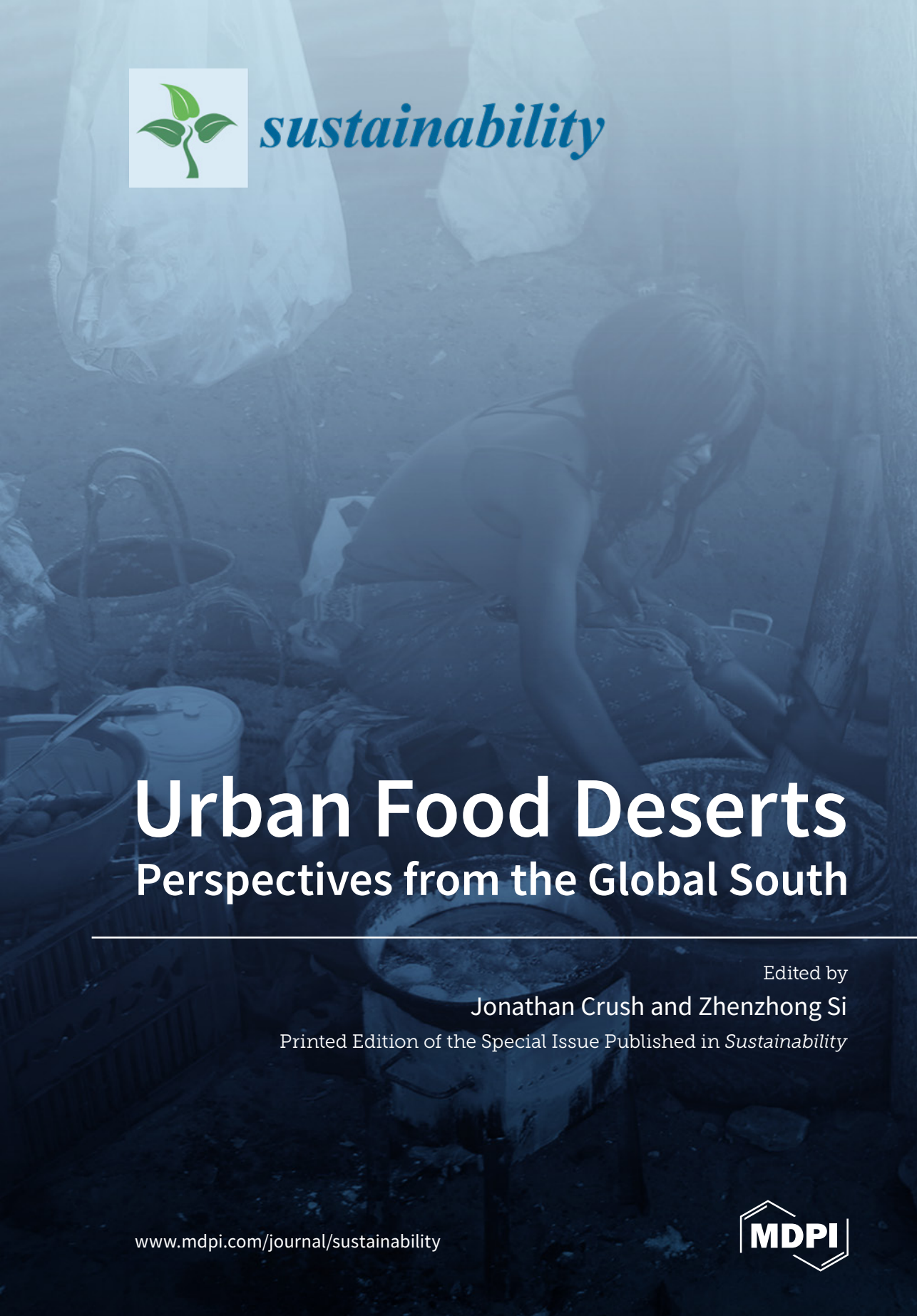

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Urban Food Deserts

Perspectives from the Global South

Edited by

Jonathan Crush and Zhenzhong Si

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Cover image courtesy of Jonathan Crush

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Preface to "Urban Food Deserts: Perspectives from the Global South"

Food Deserts in the Global South: Mirage, Metaphor or Model

Jonathan Crush and Zhenzhong Si

The rapid and accelerating urbanization of the Global South has been accompanied by a major transformation in food systems, growing food insecurity and unhealthy food consumption (Crush et al., 2020). A recurrent question is whether concepts and methodologies used to understand deprived neighbourhoods in cities of the Global North have any relevance to the unfolding dynamics of urbanization in the Global South. One such concept is the representation of urban spaces as "food deserts". Over the last two decades, the terminology of the "food desert" has generated vigorous debate across the social and health sciences on issues of definition, identification, measurement, location, characteristics and health impacts (Sadler et al., 2016). The term first entered the policy and research arena in the UK in the 1990s as part of a government effort to understand and address the issue of lack of access to foods integral to a healthy diet in low-income neighbourhoods in British cities (Wrigley et al., 2002; also Cummins and McIntyre, 2002; Whelan et al., 2002). As part of a major study of the city of Leeds, Wrigley (2002) defined food deserts as "the complex nexus of interlinkages between increasing health inequalities, retail-development induced differential access to food retail provision, compromised diets, undernutrition and social exclusion." From here, the genealogy of studies of food deserts took two different directions. In the UK, it initially led to a complex classification of different types of food desert (Shaw, 2006) but increasingly came to be seen as a potentially stigmatizing metaphor (McEntee, 2009) and fell out of general use. Shannon (2014, 2016a) and Widener (2018) imply that everyone should, in effect, follow the British example and retire the term altogether.

In North America, however, food deserts were increasingly viewed as real entities with specific quantifiable characteristics demanding particular public and private policy interventions (Walker et al., 2010). Wrigley's complex and somewhat awkward formulation was stripped to the bare essentials, with the United States Department of Agriculture defining a food desert in technocratic fashion as "a low-income census tract where a substantial number or share of residents has low access to a supermarket or large grocery store" (USDA, nd). The assumption was that supermarkets and large grocery stores were the optimal, indeed only, purveyors of healthful foods, and that food deserts were urban spaces in which the residents enjoyed limited or no access to these food retail outlets. As Dutko et al. (2012) noted with statistical precision, food deserts are "low-income tracts in which a substantial number or proportion of the population has low access to supermarkets or large grocery stores" and in which at least 500 people or 33% of the tract population reside more than one mile from a supermarket or large grocery store in urban areas. Others disaggregated further and suggested using census blocks rather than tracts as the basic unit of food desert analysis (Alviola et al., 2013). Dutko et al. (2012) concluded that 4175 census tracts in the US fit their urban food desert criteria (or 23% of all low-income tracts and 8% of all urban tracts). Chen et al. (2016) later found that the food desert status of census tracts was positively associated with rates of obesity

While the appeal of statistical exactitude for interventionist policy-makers battling poor diets and the obesity pandemic in American cities is clear, various critics have taken issue with this formulation of the food desert and the implication that expanded access to supermarkets will

inevitably have positive nutritional and health-related impacts. Researchers have argued, for example, that the idea of food deserts is more a mirage than a metaphor (Winegar, 2020). First, they suggest that food access is not the only, or indeed the primary, driver of dietary behaviour, as posited by the food deserts literature. In this vein, Rodier et al. (2017) and Wright et al. (2016) argue that access to supermarkets is not the main factor in whether or not households consume healthier foodstuffs. Second, some have questioned whether the advent of supermarkets in food deserts automatically leads to greater availability, access and consumption of healthy food (Allcott et al., 2019; Dubowitz et al., 2015; Ghosh-Dasditar et al., 2017; Shannon, 2016). Third, equating healthy food access with supermarket presence/absence ignores the presence and role of other actual and potential sources of healthier foods, including farmers and ethnic markets (Brinkley et al., 2017; Joassart-Marcelli et al., 2017). Finally, there is the argument that the conventional literature on food deserts downplays or overlooks the key role of unhealthy but accessible food sources, including fast food outlets and supermarkets themselves (Vaughan et al. 2017). The newer focus on unhealthy eating has led to the labelling of some urban spaces as "food swamps" rather than deserts, defined as areas with a high density of establishments selling high-calorie fast food and junk food relative to healthier food options (Cooksey-Stowers et al., 2017; see also Lucan et al., 2020; Osorio et al., 2013; Otterbach et al., 2021; Yang et al., 2020). The alternate term, "obesogenic environments", is sometimes used to describe a combination of poor food consumption and sedentary lifestyle (Townshend and Lake, 2017).

Turner et al.'s (2020) recent survey of food research in the Global South identified "a significant research gap given the fundamental differences between HICs [High-Income Countries] and LMICs [Low- and Middle-Income Countries] with regard to food systems, food environments, food acquisition and consumption practices, and public health nutrition challenges." They find only a smattering of case studies focused on whether food deserts, conventionally defined, exist in cities of the Global South (Su et al., 2017; Bridle-Fitzpatrick, 2015; Davies et al., 2017; Gartin, 2012; see also Gartin, 2015). A similar review of research on urban food environments in Africa makes no mention of food deserts at all (Osei-Kwasi et al., 2020), although the same authors use the more generic term "deprived neighbourhoods" in their study of unhealthy eating practices in urban Ghana and Kenya (Holdsworth et al., 2020). The emerging African urban food security literature has argued, in essence, that in African cities, classic food deserts are at best a metaphor and more likely a mirage (Battersby, 2012; Battersby and Crush, 2014; Crush and Battersby, 2016). In other words, this essentially mechanistic Northern conception seems to have no place in the new urban lexigraphy of Africa and the South more generally (Parnell and Oldfield, 2014).

The limited application of the concept of food deserts in the Global South is certainly not because poverty and food access insecurity in towns and cities is not a problem. On the contrary, lack of access to healthy foods is endemic in many cities and spatially concentrated in informal or slum settlements (Crush, 2016; Ruel et al., 2017; Tacoli, 2020). Evidence is rapidly mounting about the nature, extent and drivers of the access dimension of urban food insecurity and inequality in Africa (Battersby and Watson, 2019; Crush et al., 2018; Frayne et al., 2018, Owuor, 2018; Raimundo et al., 2018; Tuholske et al., 2020), Asia (Anand et al., 2019; Rautela, 2020; Koduganti et al., 2019) and Latin America and the Caribbean (Capron et al., 2018; Kinlocke et al, 2019; Rossi et al., 2017). Various reasons have been advanced for why the concept of food deserts has been marginal to date in the growing literature on urban food insecurity in the Global South (Crush and Battersby, 2016; Tacoli, 2020). First, there are currently significant data limitations at the city level, constraining the kind of spatial mapping and analysis common in the literature on food deserts. Such data could certainly be collected, but current

city-wide data on food consumption and sourcing behaviour has to be generated at some cost (in a context where much research funding is directed towards rural rather than urban food issues) (Crush and Riley, 2019). Second, the association of supermarkets with healthier consumption patterns that was central to the earlier food deserts literature has never been replicated in the Global South. On the contrary, the well-documented "supermarket revolution" (das Nair, 2020) is more often associated with a nutrition transition involving increased consumption of unhealthy foods and an associated pandemic of obesity and non-communicable disease (Hawkes, 2008; Kimenju et al., 2015; Popkin, 2017; Popkin and Reardon, 2018; Zhou et al., 2015). While supermarkets have a limited presence in many low-income neighbourhoods and informal settlements, they do not appear to have a significant positive nutritional impact when they become more physically accessible (Battersby and Peyton, 2016; Demmler et al., 2017; Holdsworth et al., 2020; Khonje and Qaim, 2019; Peyton et al., 2015; Wanyama et al., 2019). This finding, at least, is consistent with the emerging critique of supermarkets and food deserts in North America cited above.

Third, as Battersby and Crush (2016: 12) argue, the dynamism and complexity of the informal food economy offers a particular set of challenges to the conventional food deserts approach. The informal food sector (which includes informal markets, street vendors, mobile vendors, home-based traders and informal shack structures) is an essential component of the foodscape in all cities of the Global South, despite the best efforts of governments to eliminate, control or circumscribe its activities (Young and Crush, 2020). In many countries, informal and formalized small-scale food vendors operate out of publicly sanctioned food markets, which, along with other forms of informal vending, play a critical role in making food more accessible in low-income and impoverished urban neighbourhoods, many of which are also informal (Si et al., 2019). Although the jury is out on the importance of non-market food sources, both urban and peri-urban agriculture and rural–urban food remittances are also potentially important routes of access to food in deprived neighbourhoods (Conforti et al., 2020; Crush and Caesar, 2020).

