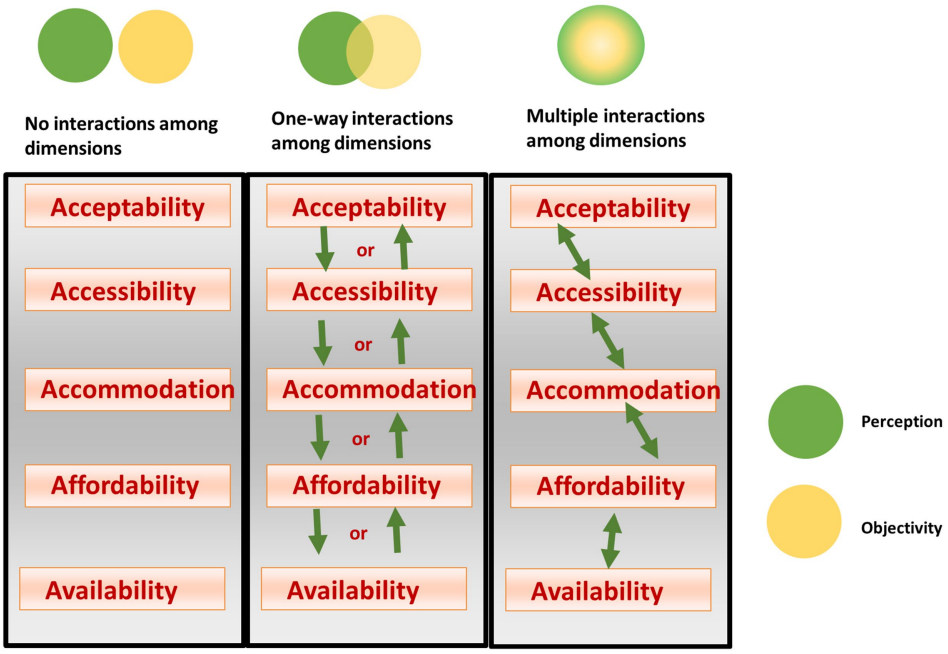

FIGURE 3
Interactivity framework conceptualized for food access.

3.3 Interactivity explained using spiderweb diagrams for hypothetical cases (step 2)

We developed the spider web diagrams (Figure 4) to conceptually represent the five dimensions and two measures individually for the three levels of interaction (Figure 2).

In this spider web diagram (Figure 4), we begin to model (or show) the hypothesized interactions and outcomes among objective and perceptive realities and the Five Dimensions of Access with three scenarios of increasing interactivity (rows). The corners of the spiderweb diagrams represent the indicator variables for each of the 5 dimensions. The length of the black line shows the trade-offs/differences among the least interactive (no interactions) to the most interactive (multi-way interactions), for the five dimensions and two silos.

The most complex Figure 4 scenario, as shown in row 3, depicts high, multi-way, and co-equal interactions among the five dimensions of food access and the social components of objectivity and perception. The least complex scenario, as shown in row 1, depicts no interactions and no influence among the dimensions and the social components. The intermediate complex scenario, as shown in row 2, depicts medium, one-way and variable interactions among the dimensions and social components. Here in general, the influence is intermediate between least and most complex scenario.

3.4 Interactivity explained using DPSIR framework for hypothetical cases (step 3)

From the corners of the spider web, the social components were viewed in the DPSIR framework (Figure 5). Causal chain and loop diagrams were developed.

Our model shows the interactions among the two (O, P) along with the exogenous drivers/variables, using the Driving Forces Pressure State Impacts Response (DPSIR) framework to develop the causal chain diagram (Figure 5). Essentially, the diagrams convert the complexity of access in urban food systems into relatively simple, easily understood cause and effect diagram for the three hypothesized interactions. They are used as an assessment of the linkages between problems and their underlying (root) causes. This can include intermediate causes, and the root causes that lead to the creation of the problem. The causal chain is an ordered sequence of events in which any one event in the chain causes the next. Causal loop is when an event in the chain causes an earlier event in the chain, then the loop developed is referred to as causal loop (Anandhi et al., 2018).

