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INCREASING THE USE OF SPATIAL DATA IN URBAN HOUSEHOLD-LEVEL FOOD SECURITY MEASUREMENT

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Abstract

Measuring urban food security in Africa is challenging because the current food security metrics were designed for rural contexts, and often feature a bias toward food availability, yet limited urban food production means urban food security measurement requires a multi-dimensional evaluation that also takes stock of the spatial and behavioural dimensions of food security. Current metrics are poorly suited to evaluate urban food security because they do not incorporate the spatial and behavioural dimensions of urban livelihoods, which relate to the variability of entitlements across space and how urban infrastructure accessibility enhances or constrains the choices available for a household to select. In this paper, we illustrate why the spatial dimensions of urban food security are critical to include in household-level evaluation of food security, with specific focus on the lived experience of vulnerable urban households. We then identify how the behavioral dimensions of food security are inseparable from infrastructure, how the association between poverty and stress influences choices, and how infrastructure and decision-making are connected to agency. Lastly, we highlight how integrating spatial data on food retailer distribution, transportation networks, and population density can enhance existing food security metrics in the urban context. Enhancing our approach to measuring urban food insecurity will provide insight into the spatial inequalities that can limit household choices and shape household agency.

Keywords

urban food security, spatial inequalities, urban livelihoods

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Introduction

Food insecurity must be appropriately and accurately measured to create effective policy (Barrett, 2010). An appropriate food security metric must identify who is food insecure and where they are located (De Haen et al., 2011). Unfortunately, no single measure of food security can capture the multi-dimensionality of food security (Barrett, 2010; Becquey et al., 2010; Carletto et al., 2013). As a result, researchers have developed multiple metrics to capture different aspects of food security. Despite the prevalence of these tools in the development community, how to effectively measure food security remains an important challenge and point of contention (Barrett, 2010; Headey & Ecker, 2013; Jones et al., 2013).

Historically, food security-related issues in Africa have focused on rural areas (Crush & Frayne, 2010), yet increased urbanization and concomitant increases in urban poverty challenge our theoretical conceptualization of food security and which aspects of food security are relevant in the urban context. While the importance of evaluating food security in urban areas continues to rise, our ability to effectively evaluate it has stagnated. In southern, eastern, central, and western regions of Africa urban populations are expected to grow from around 375 million people in 2015 to over 1.25 billion people by 2050 (United Nations, 2018). The growth of urban areas in different African regions will exacerbate existing challenges to urban livelihoods, notably urban food insecurity. Multiple studies have quantified aspects of urban food security by using metrics developed for rural areas (Battersby, 2019; Becquey et al., 2010; Blekking et al., 2020; Crush et al., 2018; Tuholske et al., 2020). Using metrics developed for rural areas does not account for the drivers of food insecurity that are prevalent in urban areas, such as spatial and infrastructural inequalities (Haysom & Tawodzera, 2018).

The goal of this discussion paper is to outline how urban household food security measurement and monitoring can be improved. We describe the nature of urban food security, how the current metrics evaluate household-level food security, outline important spatial and behavioural dimensions, and comment on how existing spatial data can be used to understand access and agency in the urban context. We pay special attention to the importance of incorporating the lived experience of urban food insecurity, including how households navigate the spatial layout of an urban area and food system-related infrastructure to access food and how the spatial features of an urban food system shape the choices available to a household and the behavioural dimensions of food security. For this research, we draw largely from empirical studies conducted in urban Africa, because subregions within the continent contend with high rates of urban poverty (World Bank, 2018), food insecurity (FAO, 2021), and urbanization (United Nations, 2018). We use the household as the level of examination because this is where food consumption often occurs (Wilk, 1990), and including household-level information is essential to link food security with livelihood experiences (Barrett & Maxwell, 2007).

The paper is organized as follows. In the next section, the history of the conceptualization and development of food security is detailed. We then highlight the importance of economic access for household-level food security and identify why using primarily economic factors to assess food access can misrepresent the lived experience of urban food security. In the following section, we illustrate why the spatial and behavioural dimensions of urban food security are important to include in urban food security measurement. We also consider the relationship between the spatial distribution of the food system and household food security, because of the nested nature of household food security within urban food systems.