Growing reservations about the concept of food deserts in the Global North and limited uptake in the Global South raise an obvious set of questions. Do conventional food deserts actually exist in rapidly urbanizing cities and towns in the South? Or is the concept of food deserts simply a helpful metaphor to highlight profound spatial inequities in healthy food availability and access in urban spaces? Or should it simply be dismissed as a misleading mirage without form or substance? Another alternative is to (re)model the concept and redefine the term to "fit" Southern urbanization and food system realities. Crush and Battersby (2016: 13) argue that any use of the food deserts concept in the South requires a much more sophisticated understanding of multiple market and non-market food sources, the spatial mobility of informal food retail and poor consumers, the changing dynamics of food security over time, the inter-household differences that lead to different experiences of food insecurity, and the specific conditions that lead to compromised diets, undernutrition and social exclusion. They propose an alternate definition of Southern urban food deserts as "poor, often informal, urban neighbourhoods characterised by high food insecurity and low dietary diversity, with multiple market and non-market food sources but variable access to food." While the chapters in this book do not necessarily subscribe to this alternative definition, most address questions and hypotheses about the spatial dimensions of food retailing, food accessibility, food consumption and food outcomes suggested by such a (re)modelling of the Northern concept of food deserts.

Article 1, by Jane Battersby, revisits the relevance of the food desert as a concept and policy tool in Africa and concludes that it offers both opportunities and risks. She argues that the policy fix for food

desertification of promoting supermarket expansion rests on three problematic assumptions: that supermarkets improve access to healthy food, that residents of low-income areas have poor access to healthy foods and that food insecurity in urban areas is simply about economic and physical access to food outlets. Based on data from South Africa, Zambia and Kenya, she systematically deconstructs each assumption, concluding that supermarkets are not providing access to healthy food but rather are increasing the consumption of processed foods and accelerating the nutrition transition; that many residents in low-income areas do have very food access to fresh produce through informal vendors; and that food utilization (not availability and access) is the key determinant of food insecurity in urban centres. As a result, the model of supermarkets as a pathway to food security derived from the orthodox food deserts literature is inherently problematic as a policy fix.

Article 2, by Jeremy Wagner, Lucy Hinton, Cameron McCordic et al., suggests and tests three alternative models from the food deserts literature—what they refer to as classic food deserts (Model 1), food deserts plus (Model 2), and food deserts in the Global South (Model 3 as redefined by Crush and Battersby (2016)). They then test the validity of each of these models using household survey evidence from two contrasting cities: Mexico City and Nairobi, Kenya (Capron et al., 2018; Owuor, 2018). Through testing various hypotheses about the relationship between food insecurity and consumer purchasing behaviour, they conclude that food deserts in the South "should not be understood through the proxy measurement of supermarket access," since this ignores the plurality of food sourcing options that residents patronize. They conclude with a call for greater understanding of the complexity of food deserts that includes factors such as mobility, transportation, time, education, structural inequalities and neighbourhood policy environments.

Article 3, by Jonathan Crush, Ndeyapo Nickanor and Lawrence Kazembe, suggests that city-wide surveys may help identify food and nutrition security inequality and spaces of deprivation, but it is important to drill down into the food environment in these urban spaces and assess whether they resemble any of the orthodox and newer definitions of food deserts. They build on the earlier analysis of Nickanor (2013) and Nickanor and Kazembe (2016), labelling urban informal settlements in Namibia as food deserts and showing that these are spaces of extremely high vulnerability to food insecurity. However, at the same time, they are not food-deprived. Formal and informal retailers ensure that food is available. Poor households do not patronize supermarkets for fresh produce but rather find it more economical to buy staple cereals in bulk on a monthly basis from distant supermarkets and rely on informal vendors for daily food purchases. In these informal food deserts, however, poverty and irregular income mean that most are unable to access food in sufficient quantity, quality, variety and regularity.

Article 4, by Cameron McCordic and Ezequiel Abrahamo, develops the core idea that residents of low-income food deserts are not all equally deprived or food-insecure. One of the major failings of the conventional food deserts approach is that it does not incorporate a gender analysis of food inequality and accessibility (Riley and Dodson, 2020). Using household survey data from the twin cities of Maputo and Matola, Mozambique, their paper demonstrates that compromised household access to water, electricity, medical care, cooking fuel, and cash are all associated with increased odds of severe household food insecurity. In addition to the spatial accessibility of food retailers and food items, they argue that social support networks (including family structure) influence the degree of vulnerability to food insecurity associated with urban food deserts. Their analysis confirms the findings of others that female-centred households (with a female head and no male spouse or partner) are more susceptible to severe food insecurity than other household types (Riley and Legwegoh, 2018;

Riley and Caesar, 2018).

Article 5, by Feyisayo Oduntiwan-Wayas, Kufre Okop and Robert Dover et al., focuses on the food purchasing behaviour and perceptions of supermarket shoppers in the City of Cape Town, South Africa, using data from intercept surveys. The primary objective of the paper is to compare the food choice behaviours of supermarket shoppers from low, middle and higher socioeconomic areas and to show how consumers from these different areas differ in their perceptions of supermarket produce and healthy foods. They also disrupt the notion that food choice behaviour is conditioned purely by the local food environment. Many lower socio-economic shoppers were not from the neighbourhoods where the supermarkets were located, instead engaging in what they and others have called "outshopping", related primarily to the fact that they live in supermarket-deprived areas but work (and food shop) in areas of the city where there are more supermarkets. The practice of outshopping disrupts a fundamental premise of the conventional food deserts approach that implicitly assumes that residents of food deserts only purchase their food within the boundaries of the desert itself.

Articles 6 and 7 reorient the food desert discussion by focusing on the nutrition transition and increased consumption of processed foods (Reardon et al., 2021). They address the question of whether the food environment of urban centres in the Global South is increasingly dominated by unhealthy consumption behaviour and therefore whether the idea of food deserts should be replaced by that of food swamps or obesogenic environments (Bridle-Fitzpatrick, 2015; Drimie et al., 2013; Kimagi-Murange et al., 2015). In this context, Article 6 by Bruce Frayne and Cameron McCordic notes that while the literature on food deserts focuses on the limited availability of food in urban settings, food swamps may better characterize the extensive prevalence and accessibility of cheap, highly processed foods. Their paper focuses on the long-term health vulnerability implications for children of limited access to adequate and nutritious food in rapidly urbanizing cities. Their analysis uses African Urban Food Security Network (AFSUN) data for over 6000 households drawn from low-income neighbourhoods in 11 cities and 9 countries in Southern Africa. They find that children in these households consume a limited diversity of food and are more prone to experiencing both short-term and long-term food and nutrition insecurity.

Article 7, by Florian Kroll, Elizabeth Swart, and Reginald Annan et al., provides a comparative analysis of the drivers of increased consumption of ultra-processed, energy-dense and micronutrient-poor foods, and the associated rapid rise in rates of obesity and NCDs in two different African settings: Ghana and South Africa. Their paper explores correlations and linkages between neighbourhood and household food environments, as reflected in household purchasing and consumption patterns of obesogenic foods in two low-income neighbourhoods in Accra and Cape Town. They find high levels of purchase and consumption of ultra-processed foods in both urban settings, although household food environments promoting obesity are more prevalent in Cape Town and neighbourhood food environments, also make obesogenic foods more accessible and available, despite the greater incidence of poverty in the former. At the same time, households experiencing income deprivation consume far less obesogenic foods. Thus, within food swamps, higher incomes appear to be correlated with greater obesogenic food consumption.

Article 8, by Taiyang Zhong, Zhenzhong Si, and Jonathan Crush et al., examines the very different context of Nanjing, China, where private–public partnerships and a highly interventionist food system policy has all but eliminated severe household food insecurity (Zhong et al., 2019). Central to the Nanjing food system is a city-wide network of open markets selling fresh produce,

and although the market share of supermarkets is growing, they tend to be the main source of the processed and convenience foods that are becoming more prevalent in the diets of the city's residents. The paper revisits the whole concept of food accessibility and, by extension, the inconclusive evidence that the neighbourhood food environment impacts diet and obesity (An et al., 2020). Using data from a 2015 HCP household survey, the paper examines whether dietary diversity is in any way associated with physical proximity to the two major food outlets. The resultant insignificant correlations are attributed to high physical accessibility to food outlets and the extensive spatially dense food supply network constituted by wet markets, supermarkets and small food stores in Nanjing.

Article 9, by Camila Borges, William Cabral-Miranda and Patricia Jaime, also focuses on the major food sources in their study of the food environment in Sao Paulo, Brazil, against the backdrop of the Brazilian Dietary Guidelines recommendation to avoid the consumption of ultra-processed foods. They inventory the food items in over 600 different food retail outlets (including grocery stores, bakeries, convenience stores, butchers and fish markets, supermarkets/hypermarkets/wholesalers and municipal markets of fruits and vegetables) and show the availability of unprocessed foods, ingredients, processed foods and ultra-processed foods according to retail types. They actually find that supermarkets/hypermarkets/wholesalers were the outlets with the greatest availability of both minimally and ultra-processed foods. Public markets also had high availability of minimally processed food items and amongst the lowest availability of ultra-processed foods. Spatially, as predicted by the classic food deserts model, they report a lower density of food retailers selling healthy foods in low-income neighbourhoods. Other urban spaces in the municipality are classified as food swamps or, as they observe, "areas that have adequate access to healthy foods but are flooded with opportunities to consume calorie-dense foods and drinks."

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The Food Desert as a Concept and Policy Tool in African Cities: An Opportunity and a Risk

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Abstract: The idea that food insecurity can be resolved by increasing the presence of supermarkets has been gaining traction in African cities and has recently gained political traction in Africa. This paper interrogates the potential value and risks associated with the adoption of the discourse of the food desert in the African context. The paper draws on findings from a households survey, neighborhoods-scale food retail mapping and surveys, and city-wide supermarket mapping conducted in Cape Town (South Africa), Kisumu (Kenya), and Kitwe (Zambia). Following a discussion of why the concept is gaining traction, the paper identifies false assumptions associated with the food desert framing in Africa, namely: supermarkets provide better access to healthier food, low-income areas have poor access to healthy food; and food security can be reduced to economic and physical accessibility. The paper concludes that although the food desert concept may be valuable for African researchers to provoke debates about systemic inequality, the food desert policy narrative should be rejected as it is ill-informed by the lived experiences of food insecurity in African cities and may promote policy interventions that erode rather than enhance the capacity of the food system to meet the food security needs of African urbanites.

Keywords: food desert; food security; food justice; African urbanism; African food systems; food policy

1. Introduction

Having gained significant political traction in the United States, United Kingdom, and elsewhere in the global North, the idea that food insecurity can be resolved by addressing food deserts through increasing the presence of supermarkets has been gaining traction in African cities. Government support of supermarket expansion has been implicitly and explicitly articulated by urban policy makers in public statements, planning decisions and official documents.

In Kenya, for example, the national government's Vision 2030 document released in 2007 stated the intention to increase the market share of products sold through "formal channels (e.g., supermarkets) from the current 5% to 30% by 2012" in an effort to "move towards greater efficiency in the country's marketing system" [1] (p. 13). In Zambia, the growth of Shoprite has been attributed, at least in part, to tax rebates and import tariff concessions [2]. Local governments articulate supermarkets and shopping malls as not only having the potential to "provide the council with more revenues but also beautify the city" [3] (p. 136). This articulation by policy-makers has been informed, in part, by influential academics who have argued that supermarkets have the potential to improve food security in developing countries [4].

The language of the food desert itself is a recent addition to the policy lexicon and has layered a food security framing on top of this existing predilection towards supermarkets. The most explicit articulation is found in the City of Cape Town's Resilient Cape Town: Preliminary Resilience Assessment [5], which reflects on the findings of Cape Town's reporting against the Rockefeller

Foundation's 100 Resilient Cities indicators. This document asks "Where are the food deserts in the city? How can we improve access to affordable and nutritious food?" [5] (p. 75). The invocation of a food desert framing marks a shift in political discourse about urban food insecurity in Africa.

The purpose of this paper is to interrogate why the language of the food desert is gaining political momentum in the African context and what the potential impact of food desert-led policy framings on food security may be. Additionally, it reflects on whether the food desert as an analytical tool has value in the African context. Central to this discussion is the definitional politics of food deserts, and how varying definitions reflect different political framings of food insecurity and trigger divergent types of solutions.