In the DPSIR framework, there is a chain of causal links (or components) starting with "driving forces" (e.g., population increase, temperature and precipitation change) through "pressures" (e.g., changes in freeze, rain, poverty) to "states" (five dimensions) and "impacts" on urban food systems, eventually leading to "responses" (prioritization, target setting). More examples of the DPSIR components are provided in the three case studies.

Describing the causal chain from driving forces to impacts and response is a complex task especially among the five dimensions of access. In the case of the least complex scenario (row 1; no interactions among dimensions) the cause and effect due to the dimensions is not clear and difficult to document. Therefor there is no visible causal loop. While the intermediate complex scenario (row 2; one-way interactions among dimensions) has an influence on DPSIR components only in a cyclic loop with not sub-loops. The most complex scenario (row 3; multiple interactions among dimensions) have all five dimensions influence component (Objective and Perceptive) is complete. This type of interaction can result in multiple causal loops.

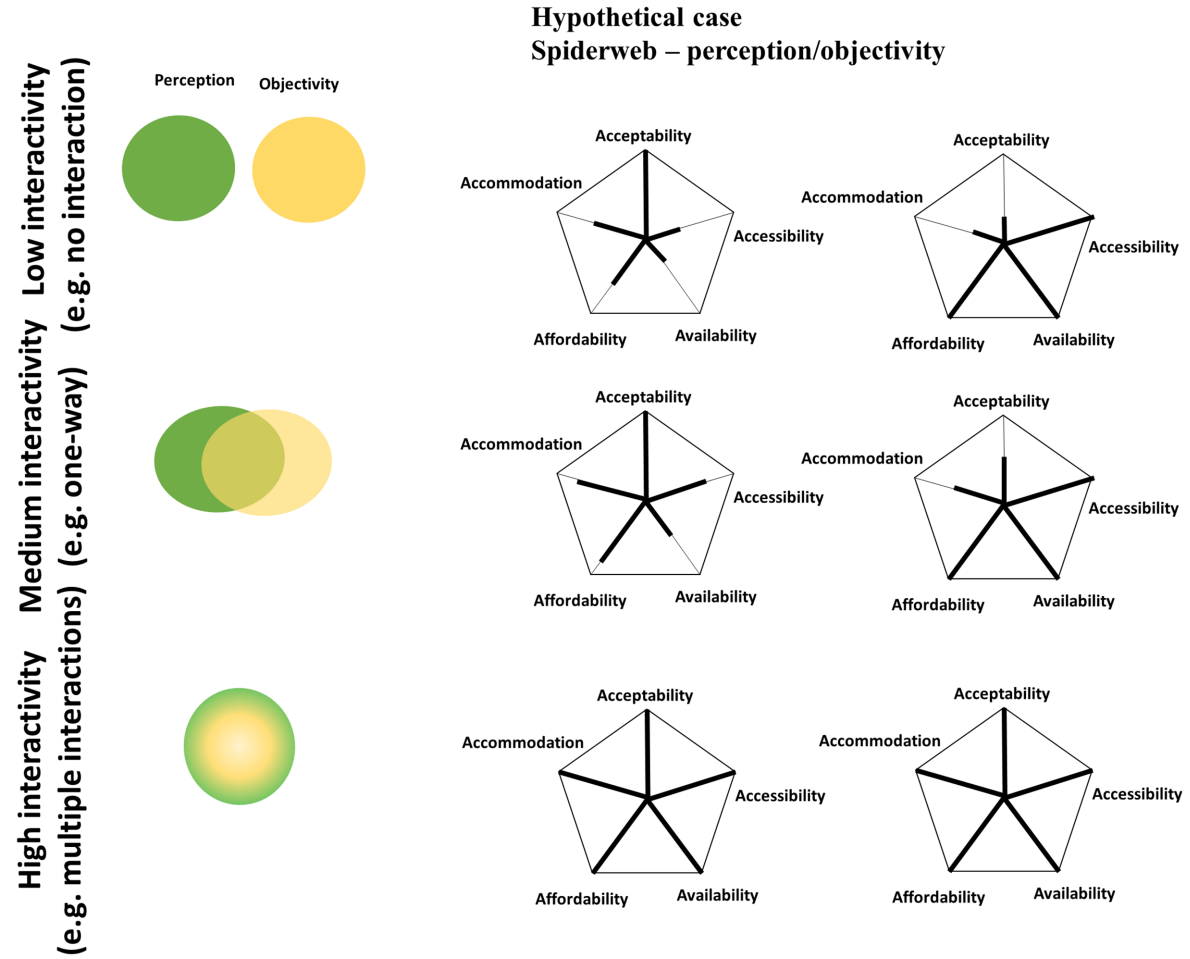

FIGURE 4
Hypothetical interactivity depicting interactions and outcomes (rows) between the two aspects of objectivity and perception (columns), and the five dimensions of access (spider diagrams).

3.5 Interactivity explained using spider web diagrams for three case studies (step 5)

In the following case studies, we apply our "Interaction Analysis" to demonstrate the interconnected relationships among the five dimensions of access in the context of perception and objectivity using spiderweb diagrams and the DPSIR framework.