Conceptualizing Food Security

Early iterations of measuring food security first considered and evaluated the absolute quantity of food available, and the amount of food required to feed a population (Barrett, 2010). This approach stemmed from concerns over widespread famines

in India and other regions (Davis, 2000). Ensuing studies critiqued this approach and illustrated an overemphasis on the role of food production and availability (Webb et al., 2006), and ignored food security issues that occur at sub-national scales. In the 1970s and 1980s, Amartya Sen reframed food security considerations from national and regional perspectives to also include the household- and individual-level. Sen (1981) argued that people rarely go hungry due to absolute shortages of food, rather hunger persists as a result of households and individuals having limited entitlements – the ability to produce food for self-consumption or exchange with others to acquire food.

Using entitlements as a framework for considering food security allows for a conceptualization of the systemic conditions that facilitate or limit food security. Food security is related to both availability and accessibility. By including accessibility, conceptualization of food security evolved from an objective approach to include subjective aspects (Maxwell & Slater, 2003), emphasizing the perceptions and experiences of a household (Webb et al., 2006). Utilization is the third dimension of food security and encompasses food preferences, food safety, and household dietary needs (Barrett, 2010). The fourth dimension of food security is stability, which relates to ebbs and flows in availability, accessibility, and utilization. Stability is consistent with Sen's notion of the waxing and waning of entitlements (Sen, 1981). The four dimensions of food security were then aggregated into a single conceptualization of food security, "a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). The Food and Agriculture Organization's High Level Panel of Experts on Food Security and Nutrition have recently proposed an extension of the framing of food security to also include agency and sustainability as dimensions (HLPE, 2020). Agency refers to the ability of people within a broader system having the ability to exercise control over their own circumstances (Clapp et al., 2021). Issues pertaining to agency are linked to inequality and consolidation of power by food system actors. Food security is embedded within food systems - a form of social-ecological system (Ericksen, 2008), and, as a result, sustainability must also be considered to ensure environmental and human well-being. Importantly, the food security dimensions are not hierarchical, rather they are complimentary. An over-emphasis or exclusion of one or more dimensions may provide an inaccurate assessment of food security.

Conceptualizing and Measuring Urban Food Security

Household-level food security metrics fall into two broad categories: experience-based metrics that account for what the household did when faced with food insecurity and consumption-based metrics that evaluate the type and amount of food a household consumes (Cafiero et al., 2014). In rural areas, low agricultural production (or more directly low availability due to seasonal production and growing season-related shocks) is often cited as the driver of food insecurity (WFP, 2022). In contrast, the seasonal production schedule of food does not necessarily drive food insecurity in urban areas. When a household lacks the entitlements necessary to obtain the food they require their access is limited. Current metrics are rural-focused and emphasize the role of food availability and production shortfalls (Haysom & Tawodzera, 2018), meaning urban food security is mismeasured using current metrics. Urban household-level food security is often limited through access – "whether the household has adequate resources for acquiring appropriate foods for a nutritious diet" (FAO, 2006, p. 1), and urban food access is the result of household- and community-level economic and spatial characteristics (Battersby, 2019). As Headey and Ecker (2013, p. 338) note, "If measurement really does drive diagnosis and response, then mismeasurement of food insecurity presumably drives misdiagnosis and inappropriate responses." Focusing on presence or absence of certain foods from household diets does not provide detail as to why food is (or is not) consumed.