The paper first grounds itself in a discussion of the ways in which food insecurity has historically been framed and engaged in the African context. This discussion is used to explain why the supermarketization-as-pathway-to-food-security notion has begun to gain political traction. Following this, the paper then critically engages the linkages between the concept of the food desert and its mobilization as a policy tool.

Having situated the concept of the food desert and its mobilization in literature and policy debates, the paper then engages with three weaknesses of the food desert concept as currently articulated with African cities, namely: supermarkets provide better access to healthier food; low-income areas have poor access to healthy food; and, food security can be reduced to economic and physical accessibility in narrow terms. These assumptions are challenged by findings from research in Cape Town (South Africa), Kisumu (Kenya), and Kitwe (Zambia), three of the countries in Africa that have been most politically open to supermarket expansion. The current market share of supermarkets in South Africa is estimated to be up to 75% of all grocery sales, with an estimated 92% of stores being from South African-owned companies [2,6]. The estimated market share of supermarkets in Kenya in 2003 was 20%, and there has been considerable expansion since then, although no conclusive figures are available. The Kenyan supermarket sector is largely dominated by domestic companies [7]. In Zambia, in 2009 it was estimated that supermarkets had a 12% market share [8], and as in Kenya, there has been significant expansion in the number of supermarkets since then. According to 2016 figures, just four of the 77 supermarkets counted in Zambia were Zambian owned, with South African stores dominating the sector [2] (p. 322).

The work seeks to address what Thow et al. [9] have identified as an under-researched area, that of consumer interaction with food supply via purchasing behavior, by consolidating food security and food systems data from two research projects explicitly designed to address the dialectic relationship between consumers and the food system in the three case study cities. The paper concludes by reflecting on how the concept of the food desert may be productively engaged by food researchers in Africa.

2. Framings of Food Security in African Cities

This section interrogates why the supermarket has come to be viewed as a solution to food insecurity in African cities. To do so, the section first examines how urban food security has historically been engaged in African food security policy. It follows this with a discussion about the discourses of urban development in Africa and how the supermarket embodies some of the aspirations of urban modernization.

For the purposes of this paper, the 1996 FAO (Food and Agriculture Organization of the United Nations) definition of food security is used: "the situation that exists when all people, at all times, have physical and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [10] (p. 169). On the basis of this definition, the paper also frames food security in terms of the four pillars proposed by the FAO: Availability; Food Access (Physical and Economic); Utilization; and Stability [11].

This definition and framing is the one most commonly used by governments in Africa and development agencies when engaging questions of food security. However, this paper

argues that despite this adoption, policies and programmes have failed to engage all four pillars and have therefore often failed to work towards food security as defined.

Historically, and currently, global- and national-scale food security reports and policies have disproportionately framed food insecurity as a rural problem. Crush and Riley [12] provide an overview of the ways in which the FAO's annual State of Food Insecurity and State of Food and Agriculture reports have persistently neglected urban food insecurity. They further demonstrate how African Union reports and other continental publications replicate the narrative evident in the FAO documents. This rural framing persists despite the recently released initial findings of a 146-country survey by the FAO which found that 50% of urban populations in least-developed countries were food insecure, compared with 43% in rural areas [13] (p. x).

As a result of this framing, the primary targets of food security policy are rural smallholder farmers. Current approaches to food insecurity are therefore dominated by what has been termed the "twin-track approach" of "(a) direct interventions and social investments to address the immediate needs of the poor and hungry (food aid, social safety nets, and so on) and (b) development programmes to enhance the performance of the productive sectors . . . , create employment and increase the value of assets held by the poor" [14] (p. 529). This approach largely ignores the principle of the four pillars on which food security is supposedly built. It highlights availability and access through direct provision.

It has been argued that this current rural bias in policy is a corrective against the historic urban bias in national policies. Indeed, much of African agricultural policy has been designed to ensure a constant flow of basic food to supply urban labor at relatively low prices [15]. The state historically controlled much of the food system through marketing boards, control of milling, regulation of market sites, and control of land use to prevent urban agriculture which would compete with food produced by commercial agriculture [16]. Governments in Africa have therefore sought to address a base level of food security through focusing on ensuring availability and economic accessibility of staples [17]. However, this rigid state control of the agricultural system has declined with the end of marketing boards and failures of local government to control market sites [3]. The sweeping liberalization of African food systems has enabled large-scale private sector actors to position themselves as partners in development [18]. This shifting role of the private sector in the food system is echoed in the urban system. Large private sector actors are increasingly creating city visions and funding new developments shaped by an economic growth agenda [19]. As a result of this, shopping malls are commonly viewed as deliverers of local economic development, employment, and as symbols of modernity [20], despite their frequent economic failures and clear mismatch with urban morphologies in many African cities [21].

As control of the food system shifts from public to private sector actors in Africa, it is unsurprising that supermarkets are viewed by city planners as effectively replacing state-managed market places as the means by which urban residents access affordable food. The rise of the language of food deserts in African cities must be understood in the context of the shifting power structures within both the food system and the urban system.

However, while support for supermarkets as a means of private delivery of a public good (i.e., affordable food) is implicit, as typified by Zambia [2], formal urban food security policy focusses almost exclusively at the household scale [22]. Municipal governments in Africa generally do not have a formal food security mandate as a result of the historical framing of food security as a rural issue, and therefore have very limited policy and programming to address the challenge. Any programs tend towards interventions at the household and individual scale, such as support for urban agriculture, direct social assistance, and nutrition education. It is clear though that the determinants of food security extend beyond the household and individual scales. From a research and policy perspective, the concept of the food desert forces a shift in scale and framing of food insecurity, from the household to the neighborhood and city scale, and from being a problem of poverty to being one of structural inequality. It is therefore of value to consider the use of the food desert concept as a way to progress

policy framings. However, at the heart of the food desert work is a contradiction, which has been evident from its earliest application in the US context.

3. The Food Desert as a Concept and a Policy Tool in the US

There is a fundamental tension at the core of the food desert concept between its use as an analytical tool and a policy tool. The food desert as an analytical tool has been extremely influential in raising civic and political awareness of challenge of food insecurity in the United States. The origins of the concept of the food desert are important to note in the context of this paper's argument. The first recorded articulation of the problem of the food desert was by a resident of a Scottish public sector housing scheme in the early 1990s [23]. The fact that the concept was first articulated by civil society actors and not academics or policy-makers is important, as it perhaps explains why there is no single agreed upon definition of food deserts in the academic context, but also because it situates the identification of the problem as a community-driven, context-specific issue.

Unlike in the African context where food insecurity has generally been analyzed and responded to at the household scale, the way the food desert concept has been mobilized by academics and civil society actors privileges the community/neighborhood scale. In doing so, it has the potential to raise issues about structural inequalities in the food system and how this inequality co-exists and is compounded by other forms of structural inequality [24] through evocative maps providing undeniable evidence of inequity when poor food access data are overlaid on other spatial indicators. The early food desert work therefore highlighted issues of income poverty, race, and mobilities and other markers of structural inequality [25,26]. Further, it drew attention to urban planning and financing processes which drove the development of food deserts, historicizing the food desert the context of residential and retail redlining [27]. The food desert was therefore viewed as a political problem to be engaged, not a policy problem to be fixed.

Despite cautions from academia to not conflate food deserts with the absence of supermarkets mboxciteB28-sustainability-395854,B29-sustainability-395854, the adoption of a national food desert mapping project by the USDA in 2009 reinforced this simplistic framing of the issue and effectively depoliticized it. While a firm definition of food deserts had been (intentionally?) elusive to food justice researchers, the USDA provided a single definition of a food desert. A food desert, according to the USDA is "a low-income census tract where a substantial number or share of residents has low access to a supermarket or large grocery store," and "large grocery stores" are "stores with at least $2 million in sales that contain all the major departments found in a traditional supermarket" [30]. This definition does three things. Firstly, it simplifies the relationship between consumer and food retail, ignoring people's lived geographies and foodways [31]. Secondly, it privileges large retailers over other forms of access to healthy foods, be they small retailers, farmers markets, or urban agriculture [32]. Finally, it makes the food desert a problem to be solved by large private sector actors and reduces the agency of residents. Activist scholars have equated the relationship between the state and supermarkets in food desert amelioration efforts as akin to land grabs in the global south, both driven by public subsidies and below market land prices. They have argued that the current food desert framing is ahistorical, failing to acknowledge the reasons for current retail geographies [33]. Researchers have also highlighted the way in which incentivized supermarket entrance into areas labelled as food deserts acts as a form environmental gentrification, ultimately driving multiple forms of displacement [34].

As Block et al. [35] (p. 204) have noted, "Food access inequalities highlight how the experience of living in poorer communities is hugely different from the experience of living in wealthier ones and that these differences can even lead to increased death. However, their abilities to highlight these inequalities often leads to a public response that focuses on only the food stores themselves, rather than a broader focus upon the broader inequalities in economic investment, political and economic power, and health that the food desert issue highlights." The food desert concept had its origins in a community articulation of food system injustice, the policy trajectory marks an erasure of community agency.

The power of food desert maps as a diagnostic tool has led to a fundamental challenge for food justice activists [36]. The production of a food desert map as a technical artefact has enabled policy-makers and retailers to condense the complex dynamics of the food desert into a technical issue that can be solved by the insertion of a supermarket, a farmer's market [37,38], a new bus route [39] or some other externally-generated single solution, and effectively reduced community agency [32]. Giacalone [36] argues that the production and circulation of the maps has depoliticized the food desert and has reduced the food access problem to a technical, rather than structural and political challenge. It is within this critique of the technical solutions to a complex problem as a result of the act of mapping which is the starting point for the discussion of food deserts within the African context.

In 2016 the USDA released findings that the presence or absence of supermarkets in fact had limited access on food choice [40]. However, despite this, the rhetoric of the food desert as a problem to be solved by the establishment new supermarkets persists and is reinforced by the technopolitics of the production of food desert maps.

4. Methods

This paper draws on research conducted for the African Food Security Urban Network (AFSUN) in Cape Town (South Africa) and the Consuming Urban Poverty Project (CUP) in Kisumu (Kenya) and Kitwe (Zambia). These countries are particularly appropriate to interrogate the political mobilization of the notion of the supermarket as the solution to urban food insecurity, as they have been implicitly and explicitly among the most supportive of retail formalization in Africa, as explained in the introduction.

Thow et al. [9] have argued that although there are bodies of work focusing on consumers and on food supply systems in Africa, there is a critical gap on consumers' interactions with the food supply systems in operation. The AFSUN and CUP work explicitly to address this gap, and framed it in a wider set of governance questions. In both projects there were three independent research components designed to be brought together to address this gap, which are described below. This paper brings the findings from these three components together to address the question of the food desert in African cities.

The methods and sample strategies for each research component have been previously published and references are provided in text. Given the local contexts in each city, there was slight variation in sampling strategies.

The first research component was a household food security survey, which included questions on the food-sourcing strategies of households, which provide insights on the relative importance of the informal food economy and other retail sources, including supermarkets. Levels of household food insecurity were measured using the Household Food Insecurity Access Scale (HFIAS) and the Household Food Insecurity Prevalence (HFIAP) tool [41]. The survey was conducted in 1060 households in three low-income areas of Cape Town in 2008 [42], in 882 households in two low-income areas of Kitwe in 2016 [43], and 841 households in a city-wide survey in Kisumu [44].

The second component was a food retail census and survey. The purpose of this work was to generate a spatial representation of the nature and distribution of informal food retail, and then to examine retailer characteristics, locational strategy, business practices, sourcing of retail products, and problems experienced by vendors. In Cape Town this research was conducted in 2013 and mapped 492 retailers and surveyed 100 of these retailers in two of the low-income neighborhoods in which the food security surveys had been conducted [45]. The corresponding research in Kitwe and Kisumu was conducted in 2016. In Kitwe, 705 retailers were mapped in the city's central market area and the two neighborhoods in which the household surveys had been conducted. From this mapping, 389 retailers were surveyed [46]. In Kisumu, 2185 retailers were mapped in the city center, at the city's main central retail and wholesale markets, and in a low income neighborhood. From these, 705 surveys were conducted [47].

The final study was a mapping of supermarkets. In Kisumu and Kitwe, the mapping was restricted to currently present supermarkets. In these cities, street addresses of the retailers were mapped onto current city maps in order to identify the kinds of urban spaces that supermarkets were located in, in terms of residential characteristics, business areas, and proximity to other critical infrastructure, such as transit hubs, markets, and malls. In Cape Town, a time-series of supermarket expansion from 1994 to 2013 was conducted [20]. Detailed analysis of the 2013 supermarket location was conducted with reference to supermarket company, and income levels of neighborhoods in which stores were located [48].