3.5.1 Case study 1. Florida health: food access (regional scale)

This case[1] discusses four ways in which the State of Florida is working to increase access to healthy food to residents within the state. This is done by establishing and increasing the number of Farmers' markets in low-income, low-access areas, and concomitantly, increasing the number of *farmers' markets* that accept *SNAP* (Supplemental Nutrition Assistance Program), *WIC* (Women, Infants and Children) and *FAB* (Fresh Access Bucks).

When we applied the Five Dimensions of Access we found that:

- *Farmers' markets* align with *Accessibility* and *Availability*; however, *Acceptability*, Accommodation and Affordability and not directly addressed. Indeed, food at farmers' markets tend to cost more than at grocery stores. Also, farmers' markets tend to be seasonal and even during season they are not opened for an entire day. And although they provide fresh fruits and vegetables, these may not be culturally acceptable for peoples of all cultures particularly immigrants. The low interactions are applied to the DPSIR frameworks and are represented as dotted lines (Figure 6, row 1).
- *SNAP*, *WIC*, and *FAB* all address the dimension of *Affordability*. These in compliment to farmers' markets would improve access to healthy foods. However, they do not address the other dimensions.
- These interventions, while necessary, are not sufficient as they are focused on objective measures alone and do not consider subjective/perception nor temporal components.

1 https://www.floridahealth.gov/programs-and-services/community-health/food-access/index.html