Barring large-scale shocks to a food system, food is typically available in urban Africa; therefore, unavailability is less of a limiting factor to urban food security. In urban areas household economic characteristics (i.e. income, employment stability, and assets) are critically important to ensuring food access (Demmler et al., 2017; Webb et al., 2006). Economic food access in any context is the result of three underlying characteristics: income, food prices, and social safety nets (Barrett, 2010). Some urban food security studies use income as a proxy for food security due to the high correlation of the two (Peyton et al., 2015) and because income is often a proxy for poverty - which is also highly correlated with food security (Wratten, 1995). The high correlation stems from the fact that urban food security is associated with broader issues related to structural inequality in urban areas (Maxwell, 1999; Battersby, 2019). Assessing urban food security only in terms of income portrays food security as a singular issue related to economic standing and does not capture the broad structural and systemic inequalities related to uneven access to, investment in, and provision of social safety nets, public services, and infrastructure in urban areas.

During periods of high food prices, food access is unevenly distributed across socio-economic groups. Low-income households often spend over half of their income on food – when food price shocks occur these households must pay more for food or alter their food consumption behaviour (Tadasse et al., 2016). Higher-income households can withstand the economic shock because their real income is less impacted by increases in food prices. Looking strictly at food prices overlooks other costs associated with procuring and preparing food, like home energy and transportation costs. Furthermore, household income is distributed across a number of fixed costs not directly associated with food consumption (D'Souza & Jolliffe, 2016), such as education and medical expenses, rents, and contributions to larger social networks. Focusing only on food prices neglects the broader economic context in which household decision makers exist. When household-related costs are too high, urban households alter their consumption patterns or seek out alternative avenues to procure resources, such as through social safety nets.

Accounting for both the formal and informal social safety nets households rely on provides a better understanding of the lived reality of urban households. Formal social safety nets created by the state or social organizations use tools like food ration cards and cash payments to improve urban food security (Anand et al., 2019); however, informal social safety nets are also critical (Crush, 2013). Informal safety nets facilitate flows of income and food transfers (Crush & Caesar, 2018; Devereux, 2002), and even facilitate the movement of individuals to households that are more financially stable (Crush, 2013). Considering the extent of a household's informal and formal social safety nets provides insights into how social relations and social policy can help to mitigate food shortfalls. Insight into the size, location and stability of these social safety nets indicates the extent to which they can facilitate food access when other sources are not available. Just as ebbs and flows in income or food prices can affect food security, so can changes or instability in social safety nets.

The Spatial and Behavioural Dimensions of Food Security

In this section, we focus on 1) how the spatial dimensions of food access, including both local infrastructure and the spatial layout of the food system, shape what food-related choices are available to a household, and 2) how the food choices available to a household shape the behavioural responses to food security and relate to agency.

The Spatial Dimensions of Food Security

Identifying where food insecure households are located and assessing their access to affordable, preferred food is the primary reason why it is important to understand the relationship between space and food security. Given the importance of targeting

in food security (Barrett, 2010) and the centrality of access (both economic and spatial) within urban food security, it is surprising that current metrics are not more spatially explicit. The spatial dimensions of food security relate to the physical infrastructure of an area, the investment and development of the food retail sector, and limited physical access to food. Previously, the concept of food deserts was used to highlight some of these challenges, and while the concept of food deserts has largely been retired from academic circles (Widener, 2018), the conceptual point that food security can vary spatially based on systemic inequalities remains a point worth evaluating.

The physical infrastructure of a city, like transportation, energy, and water infrastructure, can encourage or limit food security (Frayne & McCordic, 2015). The distribution of necessary infrastructure throughout a city is linked to urban planning – unfortunately different forms of infrastructure are not uniform across the urban landscape and uneven development and access can limit food security (Pothukuchi & Kaufman, 1999). Typically, urban planners in Africa are not tasked with considering food needs (Haysom, 2021), and the lack of food-related planning indirectly contributes to food system inequalities and household-level food security. Cities in Africa tend to develop rapidly through checkerboard patterns of physical development (Cobbinah et al., 2015), with uneven investment in and development of public infrastructure. This form of development can enhance existing urban inequities by creating areas of socio-economic segregation (Hemerijckx et al., 2022). Vulnerable populations living in undeveloped or underserved areas of rapidly growing cities can face increased challenges as a result of travel times and costs (Wegerif, 2020), and food prices (Battersby & Crush, 2014). For instance, limited public transportation and long commuting distances can both independently and jointly limit urban household food security through increased transportation and transaction costs. Transportation costs are compounded through other infrastructure shortfalls, like poor energy infrastructure. Households with poor energy access are not able to refrigerate food, thus they may be required to purchase food more frequently (e.g. daily or every other day) (Crush & Frayne, 2011). Food security is also intertwined with water access. Unsafe or inaccessible water is increasingly recognized as a contributing factor to food insecurity around the world (Brewis et al., 2019; Young et al., 2021). For instance, in a study from Kenya, water insecurity predicted future food insecurity among study respondents (Boateng et al., 2020). The interconnectedness of infrastructure with food security outcomes highlights the importance of integrating space into our evaluation of urban household food security.