5. Core Findings

This section presents the key findings from the three components of the AFSUN work in Cape Town and the CUP work in Kitwe and Kisumu. In many ways, these core findings accord with the other limited research on urban food issues in African cities.

The field work in the cities found high levels of food insecurity (Table 1). The Cape Town survey, working in three low-income neighborhoods found 80% of households to be moderately or severely food insecure according to the Household Food Insecurity Access Prevalence tool [42]. A follow-up city-wide survey in 2013 found about half of the sampled population, which included all income groups, found around half of households fell into these categories [49] (p. 27). In Kisumu, a city-wide survey, 71% of households were moderately or severely food insecure [44], and in Kitwe, the corresponding proportion in the two low-income areas sampled was 90% [43].

Table 1. Levels of food security in case study cities. Note: The Cape Town and Kitwe surveys were conducted in low-income neighborhoods. The Kisumu survey was a city-wide survey.

	Severely Food Insecure	Moderately Food Insecure	Mildly Food Insecure	Food Secure
Cape Town	68%	12%	5%	15%
Kitwe	79%	12%	3%	6%
Kisumu	45%	26%	9%	20%

This food insecurity was characterized by limited dietary diversity and distinct hungry seasons. These findings accord with those of the wider AFSUN project working in 11 cities in nine southern African countries [50] and recent research in Accra [51].

Within each of the three household surveys it was clear that although most households did access food through supermarkets, they were far from the main source of food for the sampled households. In Kitwe and Kisumu, 53% and 55% of sampled households, respectively, got less than a quarter of food purchased from supermarkets [43,52] (Table 2). On a day-to-day basis, households sourced food from the ubiquitous local neighborhood street traders, house shops, and markets, and central city street traders and markets. Recent work in Tamale, Takoradi, and Accra in Ghana found similar purchasing patterns [53], as did earlier work in three small towns in Kenya [7]. Traders in all three case study cities identified proximity to customers as a key determinant of locational choice and were deeply embedded, with many offering credit to known consumers [32–34].

Table 2. Proportion of food purchased bought at supermarkets. Note: The Kitwe survey was conducted in two low-income neighborhoods. The Kisumu survey was a city-wide survey.

	Less than 10%	11–25%	26–50%	51–75%	76%+	Don't Know/Refused to Answer
Kitwe	39%	14%	7%	2%	1%	37%
Kisumu	29%	26%	19%	8%	3%	14%

In these, and in other cities such as Windhoek [54] and Nairobi [55], supermarkets are predominantly located in central city locations and are more typically present in higher-income

residential areas [48,55]. Research in Cape Town found rapid expansion in the number of supermarkets, with a 2.6-fold increase in the number of supermarkets in the city from 1994 to 2012. This expansion was characterized by two key trends, namely expansion into lower-income areas of the city, and the concentration in existing middle- and high-income areas, in the form of smaller standalone convenience outlets [20]. The outlets opening in lower-income areas were often more limited store formats, lesser a smaller variety of foods than those in wealthier areas [48].

While the findings from each individual research component largely corroborate findings from other studies, with exception of Blekking et al.'s [56] recent work in Lusaka, which thus far has focused on governance issues emanating from their findings, these other studies have focused either on the food system dynamics or on food security. The AFSUN and CUP findings across the three research components allow for critical reflection on the dialectical relationship between food security and the food system, and therefore for critical reflection on policy approaches to alleviating food insecurity through food system interventions, as discussed below.

6. What the Food Desert Policy Fix Misses

There are three assumptions at the center of the supermarket as the solution to food insecurity policy discourse. These are: Supermarkets provide better access to healthier food; low income areas have poor access to healthy food; and food security can be reduced to economic and physical accessibility in narrow terms. This section of the paper addresses each of these in turn.

Assumption 1: *Supermarkets improve access to healthy food.*

Recent work published by Demmler et al. [57] working in urban Kenya found that consumers shopping in supermarkets were not accessing healthier food or better diets. Instead, shopping in supermarkets was found to contribute to higher consumption of processed and highly processed foods and lower consumption of unprocessed foods. This is supported by the work in Cape Town that indicates that the supermarkets entering lower income areas are more likely to be the "budget" lines of major supermarket chains, which sell a much more limited variety of fresh produce [48].

The failure of supermarkets to provide access to healthy foods was clear from field observations in Cape Town, Kisumu, and Kitwe. In all cities, fresh produce traders are regularly located directly outside of the supermarkets. These traders are often selling produce cheaper than the relatively limited stock available within the supermarkets.

Household surveys in Cape Town, Kisumu, and Kitwe confirmed that households do not typically use supermarkets for fresh produce purchases. They more typically use supermarkets infrequently and predominantly use them for non-perishables. They may also be preferred for luxury items like fresh fish, rather than the cheaper dried or smoked fish. Within the Kisumu and Kitwe household surveys, participants were asked to identify where they sourced five foods considered key to the urban diet in those cities. In Kitwe just 15 out of the 882 (1.7%) households surveyed said they bought tomatoes from supermarkets, but 119 (13.5%) said they normally bought maize meal from supermarkets. In Kisumu 51 out of 841 households (6.1%) indicated that they normally bought green vegetables from supermarkets, but 299 of 841 (35.6%) normally bought maize meal from supermarkets. Interestingly, in Kisumu just 12 households (1.4%) indicated that they normally bought fish from supermarkets. This extremely low proportion reflects the importance of traditional food purchasing patterns and desire for kinds of products that are not readily available in supermarkets, such as small, dried fish or smoked, whole fish.

In Kisumu households who reported using supermarkets frequently were asked why they did so. Key reasons were variety of foods (99%), quality (83%), bulk purchasing (77%), and lower prices (50%). O'Neill [58] (p. 266), also working in Kenya, argues that further reasons for supermarket use include the sales strategies used by stores to attract customers, including flyers, loyalty programs, and sales as well as some stores providing a "lifestyle" experience by selling other household and clothing items as well as food, thereby appealing to a cosmopolitan aspiration. Households who reported not

shopping at supermarkets frequently were asked why they did not use them. Here, key reasons were lack of provision of credit (69%) and the high costs of supermarkets (64%). The conflicting data on price is interesting. It suggests that for those who can afford to buy in bulk and buy "luxury" products, supermarkets make economic sense, but for those depending on staples and buying in smaller units, the informal sector meets their economic needs more effectively. Within the Cape Town food security survey, it was found that food secure households were more likely to purchase food regularly from supermarkets than food insecure households, despite having similar physical access to the stores. Physical access to supermarkets does not necessarily increase a household's ability to purchase food from these stores.

It therefore appears as if the assumption that supermarkets provide good access to healthy food for an urban population is flawed in its assumptions of what the stores themselves provide and how consumers choose to use them. Supermarkets are not providing better access to healthy food, but instead have been implicated in making more highly processed foods more available [7,57]. Therefore, supermarkets may be viewed as accelerating the nutrition transition, rather than addressing food insecurity.

Assumption 2: *Low-income areas and their residents have poor access to healthy foods.*

The second assumption underlying the promotion of supermarkets is that low-income areas and their residents have poor access to healthy food. However, the research conducted in Cape Town, Kisumu, and Kitwe all demonstrated in both low-income neighborhoods and the central city areas in which many residents of low-income areas work have very good access to fresh produce through informal vendors.

In the Cape Town food mapping work, 19% of traders in the two sampled wards were fruit and vegetable vendors. Further, the spaza stores (small informal general dealers), which accounted for 39% of the sampled retailers also stocked limited fresh produce. In Kisumu, of the 2185 recorded vendors, 26% reported selling vegetable, 30% fruit, and 11% roots and tubers. In Kitwe, of the 705 recorded vendors, 31% sold vegetables, 6% fruit, and 9% roots and tubers. In addition to making these foods available, these vendors sell in unit sizes and qualities that the urban poor can access. Produce from these vendors is often cheaper than that of the supermarkets, as they tend to buy direct from wholesale markets, and therefore have shorter supply chains and have fewer costs, such as transportation and cold storage, which increase the price of produce. Furthermore, due to their necessary embeddedness in their location, they often offer food on credit. In the Cape Town sample, 58% of vendors indicated that they would offer credit. In Kisumu, 48% offered credit to customers. In Kitwe the proportion was lower at 31%. Although interest was not generally charged, credit was only made available to known customers who were likely to repay.

There is not a shortage of fresh produce available to the urban poor. Physical access to healthy food is not the fundamental food security challenge. Traders provide relatively affordable access to fresh produce and structure their business models to meet consumer needs as best as possible, given their limited margins.

However, as will be discussed in the following section, issues of food utilization through limited cooking resources and storage capacity mean that access to fresh produce alone is not sufficient to ensure consumption of these products. In the sampled cities, relatively healthy prepared foods are also made available through the informal sector. In Kisumu dried porridge mix is commonly sold, which can be quickly reconstituted. In Cape Town, prepared meal vendors of often locate near transport interchanges to sell relatively healthy meals to consumers after long commutes.

Contrary to the vision of the food system invoked by a city-scale food retail mapping focusing on supermarkets to illustrate food deserts, low-income areas are not food deserts in the conventional sense of limited of access to healthy foods. However, there are important questions of physical food access that need to be addressed.

The first is that of the relative balance of healthy and less healthy foods. While some street vendors are selling healthy cooked meals, a number of street foods are significantly less healthy. Vetkoek or Mandazi (savory doughnuts) are widely sold street foods. And while spaza stores do sell some fresh produce, they generally sell sweets, sodas, potato chips, and other highly processed foods in greater quantities. The high presence of unhealthy traditional street foods and modern highly processed foods has also been noted in research in Ghana [59] and across the SADC region [60] and calls a wider interrogation of trade and agricultural policy. This mixed-food environment with a high presence of less healthy foods has provoked some researchers to discuss the food swamp rather than the food desert [61].

Second, there are important questions about the health and safety of foods sold by informal sector retailers. Across Africa, one of the main ways that urban governments have engaged with the food system has been through repressive health and safety regulation. This is in part the result of colonial governance structures that used public health regulations as a means to entrench urban racial segregation as official state policy [17] (p. 86). This framing has led to present day perceptions by the state of informal food retail as inherently dangerous. However, Skinner [62] (p. iii) argues, "Contrary to the claims of many public officials, the results of toxicology tests of street foods show that informal traders can sell food with low bacterial counts, with access to infrastructure being a decisive factor". Work by the IIED (International Institute for Environment and Development) in Nairobi suggest that the interest of increased food safety (and perhaps transition to a better balance of healthy and less healthy foods on sale) could be better achieved through creating an enabling retail environment with adequate water, sanitation, drainage, regular rubbish collection, storage for vendors, better designed markets with waste disposal site, than by repressive regulation [63].

In many cases, the state's antipathy towards the informal sector has led to the informal food retailers, who remain the primary source of healthy food for the urban poor, having precarious livelihoods impacted by exclusionary zoning schemes, forced removals, and lack of integration into neighborhood planning [64,65]. Through these governance actions, the viability of the food system is undermined.

In the context of the discussion about food deserts as it is currently playing out in the African context, it is important to note that the supermarket companies and the developers who are facilitating the expansion of shopping malls in African cities are not neutral agents around whom these clearance and regulations take place. They have been active agents in advocating for street clearances [3,20].

Assumption 3: *Food insecurity in urban areas is simply about economic (and physical) access.*

The final assumption is that food insecurity in urban areas is simply about access—economic and physical. This is evidenced in long-term agricultural policy to control maize prices as the central urban food security strategy in many Africa countries. Physical and economic access are necessary, but not sufficient determinants of food security. There is a need to better appreciate how households choose to use limited household economic resources. Food is expenditure is often one of the few discretionary expenditures for poor households. These households often sacrifice economic access to food in order to meet other urban costs of living, such as the cost of transportation, rent, or water [66]. During periods of economic stress, households decrease expenditure on food to meet other household needs and preserve household assets. Research conducted in Manenberg, Cape Town found that income stability rather than amount of income alone was an important determinant of food security. Households with fixed, guaranteed incomes were found to be more food secure than households with equal, or even greater, inconsistent income, as they were able to plan food purchase and preparation better [67].