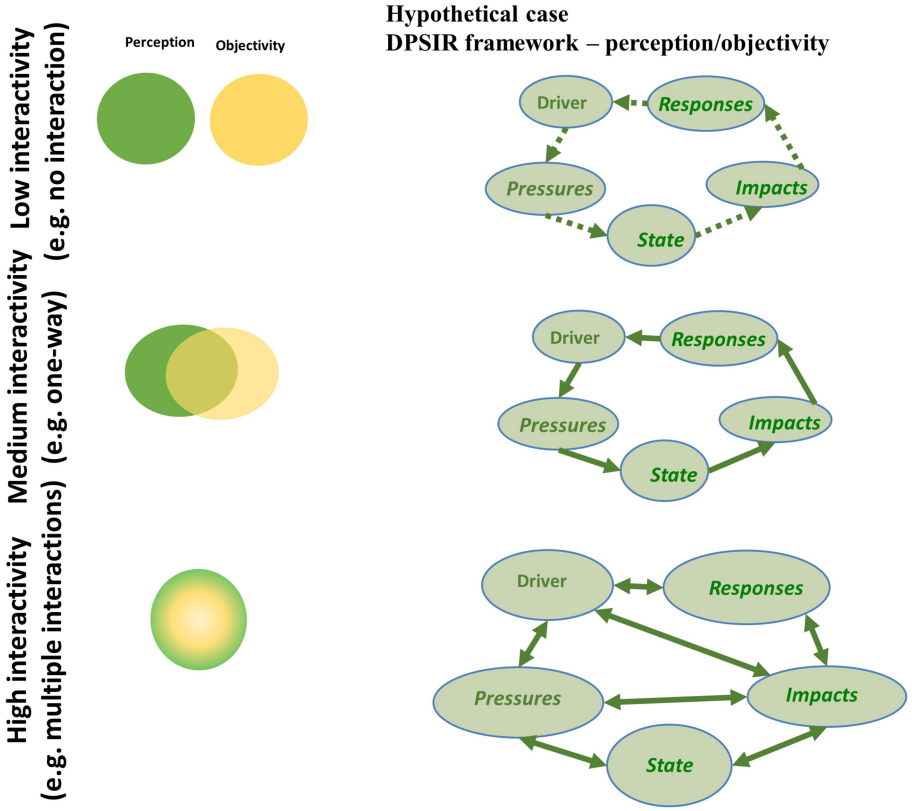

FIGURE 5
Depicts the hypothesized interactions and outcomes (rows) between the two social components, Objectivity and Perception, (columns) using DPSIR. The bold arrows in the DPSIR show the trade-off/differences between the least interconnected (no clear interactions) to most interconnected (two-way interaction) for the two. The dotted arrow represents the lack of clarity among the interactions.

3.5.2 Case study II. Food Security and Social Work at Virginia Commonwealth University

The Social Work program at Virginia Commonwealth University[2] specifically trains social workers to address food insecurity and food access. Social workers improve food access by providing residents with emotional support as well as knowledge and connecting them to services such as SNAP, WIC and the National Lunch Program. Here the perception is high.

In terms of public policy remedies, in February 2021, a bipartisan Bill[3] to increase access to healthy food in "food deserts" areas was introduced by Sen. Mark Warner of Virginia. The Bill sought to increase healthy food *Availability* by incentivizing grocery shops in low-access areas through subsidies for new store construction with 15% tax credit, retrofitting existing stores in the area, supporting new-build food banks with grants of 15% of construction costs and supporting "temporary access merchants" that have 501(c)(3) status such as mobile markets and farmers' markets grants for 10% of their annual operating costs. The medium interactions are applied to the DPSIR frameworks and are represented as solid lines with one-way arrows (Figure 6, row 2).

3.5.3 Case study III. Ecker & Breisinger Conceptual Framework (2012) (several scales form global/national scales to individual)

In this case,[4] This case study discusses the Ecker & Breisinger's conceptual framework presented in their IFPRI Discussion Paper 01166. They discuss three major shifts in how we conceptualize food and nutrition security: (a) From objective to subjective/perception indicators, (b) From global and national to household and individual, and (c) From food first to livelihood. They also offer Four Pillars of food security: Availability, Access, Utilization and Stability. The *availability* pillar relates to our conceptual model and the interaction between objectivity and perception is high across the scales. However, *Accessibility, Acceptability, Accommodation*, and *Affordability* are not directly addressed, and they are indirectly part of the other three pillars. For example, they are addressed indirectly at global/national scales while discussing the overall agricultural growth for lower food prices, agricultural exports/imports through trade and transport, health and education through high interventions (cost-effective,

2 https://onlinesocialwork.vcu.edu/blog/food-access/

3 https://www.warner.senate.gov/public/index.cfm/2021/2/warner-introduces-bipartisan-bill-to-increase-access-to-nutritious-foods-help-eliminate-food-deserts

4 https://ers.usda.gov/sites/default/files/_laserfiche/publications/45432/53943_err195.pdf?v=47702