Most food security measurement occurs at the individual, household, or national level (Haysom & Tawodzera, 2018), but community-level factors also matter, like the local food retail environment. Uneven investment in and development of the urban food retail sector further contributes to food-related inequalities. Households throughout Africa's sub-regions exist across a broad range of socio-economic standing, thus requiring a range of food retailers to source food from, like public markets, supermarkets, small shops, street vendors, and, increasingly, supermarkets (Battersby & Watson, 2018). As such, local food systems feature a wide array of food retailers that sell different quantities of food and at variable prices (Blekking et al., 2017). The need to source from different outlets and uneven distribution of retailer types across space can exacerbate the food insecurity of households (Battersby & Watson, 2018). Environmental factors can significantly influence food choices for better or worse (Larson & Story, 2009). For instance, research from South Africa finds that both urban poverty and food security rates are associated with the presence or absence of key infrastructure and use of different retailer types across space (Davis et al., 2022). Research from a small city in Zambia finds significant correlations between where households reside and which food retailer they typically purchase from (Blekking et al., 2022), suggesting that convenience guides food security decisions. Evidence from Vietnam shows that the food retailers available and accessible to households within an urban area shape the food budget and choices available to the household – directly influencing food consumption (Wertheim-Heck & Raneri, 2019). By not

considering the spatial layout of food retailers in our evaluation of urban food security, we fail to identify important linkages between households and food purchasing behaviour. Altering our conceptualization of food security to include an understanding of how households interact with their respective food retail environment may serve as a useful approach to improving urban household food security measurement. This approach will enhance existing research that links food access, infrastructure, and spatial variability.

The Behavioural Dimensions of Food Security

The behavioural dimensions of food security connect to food systems through "situated agency" – the ways in which inequalities in society constrain people's ability to exercise control over their own life circumstances (Peter, 2003). In other words, the choices available to the household are constrained by variations in their social and physical environment and are thus defined by the food system. For instance, public markets and street vendors are critical sources of food for vulnerable urban households (Tuholske et al., 2020; Wanyama et al., 2019), but government responses to these retailers, like removing them or delegitimizing their work in the name of modernizing cities or enhancing food safety (Kiaka et al., 2021), can limit the choices vulnerable households are able to opt from. Changes in how agency (i.e., their place within the overall food system) is perceived or feelings of a loss of empowerment can transform the social embeddedness of food - how consumers identify with and value their food (Friedmann, 2019). Including agency as a dimension of food security in metrics shifts our conceptualization of choice from an issue of aggregation at the individual-level to an issue of participation and inclusion at the community-level (Peter, 2003). The current household food security metrics are not structured to assess the agency of urban households or provide insights into how they process or act on information in the context of existing inequalities.

Current metrics treat the experience of food insecurity and subsequent coping as if actors are responding optimally, and measure household behaviours against assumptions predicated on normative reactions. Yet, humans tend to make "boundedly rational" decisions in situations of limited information or uncertainty – due to a lack of time to plan, complexity of the problem requiring a decision, and the cognitive capability of the mind (Simon, 1955). Chronic poverty creates situations in which households exist in circumstances that are not normative, and can lead to feelings of futility (Kiser & Black, 2005), which makes navigating everyday challenges difficult for households - often leading them to struggle with making important tradeoffs. For instance, Spears (2011) used an experiment involving casual laborers in India to show that poverty is associated with challenges in differentiating between tradeoffs - those with fewer resources struggled to make choices. Assuming households will follow predicative responses during periods of upheaval or chronic poverty hampers our understanding of food security if the underlying relationship between the behavioural dimensions of food security are not well understood or accounted for. To contend with food insecurity, urban households make choices to mitigate or cope with food insecurity based on available information regarding the food system. The behavioural dimensions of food security are about understanding the types and relevance of information people have access to, how that information is processed, and identifying if they can make choices based on concerns emanating from that information – a central aspect of agency.