It is important that food security policy in cities considers the multidimensionality of poverty and how these shape food security outcomes. This requires expanding the framing of food security beyond simple physical and economic access. It demands consideration of the third pillar of food

security, utilization. According to the FAO, food utilization considers the ability of individuals and households to utilize food through "adequate diet, clean water, sanitation and health care to reach a state of nutritional well-being where all physiological needs are met" [11]. In the Kisumu and Kitwe studies, the Lived Poverty Index was used in which households were asked how often they had gone without access to food, fuel for cooking that food, water, energy, medical treatment, and income [68]. In both cities, households reported significant challenges of access to these (Table 3). The multiple deprivations experienced fundamentally shape households' abilities to ensure food security and dietary quality. Inadequate access to energy to cook shapes food choice, as does access to water to clean and cook foods safely [44].

Table 3. "*Over the past year have you or your household ever gone without . . .* " Note: The Kitwe survey was conducted in two low-income neighborhoods. The Kisumu survey was a city-wide survey.

	Enough Food to Eat	A Cash Income	Water for Home Use	Fuel for Cooking	Medicine or Medical Treatment
Kitwe	80%	88%	61%	72%	62%
Kisumu	53%	65%	57%	50%	50%

The informal components of urban food systems in African cities are responsive to these utilization challenges. In order to address limited household storage and refrigeration, traders bulk break and sell food in small quantities. In recognition of the high cost of energy, street traders sell pre-cooked foods for urban consumers unable to afford to buy raw materials and cooking fuel [69]. Traders respond to the time poverty of the urban poor by locating close to transport interchanges and selling prepared foods [45]. In Cape Town, Kisumu, and Kitwe traders reported operating long hours to meet commuter needs [45].

However, it is important to note these traders are hampered by the same infrastructure deficiencies impacting household utilization. They also commonly lack storage and refrigeration, meaning that they buy in relatively small units to ensure regular throughput of products and therefore food safety [46]. Similarly, traders are also impacted by the high cost of energy, and a number of them use unsafe energy sources to operate [70].

One of the concerns about the increasing presence of supermarkets in African cities is that they are crowding out smaller retailers and informal traders [20]. The concern is that this refining of the market may actually reduce food security. Poor urban households enhance the stability of their food access by accessing food from a range of sources. These different sources respond to supply chain changes differently and prices often vary considerably across different retailers and retail types. In a diverse retail environment, households have greater capacity to find the most affordable prices [71].

This paper argues that it is essential to shift national and global food security policy from its partial interpretation of food security as only encompassing the availability and accessibility pillars. The articulation of economic access needs be extended from its simplistic income and expenditure modeling, to appreciate the role income stability and the economic rationalities of the food insecure. It is further essential to better appreciate how access and utilization interact in the urban context to enhance or hinder food security. The capacity, and infrastructural limitations on adaptive capacity, of small-scale retailers to respond to the food security needs of the urban poor requires that policy-makers and planners adopt an approach to food security that is based on an understanding of the food system that feeds the urban poor and design interventions that support rather than inhibit food security.

7. Conclusions

The concept of the food desert is a useful way to raise debate about the structural inequalities in the food system. This is an important addition to policy and academic discussions on food security in the African context, which have often focused either at the household scale or at the national scale, with little consideration of the complex, interrelated determinants of food insecurity. The food desert

concept also demands that research and policy-makers interrogate the root causes of these determinants, thus raising issues of equity and justice that have often been neglected in African food policy, which is driven more by a poverty-focused development discourse. The application of the food desert concept highlights how food system inequalities overlay with other forms of inequality, such as income poverty, transport poverty, and a lack of basic infrastructure. It is therefore useful in the African context for shifting scales of thinking about food security from the household scale and providing impetus for more structural sets of responses.

However, methodological approaches that generate food desert maps need to be approached with caution. Firstly, the approach may continue to privilege issues of access over a richer understanding of how access and utilization interact. Secondly, maps are powerful and evocative visual references that create particular understandings of issues [72]. The food desert maps that are commonly produced use supermarkets and their absence as a proxy indicator for food access limitations. In order to illustrate the city-wide structural inequality, they generally focus at the city scale. Mapping at this scale necessitates extremely simplistic representations of food retail. The density and diversity of food retail in each neighborhood in the city is inevitably omitted, therefore making the areas without supermarkets appear as food deserts, which invites the framing of the supermarket as the solution to food access problems. This paper suggests that food environment mapping work should be conducted at more than one spatial scale in order to better understand physical access to healthy foods in our cities.

While this paper asserts that the food desert concept has value as a mechanism to shift food security analysis and direct food security programming in cities beyond the household and individual scales, and to increase dialogue about issues of structural inequality, it urges caution. There is a real danger that the operationalization of the food desert concept by researchers will facilitate policy-makers and private sector actors to press forward with a food desert, supermarkets-as-pathway-to-food-security policy discourse and not acknowledge the vital role that informal food retail plays in the food security of African cities. The emergence of the food desert as a policy articulation needs to be understood in terms of the transposition of a problematic policy framing from the United States on pre-existing entrenched narratives about the value of formalization within urban policy [20], powerful industry voices influencing policy positions [2], and the long-term historical framings of food security as being delivered by large scale, economically efficient formal systems [25], at odds with the spatial logic of African cities [21].

In conclusion, there is a need to exercise caution when translating to the concept of the food desert to the African context. The food desert as a policy narrative should be rejected as it is ill-informed by the lived experiences of food insecurity in African cities and may promote policy interventions that erode rather than enhance the capacity of the food system and community agency to meet the food security needs of African urbanites.

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Do Urban Food Deserts Exist in the Global South? An Analysis of Nairobi and Mexico City

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Abstract: Recent conceptualizations of 'food deserts' have expanded from a sole focus on access to supermarkets, to food retail outlets, to all household food sources. Each iteration of the urban food desert concept has associated this kind of food sourcing behavior to poverty, food insecurity, and dietary diversity characteristics. While the term continues to evolve, there has been little empirical evidence to test whether these assumed associations hold in cities of the Global South. This paper empirically tests the premises of three iterations of the urban food desert concept using household survey data collected in Nairobi, Kenya, and Mexico City, Mexico. While these associations are statistically significant and show the expected correlation direction between household food sourcing behavior and food security, the strength of these relationships tends to be weak. These findings indicate that the urban food desert concept developed in North American and UK cities may have limited relevance to measuring urban food insecurity in the Global South.

Keywords: food deserts; food security; food sourcing; supermarkets; dietary diversity; Mexico City; Nairobi

1. Introduction

Since the 1990s, the 'food desert' concept has been extensively used in cities in the Global North, most often in the United States, Canada, and the United Kingdom. It has not, however, been applied systematically to cities of the Global South. While there are many potential reasons for this gap, chief among them is the way food security and malnutrition in the Global South are often framed as rural issues and related to hunger and food scarcity [1]. This particular food security paradigm is present in both research and policy discourse and has limited discussions on urban food security in the South until recently. In addition, food deserts have traditionally been related to the presence or absence of supermarkets, which, while proliferating, do not yet have a commanding presence in urban food systems in many parts of the Global South [2,3]. Researchers who use the food desert concept argue that differences in food access between households and neighborhoods can be best understood through the structural and spatial dimensions of food environments. To date, analyses of the food desert concept have not been systematically applied to cities in the Global South.

Food deserts are usually characterized as economically disadvantaged areas where there is relatively poor access to healthy and affordable food because of the absence of modern retail outlets [4]. Cities in the Global South contain many poor neighborhoods where the prevalence of malnourishment and food insecurity are often far more dramatic than in North America and the UK. Therefore, the key question is whether mainstream definitions of food deserts applied to the Global North can be usefully applied to the Global South's rapidly growing cities. If the concept can be reformulated to fit the realities of urban food systems in the Global South, 'food deserts' may prove to be a useful analytical tool which urban food researchers and policy makers have yet to fully explore.

In order to perform a preliminary test of the applicability of the food desert concept in the Global South, this paper uses household survey data collected in Nairobi and Mexico City by the Hungry Cities Partnership. The paper first provides an account of three iterations the food desert concept that that are based on the authors' interpretations of the literature.

1.1. Classic Food Deserts

The concept of a food desert grew out of a small but growing body of evidence that suggested food items may be more difficult to access in deprived areas [5–7]. While policy interventions were undertaken by the UK government, there was a dearth of evidence on the causal factors of food deserts. Originally, conceptions of food deserts were based primarily on distance to supermarkets. The further a neighborhood was from a supermarket, the larger the food desert was considered to be. An absence of supermarkets in a neighborhood was deemed a result of redlining: a spatially discriminatory practice among retailers of not serving certain areas, based on their demographic composition [8]. These same neighborhoods were sometimes characterized as 'too low-income', leaving retailers concerned with profitability. This first version of the food desert was tied to highly quantitative, easily calculable values like distances and food prices. However, without significant evidence to endorse the quantifiable variables being used, the food desert concept has since evolved in its application to cities in the Global North.

1.2. Food Deserts Plus

More recent conceptualizations of food deserts are characterized by recognition and acceptance of the nuanced nature of food accessibility in a city. In this iteration, food deserts are no longer considered simply a spatial issue, to be analyzed through the addition of more variables. Instead, the food desert is seen as a dynamic meshwork of social, economic, and political interactions [9–11]. Studies increasingly consider the interrelated nature of income, mobility, transportation, time, seasonality, family structure, presence of different type of retail location, dietary diversity, education, structural inequalities, and so on [12,13]. Policy environments that shape inequalities in neighborhood access to food have also been further explored. Perhaps the most important shift was the growing understanding that distance to supermarkets was a proxy measure for food access, and that this may be an inadequate way to measure how marginalized populations were actually eating.

In this iteration of the food desert concept, the inclusion of dietary diaries into research methodologies was popularized, and many studies underlined the need to grasp the 'healthiness' of foods being accessed [13]. This gave rise to concepts such as the 'food oasis' (pockets of healthy food access) and the 'food swamp' (an abundance of unhealthy food), further elaborating on the spatial component of inequality in food access in urban areas. Food deserts became more complex conceptualizations, and fruit and vegetable consumption became nearly as ubiquitous as supermarket analysis had once been. Food Deserts Plus represents a more recent understanding of the food desert concept reflected within the literature and remains predominantly applied to cities in the Global North.

1.3. Food Deserts in the Global South

Along with more complex and nuanced understandings of food deserts emerging, researchers have also began providing supplemental perspectives on food deserts by using empirical evidence to

test whether these assumed associations hold in cities of the Global South. There are, of course, reasons for caution when applying a Euro-American understanding of food deserts in cities with histories and geographies of urban food retailing and food system development that are remarkably different. For one, the importance of the informal food economy for residents' food security in growing cities in the South poses a set of challenges to conventional approaches measuring food deserts. Informal food vending is fluid and dynamic, and retailers might relocate their business frequently. Retail typologies and geographies are therefore significantly different, and lack of access to a supermarket is potentially less important of a factor in facilitating neighborhood food insecurity. Supermarkets are, of course, an increasingly important retail type in many Southern cities globally, but a sole focus on modern retailing cannot capture all of the market and nonmarket food sources, or the spatial mobility of informal retailing. With important contextual differences to be taken into account, Crush and Battersby redefine food deserts in the Global South as "poor, often informal, urban neighborhoods characterized by high food insecurity and low dietary diversity, with multiple market and nonmarket food sources but variable household access to food" [4]. As such, this adapted concept has potential to be a useful analytical tool to understand the structural barriers leading to inequalities in food access in the Global South.

This paper intends to add to the growing body of literature on urban food deserts in the Global South by empirically assessing these three conceptualizations of urban food deserts in the contexts of Nairobi and Mexico City. The following sections evaluate the usefulness of three definitions when applied to these contexts. By examining two cities from different geographical areas, this paper explores how differing urban food environments in the Global South affect the relevance and findings of the three food desert iterations tested. Following an analysis and discussion of the results, the paper concludes by highlighting the research and policy implications.

2. Materials and Methods

Mexico City and Nairobi were initially selected as study sites because of their distinct contexts as cities located in the Global South—a geographic area where the concept of food deserts has not been systematically applied. Each city and their food systems have contrasting cultural, structural, and development patterns. These location selections provide an opportunity to operationalize food desert definitions and utility in unique settings and provide comparative analyses between the two.

Nairobi is a relatively young city experiencing a rapid rate of urbanization that is stretching existing food and agriculture systems, now struggling to provide food and nutrition security for inhabitants [14]. In 2009, the population of Nairobi was 3.1 million, with projections estimating this number to double by 2025 [15]. As a result, the city is dynamic and growing, and its food supply chains are always adapting to changing local conditions. Kenya's domestic food supply chain system is a significant contributor to the economy: the agricultural sector is 26% of national GDP [16]. Informal traditional value chains continue to play a vital role in food provisioning throughout the city. These chains are characterized by the variety of actors and intermediaries that increase transaction costs, creating an inefficient postharvest procurement network, and thereby pushing food products out of reach for those who need them most. Local authorities have used by-laws and regulations to suppress the development of street vending and other forms of informal trade. As a result, Kenya's informal economy has often been subject to policies that produce unfavourable business environments. Even so, the informal food economy is dynamic and persists as a central source of food for the cities inhabitants [14].