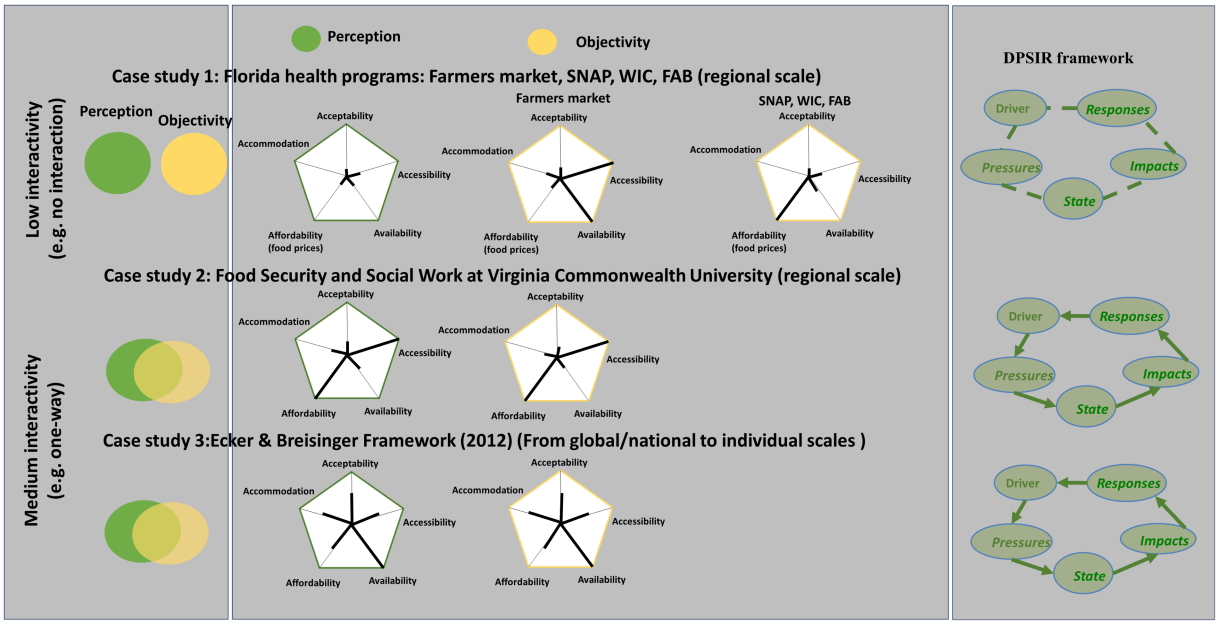

FIGURE 6
Interactions in case studies between the two aspects of objectivity and perception (rows), and the five dimensions of access (spider diagrams). The DPSIR framework (column) shows the cause-effect between the least interconnected (no clear interactions to medium interconnectedness one-way interaction) for case studies 2 and 3. The dotted arrow represents the lack of clarity among the dimensions interactions in case study 1.

increased awareness of nutritious food, etc.). At an individual scale they address volatility in nutrition supply, food shortages, intrahousehold allocation. Here we can observe medium interactivity among perception and objectivity.

The intersection of food systems and urban sustainability is a critical issue as cities confront growing populations and environmental challenges (Morain and Anandhi, 2022). The principles of sustainable cities rely on the integration of sustainability practices in urban and regional planning, building retrofits, green transportation, integrated waste management, environmental education, natural resource management, the food-water-energy nexus, and policymaking, among other factors (Elkamel et al., 2023; Bustamante et al., 2024). Systems thinking offers valuable insights on employing a comprehensive approach when enhancing food environments (Wopereis et al., 2024).

One key concern is ensuring equitable access to nutritious food, particularly in food deserts, where fresh produce is scarce. To address this Elkamel et al. (2023) an urban agriculture network linking different farmers' markets could be established. Residents without access to fresh produce could utilize green transportation (GT) options, such as electric vehicles (EVs), including autonomous electric vehicles (A-EVs), to improve mobility. This approach could help bridge the gap in food deserts, mitigating the impact of food insecurity while promoting more sustainable and accessible food systems.