Considering feelings of inclusion and exclusion related to local food environments can shed light on the situated agency of households. Feelings of exclusion or being ignored can also affect the cognitive state of humans (Baumeister et al., 2002), which has important implications for agency as a food security dimension. Poverty and livelihood shocks can further increase levels of anxiety and worry, changing decision makers' affective state (Haushofer & Fehr, 2014). Changes to the affective state of a decision maker can influence how choices are made, responses are selected, and feelings of empowerment and agency. For instance, research from Hanoi, Vietnam, found that residents understood the government's rationalization to

modernize the food retail sector, but felt powerless to voice their misgivings about the approach (Wertheim-Heck & Raneri, 2019). The lived reality of vulnerable households in the context of poverty and uncertainty is that they regularly encounter food security limitations – beyond information shortfalls – related to the spatial layout of where they live, time, and economic standing. Due to the challenges vulnerable households face, they may make strategic choices that encourage risk-averse behaviour or are preferable for achieving short-term goals, but increase poverty, food insecurity, or adversely impact another livelihood outcome in the long-term (Haushofer & Fehr, 2014). For example, households may choose to consume processed foods and carbonated drinks because energy sources for preparing food are too expensive or water for home consumption is unsafe, despite the understanding that highly processed foods are linked to negative health outcomes (Popkin et al., 2012). Limitations can spur the use of behaviours that are often broadly classified as unhealthy food choices. These choices reflect strategic decisions involving balancing trade-offs between immediate needs and longer-term consequences of the choices – something current metrics do not account for. Current experience- and consumption-based metrics account for specific actions or coping strategies employed but do little to account for the ways in which households make decisions under uncertainty.

Ideally, identifying variables related to the affective state of a household through household surveys would increase our understanding of the behavioural dimension (i.e. preferences and feelings of inclusion among others). By combining affective state variables with an understanding of the choices that households make, we can enhance our understanding of how the food retail environment relates to participation in and inclusion of the food system. However, survey data is financially costly and time intensive to acquire and often only targets selected areas (Hemerijckx et al., 2020), thus our ability to directly evaluate the behavioural dimensions of food security are limited. Instead, leveraging spatial data can provide an understanding of the physical inequalities that constrain people's ability to exercise control over their own life circumstances.

Situating Agency with Spatial Data

We focus on two sets of contributions to improving food security metrics. The first is to situate agency by using spatial data to develop a contextualization of the food environment that households interact with. Because the spatial dimensions of food security broadly shape the choices that are available to households, leveraging spatial data to understand the interplay between agency and access will enhance our ability to integrate the behavioural dimensions of food security into measurement in the urban context. Then, we discuss three easy to acquire pieces of spatial data that can be used to evaluate urban food security: retailer locations, public transportation routes, and population estimates. The integration of spatial data in food security evaluations can provide sub-city scale evaluation, while also providing city-wide overviews.

Two important benefits highlight the usefulness of remote sensing spatial data products for evaluating urban food security. First, they are cheaper to acquire than collecting household-level survey data (Burke et al., 2021). Second, they offer the opportunity to identify the associations between the spatial layout of an entire city and household outcomes across disparate sub-areas of a city (Hemerijckx et al., 2020). Using spatial data does not supplant household surveys, rather spatial data supplements household-level data by contextualizing the environment in which households reside and make choices. Three remotely sensed pieces of data are critically important for improving our understanding of urban food security in the context of urban areas that are increasing in spatial footprint and population, while also undergoing important food system changes: food retailer types and locations, transportation networks, and population density.