Nairobi's formalized food system is expanding as well and relies on centralized and regionalized procurement networks, specialized wholesalers and supplier systems, and modern retailing outlets that seek competitive advantage through direct control of their procurement systems [14]. This trend towards a formalized food system development is recent however, and the impact it will have on food access, neighborhood food environments, and the city's vitally important food markets and associated informal sector within the city remains unclear.

In contrast, Mexico City is a larger city with a much longer history. Meeting the daily food demands of Mexico City's over 20 million inhabitants requires food products to be procured from a combination of traditional and highly sophisticated modern food supply chain systems from rural areas, its fishing industry, and food imports. While traditional food systems are still vital for food provisioning in the city, Capron et al. suggest that the diets of residents of Mexico's capital city are increasingly influenced by food economies of developed countries [17]. As of 2016, supermarkets, grocers, and corner stores control 52% of food sales in the Mexico City Metropolitan Area. Diets are characterized as nutrient-poor, energy-dense, and highly processed, and these characteristics are associated with growing obesity, overnutrition, and micronutrient deficiencies. Between 2000 and 2012, adult obesity increased from 16% to 26% of the city's inhabitants [17].

The geography of informal food markets and vending in Mexico City is increasingly subject to restrictive state policies related to public space, streets, plazas and parks, as well as permissive state-led, market-oriented policies towards the redevelopment of specific commercial, residential and tourist zones in downtown Mexico City through up-zoning, and changes to land use regulations and area-specific plans [17]. These policies have combined to restrict or displace the informal vending activities, particularly in high-income and central areas of the city.

In this sense, Nairobi and Mexico City as study sites reflect some of the similarities but also significant differences observed between urban food systems in the Global South. These location selections provide an opportunity to operationalize food desert conceptions in contrasting urban settings and comparatively analyze the two sets of findings.

2.1. Research Objectives and Questions

Research Objectives and Questions.

Research Objectives	Research Questions
Objective 1: Test the Original Concept of Food Deserts	1.1 Is there a relationship between household supermarket access and household food security?
	1.2 Is there a relationship between household poverty and supermarket access?
Objective 2: Test Emerging Concepts of Food Deserts (Food Deserts Plus)	2.1 Is there a relationship between household access to all food retail sources and household food security?
	2.2 Is there a link between the type food products purchased and the sources of those food products at the household level?
	2.3 Is there a link between fruit and vegetable purchase/consumption and household food security?
	2.4 Is the number of household food retail sources related to household food security?
Objective 3: Test Crush and Battersby's (2017) definition of food deserts (Food Deserts in the Global South)	3.1 Is there a relationship between access to all food sources (market and otherwise) and household income, household dietary diversity, food access/food price challenges?

2.2. Sampling

The data used to answer these questions is drawn from household survey data from Nairobi and Mexico City in 2016. In Nairobi the household sample was stratified by subdistrict population, with subdistricts randomly selected from within all districts in Nairobi City County (Figure 1). Households were then selected by enumerator teams within each subdistrict using systematic sampling, resulting in a final sample size of 1424 households.

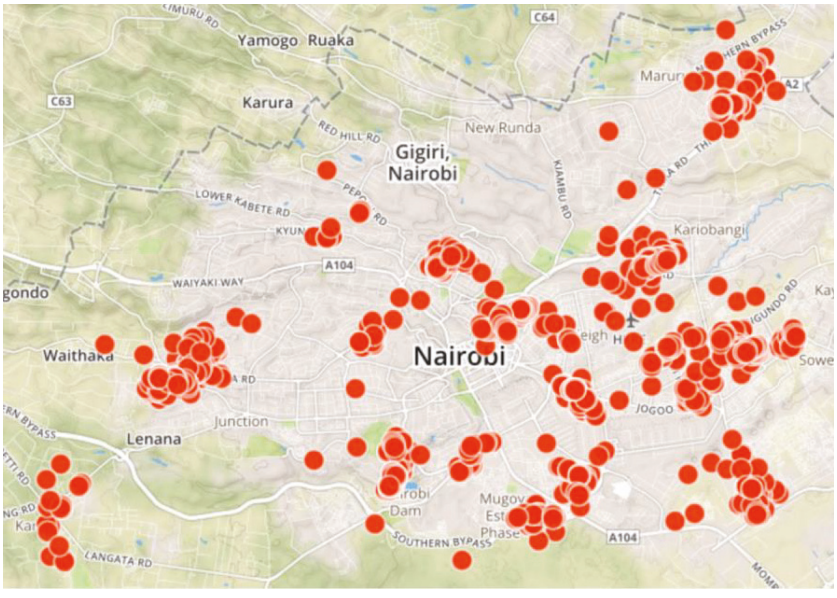

Figure 1. Nairobi sampling distribution.

In the household survey of Mexico City, enumeration areas were randomly selected across the entire metropolitan area (Figure 2). The total sample size was stratified using proportionate allocation across these enumeration areas within socioeconomic bands. Households were then selected by teams of enumerators using random systematic sampling. The total sample size for this survey was 1210 households.

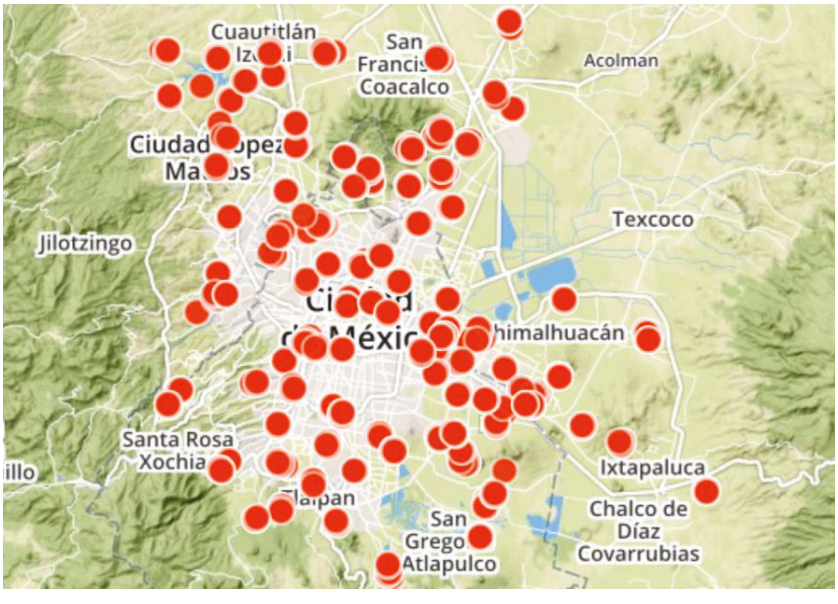

Figure 2. Mexico City sampling distribution.

2.3. Measures

These citywide surveys of Mexico City and Nairobi used the Hungry Cities Partnership (HCP) household survey instrument. This survey instrument measured household food security and food sourcing behavior, together with measures of poverty and demographic characteristics. This paper relies on the following measures taken from this survey instrument: the Household Food Insecure Access Prevalence scale (HFIAP), the Household Dietary Diversity Score (HDDS), the Lived Poverty Index (LPI), household income quintiles, food price impact, and household food sources.

The HFIAP is an ordinal-level scale that measures the severity of household food insecurity in the last month [18]. The score is calculated using nine Likert scale questions on the frequency with which households have experienced various dimensions of food access challenges in the last four weeks. The answers to these questions are then aggregated using a scoring algorithm to classify households according to four categories of food insecurity: Food Secure, Mildly Food Insecure, Moderately Food Insecure, and Severely Food Insecure.

The HDDS is an ordinal-level scale that represents the number of food groups that have been consumed by any member of the household in the last 24 hours (with a total of 12 possible food groups included in the scale) [19]. A higher score on the HDDS indicates greater dietary diversity. The LPI is an ordinal-level scale that measures lived poverty. The scale is made up of six Likert scale questions measuring the frequency with which households have gone without electricity, clean water, medical care, cooking fuel, food, or a cash income in the last year. The LPI scale score is the average of these six subscale questions. A higher score on the LPI represents greater severity of lived poverty.

Household income quintiles were calculated by summing the amount of income earned by households in the last month across all household income sources (except for any loans or credit). This total household income was then binned into five ranked and proportionately equal categories or quintiles. This calculation was done within each city and not across both cities. A higher score on the household income quintiles represents higher household income.

The HCP household survey instrument also included a question on food price impact. In this question, the respondent was asked to indicate the frequency with which his or her household went without food due to rising food prices in the previous six months. The response was recorded using a Likert scale indicating frequency of occurrence. The household food sources measured in the survey instrument indicate the source of food accessed by the household in the previous month. The food items and food sources measured in each survey varied slightly to ensure that contextually important food sources were recorded in the survey instrument.

2.4. Analysis

To achieve this study's research objectives, this investigation uses frequency distributions, measures of central tendency, Pearson's chi-squared test of independence, Fisher's exact test, and Spearman's Rho correlation. All analyses were carried out using the SPSS version 24 statistical package.

Some of the assessments of the relationships between the variables included in this investigation use cross-tabulations. These cross-tabulations represent both measures of central tendency (averages) across the categories of other variables as well as frequency distributions. The frequency distributions included in this investigation are assessed using Pearson's chi-squared test of independence. This test determines whether the distributed frequency of households across any two categorical variables is random. In the case where the assumptions of this test are violated, the Fisher's exact test is used to test for the association between two categorical variables. In this investigation, Pearson's chi-squared test of independence was used to assess the relationship between the HFIAP and supermarket access and the LPI and supermarket access (to achieve research objective 1). These tests were also applied to cross-tabulations of the HFIAP by household fruit and vegetable consumption (to achieve research objective 2). The mean HFIAS scores were also calculated according to different household food sources (to achieve research objective 2).

Spearman's Rho correlations determine the extent to which two ordinal or continuous-level variables are related. This correlation is sensitive to nonlinear relationships but also assumes a monotonic relationship (continuously increasing or decreasing relationships). The Spearman's Rho correlation strength is assessed in this investigation using the criteria according to Prion and Haerling [20], where <0.4 indicates a negligible or weak relationship, 0.4–0.6 indicates a moderate relationship, and >0.6 indicates a strong relationship. In this investigation, the HFIAP, HDDS, household food price impact, and household income quintiles were all correlated with the number household food sources (to achieve research objective 3).

3. Results

3.1. Objective One Results: Test the Original Concept of Food Deserts

3.1.1. Is There a Relationship between Household Supermarket Access and Household Food Security?

This investigation found a statistically significant but weak relationship between household supermarket access the year prior to the survey and household food security status in Nairobi. As indicated in Table 1, these variables share a nonrandomly distributed relationship according to a chi-squared test of independence at an alpha of 0.05 (x2 = 73.509, $p < 0.001$, n = 1401). Among the sampled households in Nairobi that accessed supermarkets in the last year, there was a negligible but statistically significant Spearman's Rho correlation of 0.193 (n = 1093, $p < 0.001$) between frequency of supermarket access and household food security status (Table 1). Only 14.4% of those who did not access supermarkets in the last year were food secure, whereas 41.8% of those with no access were severely food insecure; 33.2% of those who accessed supermarkets in the last year were food secure, while only 20.7% with access were severely food insecure.

Table 1. Household Food Insecure Access Prevalence scale (HFIAP) scores and supermarket access in previous year in Nairobi.

Food Security Status	no access n (%)	access n (%)
Food Secure	43 (14.4%)	366 (33.2%)
Mildly Food Insecure	28 (9.4%)	148 (13.4%)
Moderately Food Insecure	103 (34.4%)	360 (32.7%)
Severely Food Insecure	125 (41.8%)	228 (20.7%)
Total	299 (100%)	1102 (100%)

There was a similarly significant but weak relationship between household supermarket access and food security in Mexico City. Table 2 indicates that these variables share a nonrandomly distributed relationship according to a chi-squared test of independence at an alpha of 0.05 (x2 = 74.933, $p < 0.001$, n = 1200) and a statistically significant Spearman's Rho correlation of 0.138 (n = 681, $p = 0.006$) (Table 2). A majority (59.9%) of those who accessed supermarkets in the last year were food secure while only 19.3% with access were severely food insecure. A total of 36.0% of those who did not access supermarkets in the last year were food secure, whereas 36.6% of those with no access were severely food insecure.