Furthermore, the COVID-19 pandemic exposed vulnerabilities in urban food systems, underscoring the need for more localized, sustainable, and resilient initiatives such as rooftop gardens and community farms (Kaushik et al., 2023; Salisu et al., 2024; Simon, 2023). These solutions offer multiple sustainability benefits, including reduced food transportation emissions, improved local food security, and environmental advantages like mitigating urban heat islands, reducing cities' ecological footprint, recycling urban wastes, containing urban sprawl, protecting biodiversity, building resilience to climate change, stimulating regional economies, and reducing dependency on the global food market (Simon, 2023; Kaushik et al., 2023).

However, urban agriculture faces challenges such as limited space and regulatory barriers. Despite these obstacles, it remains a vital component of sustainable urban food systems, promoting local food production and reducing reliance on industrial agriculture (Salisu et al., 2024). Another pressing issue is food waste, with approximately one-third of food produced globally going to waste. Urban areas are increasingly exploring circular economy models, where food waste is repurposed into compost, animal feed, or bioenergy, helping reduce emissions and redistributing edible food to those in need (Oroski, 2025).

As cities continue to grow, adopting sustainable food practices, reducing waste, and promoting local food production will be crucial in making urban environments more resilient and equitable, contributing to long-term urban sustainability (Karn et al., 2023).

The role of food systems in urban sustainability becomes even more complex during and after disasters clay. Urban agriculture has demonstrated its potential to support recovery by establishing food supply bases within cities and surrounding areas, contributing to long-term food security and urban resilience (Dakubo, 2021). Additionally, the ability to produce disaster-preparedness food, with a short shelf life necessary to support disaster survivors from the time of the event until life returns to normal, highlights the growing importance of local food production and urban agriculture (Çakmakçı et al., 2023). Ecosystems health, a model consisting of an iterative cycles of participatory study design, knowledge generation, intervention, and systematization of knowledge plays a greater role (Charron, 2022). The benefits of this approach include innovations that improve health,

evidence-based policies that reduce health risks; empowerment of marginalized groups through knowledge gained, and more effective engagement of decision makers.

4 Expanded conceptualization of food access (step 6)

Starting with the original conceptualization (Usher, 2015), our goal is to arrive at a more holistic conceptualization of the phenomenon of "food access" that more closely illustrates reality. This expanded conceptualization is important if we are to develop effective and just policies to improve the health, safety and wellbeing of our entire community. We posit that there are three major areas: the five dimensions of access, the social components of perception and objectivity, and the interactions among both areas. The final image in the figure displays this evolution (Figure 7).

In the first image (Usher, 2015), we illustrate the 5 Dimensions that constitute access—Acceptability, Accessibility, Accommodation, Affordability and Availability. Just below are the two social components of Perception and Objectivity. We offer that these two lenses/components are necessary "bi-focal" through which access can be realized. Objectivity represents the collection of physical and quantifiable elements that make up the local food environment: stores, distances, fruits and vegetables, (time, hours of operation), food costs, transportation resources. Perception addresses both the notions, ideas, feelings and attitudes of the individual perceiver of the physical/objective components of access in the food environment and the intangible characteristics of the perceiver: culture, race, ethnicity, gender, age and others.

The Spiderweb diagrams (Step 1, 3) are graphical illustrations of hypothetical interactions (possibly also representing real and hypothetical food policy initiatives) among the 5 Dimensions. Access is said to be achieved when all five lines are fully extended. So, building on the first image, we took those 5 dimensions and show their relationship among themselves. Next, after acknowledging that the 5 dimensions are interrelated and interact with each other, we build on this idea by showing how they effect and are affected by elements in the system. These interactions are characterized with the use of the DPSIR framework (Step 2, 4).