Incorporating the spatial distribution of food retailer types and public transportation can provide insights into the food retail environment with which households interact, broader food system transformations, and mobility patterns. Most urban households in

Africa purchase their food (Davies et al., 2020), and the retail environment in urban areas is rapidly transforming (Reardon et al., 2021), in part due to the increased development of supermarkets and limited investment in public markets by local governments (Battersby, 2017). The United States Department of Agriculture's (USDA) Food Access Research Atlas (FARA) (USDA, 2022) provides an example of how the interaction between households and food retail environments can be spatially assessed. By considering relationships between retailer locations, transportation opportunities, and socio-economic status, FARA identifies areas of high (low) access to food retailers. However, this approach would need to be modified for the urban African context due to a lack of available and accessible socio-economic data and the fact that African households rely on a range of food retailer types for purchasing food. Retailer data and transportation routes can be analyzed using spatial models to create covering models that are inclusive of a broad set of retailers, representative of real world mobility requirements (e.g. time and financial costs, directness), and can be reformatted to meet the demands of local policy makers or as on-the-ground contexts change (see Nantz et al., 2020). Identifying the types of retailers that are available and accessible across space will enhance our understanding of the context in which current metrics report experiences and consumption outcomes.

Due to the correlation between food insecurity and income, it is advantageous to use a measure of livelihood, like the Census tract variables used by FARA, in assessing urban food access. However, this form of data is either often non-existent, difficult to access, or expensive to collect in urban Africa. Instead, remotely-sensed population estimates can be used to gain insights into where potentially vulnerable populations live. One approach is to use household-level survey data in conjunction with remote sensing to train a machine learning algorithm for use across a broader spatial extent (sometimes referred to as upscaling). For example, Hemerijckx et al. (2020) used socio-economic household data from Kampala, Uganda, to train a remote sensing algorithm to classify land types into four housing categories to determine where socio-economic groups are residing across the city. In areas where no survey data is available, remotely sensed population estimates can be used to identify population densities at sub-city scales. For example, Blekking et al. (In Review) use WorldPop-derived population density estimates of residential areas in Lusaka, Zambia, in their comparison of supermarket and public market development rates from 2004 to 2020. We acknowledge that critical assumptions are required to use population data as a proxy for socio-economic data; however, the lack of available livelihood data requires use of proximate data. It is also important to note that considerable strides have been made in recent years to improve gridded population estimates using remote sensing (Burke et al., 2021). Each of these examples illustrate how using remotely sensed spatial data in urban food security studies can improve representativeness – enabling cross-level and socio-economic class comparisons. Often urban food security studies collect household data from specifically-targeted low-income areas, which can be helpful in targeting aid, but creates a myopic view of food security outcomes in the city as a whole (Hemerijckx et al., 2020). Using remotely sensed spatial data in connection with information on the distribution of food retailers and transportation networks would provide a contextualized representation of urban food security across an urban area at sub-city scales, and provide critical insights into the food systems and conditions that situate household agency and impact food access for across the socio- and spatio-economic spectrum.

Conclusion

Changes in choice availability can impact the situated agency of a household, but it is difficult to understand household choices because current food security metrics do little to capture the spatial or behavioural dimensions of food security. The spatial dimensions of food security include local infrastructure and the spatial layout of the food retail environment, and these features shape which food-related choices are available to a household. Uneven distribution of food retailers, transportation

networks, and water and electricity access, among other community-level infrastructure all impact the spatial layout of an urban area and can alter the set of food-related choices available to a household. We argue that more direct integration of spatial data can supplement existing household-level food security metrics to help provide a more nuanced and appropriate evaluation of urban food security. Integrating spatial data will help to broaden our conceptualization and evaluation of urban food security across scales, while also providing nuanced insights into how urban food security is nested within transforming food systems. Continuing to use current metrics that were developed for use in rural areas, without enhancing existing metrics for use in urban contexts, will restrict our ability to appropriately assess urban food security and accurately target programming and aid.

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