Table 2. HFIAP scores and supermarket access in previous year in Mexico City.

Food Security Status	no access n (%)	access n (%)
Food Secure	186 (36.0%)	409 (59.9%)
Mildly Food Insecure	66 (12.8%)	80 (11.7%)
Moderately Food Insecure	76 (14.7%)	62 (9.1%)
Severely Food Insecure	189 (36.6%)	132 (19.3%)
Total	517 (100%)	683 (100%)

These observations also extend to regular (monthly) household supermarket access. In Nairobi, regular supermarket access shared a nonrandomly distributed relationship with household food security according to a chi-squared test of independence at an alpha of 0.05 (x2 = 132.596, $p < 0.001$, n = 1382) (Table 3). Over a third (35.2%) of households with regular access to supermarkets were food secure, while only 17.7% of households were severely food insecure. Among the households that irregularly accessed supermarkets, 43.8% were severely food insecure, while only 13.9% were food secure.

Table 3. HFIAP scores and regular supermarket access in Nairobi.

Food Security Status	regular access n (%)	irregular access n (%)
Food Secure	345 (35.2%)	56 (13.9%)
Mildly Food Insecure	143 (14.6%)	31 (7.7%)
Moderately Food Insecure	319 (32.6%)	139 (34.6%)
Severely Food Insecure	173 (17.7%)	176 (43.8%)
Total	980 (100%)	402 (100%)

Similarly, in Mexico City, there is not a significant difference in the relationship between household food security scores and regular versus irregular supermarket access. Table 4 indicates a nonrandomly distributed relationship according to a chi-squared test of independence at an alpha of 0.05 (x2 = 66.660, $p < 0.001$, n = 1190). As many as 56.5% of households with regular access to supermarkets were food secure and only 20.7% were severely food insecure. Among the households that irregularly accessed supermarkets, 39.6% were severely food insecure, while 34.3% were food secure.

Table 4. HFIAP scores and regular supermarket access in Mexico City.

Food Security Status	regular access n (%)	irregular access n (%)
Food Secure	450 (56.5%)	135 (34.3%)
Mildly Food Insecure	101 (12.7%)	45 (11.4%)
Moderately Food Insecure	80 (10.1%)	58 (14.7%)
Severely Food Insecure	165 (20.7%)	156 (39.6%)
Total	796 (100%)	394 (100%)

3.1.2. Is There a Relationship between Household Poverty and Supermarket Access?

The sampled households in Nairobi indicated a significant, but weaker, relationship between supermarket access and LPI. Table 5 shows that households that accessed supermarkets shared a nonrandomly distributed relationship with the LPI according to a Fisher's exact test of independence at an alpha of 0.05 (F = 42.866, $p < 0.001$, n = 1351) and a negligible but statistically significant Spearman's Rho correlation of 0.074 (n = 1067, $p = 0.015$) with LPI. 91.1% of households who accessed a supermarket in the past year had an LPI of 1.00 or less, compared with 77.6% of households who did not access a supermarket.

Table 5. Lived poverty and supermarket access in previous year in Nairobi.

Lived Poverty Status	no access n (%)	access n (%)
<=1.00	215 (77.6%)	978 (91.1%)
1.01–2.00	52 (18.8%)	93 (8.7%)
2.01–3.00	9 (3.2%)	3 (0.3%)
3.01+	1 (0.4%)	0 (0.0%)
Total	277 (100%)	1074 (100%)

The relationship was even weaker in Mexico City. As Table 6 shows, household supermarket access shared a nonrandomly distributed relationship with the LPI according to a Fisher's exact test of independence at an alpha of 0.05 (F = 24.082, $p < 0.001$, n = 1184). There was a negligible and statistically insignificant Spearman's Rho correlation of 0.009 (n = 673, $p = 0.823$) between supermarket access and the LPI.

Table 6. Lived Poverty and supermarket access in previous year in Mexico City.

Lived Poverty Status	no access n (%)	access n (%)
<=1.00	456 (89.6%)	652 (96.6%)
1.01–2.00	47 (9.2%)	22 (3.3%)
2.01–3.00	6 (1.2%)	1 (0.1%)
Total	509 (100%)	675 (100%)

Regular supermarket access did not appear to have a significantly different relationship with the LPI in Nairobi. The variables in Table 7 share a nonrandomly distributed relationship according to a Fisher's exact test of independence at an alpha of 0.05 (F = 50.427, $p < 0.001$, n = 1349). Almost all (92.3%) households with regular access to a supermarket had a score of 1.00 or less on the LPI, compared with 78.4% of those with irregular access.

Table 7. Lived poverty and regularity of supermarket access in Nairobi.

Lived Poverty Status	regular access n (%)	irregular access n (%)
<=1.00	891 (92.3%)	301 (78.4%)
1.01–2.00	71 (7.4%)	74 (19.3%)
2.01–3.00	3 (0.3%)	8 (2.1%)
3.01+	0 (0.0%)	1 (0.3%)
Total	965 (100%)	384 (100%)

Similarly, the regularity of supermarket access in Mexico City did not have a significantly different relationship with the LPI. These variables share a similar nonrandomly distributed relationship according to a Fisher's exact test of independence at an alpha of 0.05 (F = 14.53, $p < 0.001$, n = 1182) (Table 8). 95.4% of households with regular access to a supermarket had an LPI of 1.00 or less, compared with 89.5% with irregular access.

Table 8. Lived Poverty and regularity of supermarket access in Mexico City.

Lived Poverty Status	regular access n (%)	irregular access n (%)
<=1.00	755 (95.4%)	350 (89.5%)
1.01–2.00	33 (4.2%)	37 (9.5%)
2.01–3.00	3 (0.4%)	4 (1.0%)
Total	791 (100%)	391 (100%)

Differences also emerged when examining the relationship between household poverty and supermarket access. In Nairobi, there is a consistently weak but statistically significant correlation between accessing supermarkets more regularly with household levels of poverty, indicating that access to supermarkets may be a good indicator of better lived poverty. In Mexico City, the relationship is inconclusive.

3.2. Objective Two Results: Test Emerging Concepts of Food Deserts (Food Deserts Plus)

3.2.1. Is There a Relationship between Household Access to All Food Retail Sources and Household Food Security?

This question assumes that household food security status can vary according to the type of household food sources accessed. Table 9 demonstrates that households in Nairobi accessing street sellers and venders had a higher average HFIAS score than those households that accessed supermarkets, fast food outlets, online market shopping, or restaurants. It is important to note that this is a multiple response question.

Table 9. Average HFIAS scores by household food sources in previous year in Nairobi.

Food Sources	n	Mean HFIAS
Informal street sellers/vendors	631	6.46
kiosk / corner store	961	5.91
Other shops including grocer or butcher	1144	5.83
City Council/County market	715	5.48
Supermarket	1096	4.98
Restaurant	306	3.44
Online market shopping	12	2.83
Fast food outlets	199	1.98

Similarly, there were differences in average HFIAS scores across the food sources accessed by the households in Mexico City (Table 10). The highest HFIAS scores were observed among households that accessed food from restaurants or fast food outlets and shopped at convenience stores (4.95) and markets (3.34). Those that accessed food from supermarkets had a lower mean HFIAS score than either (2.32).

Table 10. Average HFIAS scores by household food sources in previous year in Mexico City.

Food Sources	n	Mean HFIAS
Convenience stores	43	4.95
Market	1031	3.34
Small shop	816	3.1
Street seller/vendor	195	2.82
Supermarket	681	2.32
Online market shopping	12	1.92
Restaurant	82	0.83
Fast food outlets	54	0.26

3.2.2. Is There a Link between the Type of Food Products Purchased and the Sources of Those Food Products at the Household Level?

One potential reason underlying the distribution of HFIAS scores by food source may have to do with the types of food accessed at these food sources. Supermarkets were the most common place to buy many food items in Nairobi, followed by kiosks, small shops, and street sellers. Items most commonly purchased at supermarkets included maize meal, brown bread, rice, pasta, tinned food, frozen meat, sour milk, tea/ coffee, sugar, cooking oil, snacks, and sweets. Fresh foods, on the other hand, are not often purchased at supermarkets. Items such as fruit and vegetables were commonly purchased at small shops, kiosks, and street traders. Fresh fish, cooked fish, and pies/samosas were most often purchased from street sellers. Fresh and whole foods are therefore most often purchased at smaller scale retail types while more processed foods and foods high in sugar and fat are most often purchased at supermarkets.

In Mexico City, many of the food items recorded in the survey instrument were bought from supermarkets and seem to be supplemented by markets and small shops. One exception was eggs,

with 64% buying them at some point from small shops, 30% from markets, and 26% from supermarkets. Another exception is tamales, quesadillas, and tacos which were purchased primarily from street sellers and then markets. Fresh fish and chicken were primarily purchased at markets, whereas frozen fish and chicken were primarily purchased at supermarkets. Fresh fruit and fresh cooked vegetables were purchased more often from markets than supermarkets. Mexican staples, such as tortillas, were bought from specialized stores, whereas rice was bought more or less equally from markets and supermarkets. Bread was mostly bought in supermarkets, with only a small percentage in markets. Finally, the majority of cooking oil was purchased in supermarkets.

3.2.3. Is There a Link between Fruit and Vegetable Purchase/Consumption and Household Food Security?

In Nairobi, there seems to be a statistically insignificant relationship between fruit and vegetable consumption in the previous 24 hours and food security (Table 11). These variables do not share a nonrandomly distributed relationship according to a chi-squared test of independence at an alpha of 0.05 (x2 = 6.504, $p = 0.09$, n = 1402).

Table 11. HFIAP scores by household fruit and vegetable consumption in Nairobi.

Food Security Status	None consumed n (%)	Fruit/Veg. consumed n (%)
Food Secure	33 (21.6%)	377 (30.2%)
Mildly Food Insecure	17 (11.1%)	159 (12.7%)
Moderately Food Insecure	56 (36.6%)	407 (32.6%)
Severely Food Insecure	47 (30.7%)	306 (24.5%)
Total	153 (100%)	1249 (100%)

Similarly, there seems to be a relationship between fruit and vegetable consumption in the last 24 hours and food security in Mexico City (Table 12). The variables shared a nonrandomly distributed relationship with household food security status according to a chi-squared test of independence at an alpha of 0.05 (x2 = 20.740, $p < 0.001$, n = 1201). Again, this relationship is not as strong as it is between food security and supermarket access.

Table 12. HFIAP scores by household fruit and vegetable consumption in Mexico City.

Food Security Status	None consumed n (%)	Fruit/Veg. consumed n (%)
Food Secure	75 (36.2%)	520 (52.3%)
Mildly Food Insecure	25 (12.1%)	121 (12.2%)
Moderately Food Insecure	31 (15.0%)	107 (10.8%)
Severely Food Insecure	76 (36.7%)	246 (24.7%)
Total	207 (100%)	994 (100%)

3.2.4. Is the Number of Household Food Retail Sources Related to Household Food Security?

In Nairobi, there was a negligible but statistically significant Spearman's Rho correlation of -0.140 (n = 1401, $p < 0.001$) between the number of retail food sources accessed by the household in the last year and household food security status. The sign on this correlation suggests that a higher number of food retail sources is associated with greater household food security, although the correlation effect size is minimal.

In Mexico City, there was also a negligible but statistically significant Spearman's Rho correlation of -0.127 (n = 1200, $p < 0.001$) between the number of food retail sources accessed in the previous year and household food security status. As in the Nairobi survey, it appears it was common among households in Mexico City to have multiple food retail sources.

To summarize, there does appear to be a relationship between household access to food retail types and household food security in both cities. In Nairobi, households accessing street sellers and vendors are more likely to be food insecure than those accessing fast food outlets, online market shopping, or restaurants. Households accessing supermarkets are moderately more food secure than those accessing street vendors. In Mexico City, the strongest relationship is between high levels of food security and visiting restaurants or fast food outlets. Whereas in Nairobi, the most food insecure households accessed food through street sellers and markets; Mexico City households had more variety in food sources.

In both Nairobi and Mexico City, there seems to be a link between the types of food products purchased and the sources of those food products. In Nairobi, supermarkets appear to be the most common place to buy many food items. Fresh or cooked vegetables, however, are most often purchased from markets whereas fresh meats are purchased at butcheries. In Mexico City, supermarkets are the most common place to buy the most items, followed by formal and informal markets. Fresh fruit and fresh cooked vegetables, however, are bought mostly from markets, while fresh meat is bought from these sources or butchers.