Finally, in the last image (far right), we rebuild and improve our conceptualization of access. This image illustrates that the phenomenon of access is comprised of 5 dynamic Dimensions always interacting with each other and interpreted through the lenses of Objectivity (physical and tangible components of the local food system) and Perception (personal/private/resident-oriented) qualities (Step 5). Food access (true, complete, holistic) is achieved when the 5 dimensions are each fully realized, and objectivity and perception are aligned. The interaction identified between food access dimensions can inform policy, urban planning and community-based interventions to promote equitable access to healthy food (D'Hooghe et al., 2024).

5 Summary and conclusion

Access to adequate food is a core social determinant of health (Kent et al., 2020). During the COVID-19 pandemic, reduced access to food, price gouging of foods in response to increased demand impact the ability of rural residents to buy enough healthy food to meet their needs (Kent et al., 2020). A visitor in a city living in a hotel downtown (e.g., Raleigh, NC) may find it difficult to find grocery shops with healthy fresh fruits and vegetables for salads. Their options are often just restaurants or shops with processed foods. It is often difficult to find shops in google search engines when fresh fruits and vegetables because they can be part of a general store.

The objective of this study was to explore the interactions of the dimensions of food access with the view of making urban food systems more sustainable. Three levels of interactivity are hypothesized: no interaction, medium interaction, and high interaction. The interactions among the five dimensions and two social components are conceptualized using spider web diagrams. The DPSIR framework was used to explore the additional interactions of the two social components, resulting in an expanded conceptualization of food access with three levels of interactivity applied to three case studies to clearly show the interconnected relationships among the five dimensions of access in the context of perception and objectivity using spider web diagrams and the DPSIR framework. Moreover, this paper incorporated insights from Systems Thinking, which has been crucial in understanding the intricate, interconnected nature of

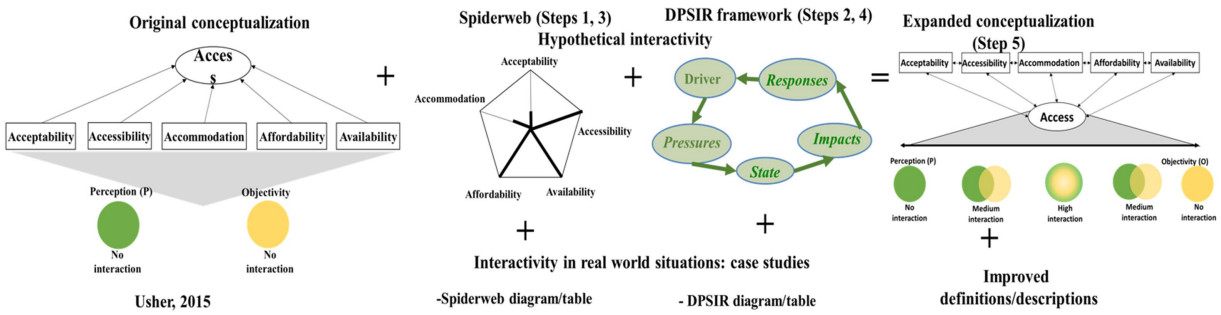

FIGURE 7
In depth analysis of edited Usher (2015) (Figure 1, above) + Spiderweb + DPSIR = revised Figure 1 by interactions (add 2-way arrows, in scale, and cross level (dimensions) interactions).

sustainable food systems. Systems Thinking allows for a comprehensive analysis of how various sub-systems within the food system interact and influence each other, offering a robust framework for tackling sustainability challenges. Ecosystem approaches to health, which emphasize holistic and systemic perspectives, are also considered. These approaches underscore the interdependencies between ecological and human health, advocating for integrated strategies that enhance both environmental and human well-being.

Future research will address the spatial and temporal aspects of the dimensions of food access, integrate these dimensions into the DPSIR framework, and adapt the conceptualization model for vulnerable populations.

Author contributions

AA: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. KU: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. RS: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing. MJ: Conceptualization, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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