In Mexico City, there seems to be a relationship between fruit and vegetable consumption and food security. This relationship is not as strong as it is between food security and supermarket access. Lastly, there was a negligible relationship between the number of food retail sources accessed by households and household food security status in Nairobi, and no statistically significant relationship in Mexico City.

3.3. Objective Three Results: Test Crush and Battersby's [3] Definition of Food Deserts (Food Deserts in the Global South)

Is There a Relationship between Access to All Food Sources (Market and Otherwise) and Household Income, Household Dietary Diversity, Food Access/Food Price Challenges?

Table 13 indicates that there was a positive statistically significant relationship between the number of food sources a household accesses and both household income and household dietary diversity in Nairobi. A higher number of food sources was related to improved household food security, dietary diversity, reduced food price impact, and higher household income. While these correlations were statistically significant, their effect sizes were small, indicating a weak relationship between the number of household food sources and each variable. The strongest relationship was observed between household dietary diversity and the number of food sources accessed in the last year, although this relationship is weak (Rho = 0.209).

Table 13. Spearman's Rho correlation of HFIAP, Household Dietary Diversity Score (HDDS), household food price impact, and household income with the number of household food sources in the previous year in Nairobi.

	Number of Food Sources		
	Rho	**P-Value**	**n**
HFIAP	−0.096 **	<0.001	1401
HDDS	0.209 **	<0.001	1413
Food Price Impact	−0.093 **	<0.001	1396
Household Income Quintiles	0.186 **	<0.001	830

* p-value < 0.05, ** p-value < 0.01.

A similar set of correlations is observed in Mexico City. Table 14 demonstrated a weak to negligible relationship between household dietary diversity and number of food sources. A higher number of food sources was related to improved household food security, dietary diversity, reduced food price impact and higher household income. However, the correlation effect sizes were small, indicating a

weak correlation relationship. The strongest relationship observed was between household income and the number of household food sources (Rho = 0.305), although this relationship is still weak.

Table 14. Spearman's Rho correlation of HFIAP, HDDS, household food price impact, and household income with the number of household food sources in the previous year in Mexico City.

	Number of Food Sources		
	Rho	**P-Value**	**n**
HFIAP	−0.113 **	<0.001	1200
HDDS	0.282 **	<0.001	1209
Food Price Impact	−0.137 **	<0.001	1204
Household Income Quintiles	0.305 **	<0.001	825

* p-value < 0.05, ** p-value < 0.01.

While there were statistically significant correlations observed in both cities between the total number of household food sources accessed in the last year and household food security, dietary diversity, reduced food price impact, and higher household income, these correlation coefficients tend to be weak. In comparison to testing the relationship between household food retail sources and food security (Section 2.4), adding nonmarket food sources does not seem to have a significant impact on the outcome.

4. Conclusions

The food desert concept has proven to be a useful way to raise debate about the structural inequalities in urban food systems overall. However, this paper has demonstrated that applying various conceptions of food deserts to cities in the Global South is potentially problematic. We show that, while these associations are, with some exceptions, statistically significant and show the expected correlation direction between household food sourcing behavior and food security, the strength of these relationships tend to be weak. When assessing the relative utility of the three food desert concepts in the contexts of Nairobi and Mexico City, they appear to be equally inapplicable.

Our findings show that food deserts in the Global South should not be understood through the proxy measurement of supermarket access. Supermarket intervention responses to neighborhood scale issues of food and nutrition insecurity would not reflect the plurality of food sourcing options residents frequent. Rather, households in both Nairobi and Mexico City access large numbers of food retail sources, including informal neighborhood retailers, kiosks, corner stores, small shops, and markets. Policy responses to food insecurity challenges should be culturally and contextually relevant, which necessitates engagement with vital food sourcing options for urban residents other than just modernized retailers such as supermarkets. There remains a need for more debate regarding neighborhood food systems in cities in the Global South, and alternative food desert conceptions might offer a useful way to raise debate about the structural inequalities at this scale. Our findings indicate, however, that the urban food desert concepts tested here may have limited relevance to explaining urban food insecurity in two distinct cities in the Global South.

There are important limitations that accompany the findings from this investigation. First, this investigation should not be interpreted as an analysis of any causal relationships between food sourcing and food security. The methods test the predictive relationship between food source access and food security assumed by the three urban food desert definitions. Therefore, the paper assesses whether food insecurity can be inferred based on limited household access to specific food sources. Additional research will be needed to assess any causal interpretations of urban food deserts. Last, investigating food deserts through an understanding of their complexity requires the inclusion of factors such as mobility, transportation, time, education, structural inequalities, and neighborhood policy environments, which have not been explored in this study.

Given that research on food deserts in the Global South has not yet systematically explored the structural drivers of food insecurity that operate outside the home, future studies should expand to neighborhood and citywide scales. This paper and future studies in the field are relevant to Sustainable Development Goal (SDG) 2—to end hunger—as well as Goal 11 to make cities and human settlements inclusive, safe, resilient, and sustainable. Urban food insecurity dynamics in the South are changing and becoming increasingly problematic. There is little chance of reversing this growth without the development and implementation of sound, evidence based, neighborhood and citywide food security strategies that contribute to the achievement of the SDGs. Future research should systematically explore their dynamics to inform policy addressing food insecurity in cities of the South.

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Informal Food Deserts and Household Food Insecurity in Windhoek, Namibia

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Abstract: Informal settlements in rapidly-growing African cities are urban and peri-urban spaces with high rates of formal unemployment, poverty, poor health outcomes, limited service provision, and chronic food insecurity. Traditional concepts of food deserts developed to describe North American and European cities do not accurately capture the realities of food inaccessibility in Africa's urban informal food deserts. This paper focuses on a case study of informal settlements in the Namibian capital, Windhoek, to shed further light on the relationship between informality and food deserts in African cities. The data for the paper was collected in a 2016 survey and uses a sub-sample of households living in shack housing in three informal settlements in the city. Using various standard measures, the paper reveals that the informal settlements are spaces of extremely high food insecurity. They are not, however, food deprived. The proximity of supermarkets and open markets, and a vibrant informal food sector, all make food available. The problem is one of accessibility. Households are unable to access food in sufficient quantity, quality, variety, and with sufficient regularity.

Keywords: Windhoek; Namibia; informal settlements; food security; informal food sector; food deserts; supermarkets

1. Introduction

With the rapid growth of Africa's urban population, has come an explosion of informal settlements on the fringes of most cities, what Doug Saunders optimistically refers to as "transitional spaces" or "arrival cities" and UN Habitat more pessimistically designates as "slums" [1,2]. These impoverished residential areas of cities have been seen as the product of "disjointed modernization" in which urban population growth outpaces urban economic and institutional development as well as government failures to proactively manage urbanization [3]. In sub-Saharan Africa as a whole, nearly 60% of the total urban population now lives in informal settlements. However, there is considerable inter-country variation [2]. At one extreme there are countries such as Sudan and Central African Republic with over 90% of the urban population living in informal settlements. In Southern Africa, Mozambique has the highest proportion of its urban population in informal settlements, at 80% [4]. South Africa, with a long history of informal settlement demolition in the apartheid era, is one of the lowest at 23% [5]. The country of Namibia, which was controlled by South Africa until independence in 1991 and had a similar history of draconian controls on urbanization, now has 39% of its urban population residing in informal settlements [6,7].

Informal settlements in African cities are urban and peri-urban spaces with high rates of formal unemployment, grinding poverty, heavy reliance on the informal economy, poor health outcomes, very limited basic services provision, and heightened vulnerability to climate change [8–15]. They are also generally areas with high levels of individual, household, and community food insecurity [16–19]. One study of 12 African countries, for example, found that at least 40% of the urban population was energy-deficient [20]. The prevalence of hunger was highest in Ethiopia, at 90%. Another study of 6,453 low-income households in 11 African cities conducted by the African Food Security Urban Network (AFSUN) found that 57% were severely food insecure and only 17% were completely food secure [21]. In some of the cities over 70% of households were severely food insecure. Studies of informal settlements in other cities have also found extremely high rates of food insecurity. In two large Nairobi informal settlements, for example, only 16% of households were food secure [22,23]. In Maputo's informal settlements in Mozambique, just 5% of households were completely food secure [24,25].

In this paper, household and community food security is defined, following the recommendation of the 1996 World Food Summit, as follows: "Food security, at the individual, household, national, regional and global levels (exists) when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" [26]. There is considerable debate in the literature on how best to measure food security [27–31]. Here we adopt the well-tested non-anthropometric measures and methodology of the FANTA Project [32–34]. The concept of food deserts is both more recent and much less expansive geographically. The concept emerged in the United Kingdom and North America in the 1990s to describe food-deprived inner-city neighborhoods [35,36]. In this context, food deserts are conventionally defined as "areas of relative exclusion where people experience physical and economic barriers to accessing healthy food" [37]. In much of the literature on food deserts in European and North American cities, however, the presence of a food desert has come to be associated with the absence or presence of supermarkets. This narrowing of the concept makes it clearly inappropriate for informal areas of cities in the Global South for at least three reasons.

First, residents of informal settlements rely on a variety of informal market and non-market sources of food both within and outside their residential areas. Supermarkets are far from being the only, or even the main, source of food in African cities [38]. Where they do exist, they tend to be located in more affluent parts of cities [39,40]. Second, despite their distant geographical location, upwards of 90% of the residents of poor areas of Southern African cities purchase food at supermarkets [41]. The typical purchasing pattern is to travel to more distant supermarkets to purchase staples in bulk (especially cereals such as maize flour and rice) once per month. In other words, supermarket patronage meets a basic daily staple food need but does not necessarily lead to a more diverse or nutritious diet. Third, the association of food deserts with the physical absence of supermarkets ignores the fact that most African cities have vibrant and dynamic local informal food sectors [42–44]. Households in informal settlements tend to rely on informal food vendors for most of their immediate food needs. In this paper, we therefore use an expanded definition of food deserts which links them to the definition of food security above, and defines them as poor, often informal, neighborhoods characterized by high food insecurity and lows dietary diversity, with multiple market and non-market food sources but limited household access to food [45].

This paper focuses on a case study of the informal settlements of the African city of Windhoek, the capital and largest city in Namibia. In this paper, we analyze data from a 2016 household survey of Windhoek to examine the current state of the city's urban food deserts, with a focus on the food purchasing behavior of households in the city's informal settlements. The first section describes the growth and location of informal settlements in Windhoek, as well as the demography and socio-economic status of the residents of the settlements. The second section presents the survey methodology and describes the sub-sample of informal housing households used in the analysis. The ensuing sections present the results of the survey. The first looks at levels of food security and

shows that like many informal settlements in African cities, the residents survive in a situation of extreme vulnerability to food insecurity. The second shows that these food insecure households in the informal settlements have high rates of supermarket patronage. The apparent contradiction is because they are largely target shoppers, only patronizing supermarkets to buy staple cereals in bulk at monthly intervals. The final section addresses the role of the informal food sector in the informal settlements, arguing that although it improves accessibility to more nutritious foods, households remain mired in the city's food deserts.

2. Windhoek's Informal Settlements

Namibia is urbanizing at a rapid rate and outpacing formal housing delivery [6]. Informal settlements are growing quickly in all urban centres [7]. Nationally, at the time of the 2011 Census, there were approximately 80,000 urban households in shacks, a number projected to grow to over 530,000 by 2031 [7]. Windhoek had a total population of 322,500 in 2011, a 36% increase from the previous census in 2001. Shack housing made of corrugated iron predominates in all the informal settlements. One third (or 27,000) of all residential units in Windhoek were shacks, a 90% increase from 2001. Windhoek's informal settlements are located in the four north-western constituencies of Tobias Hainyeko, Moses Garoëb, Samora Machel, and parts of Khomasdal North. Between 2001 and 2011, the population increase was as high as 77% in Moses Garoëb and 69% in Samora Machel, primarily as a result of in-migration from rural areas [46].

Table 1 provides basic information on demography and service provision in the three main areas of informal settlement. The total number of households was nearly 40,000 with 143,000 household members. Nearly 30% of the population were children under the age of 15 while over two-thirds were working age adults. In the informal settlements, the proportion of households in shacks varied from 37% in Samora Machel to 71% in Tobias Hainyeko. The informal settlements continue to grow through spatial expansion and densification [47,48]. Between 2012 and 2016, an additional 15,000 shacks were built, i.e., around 3,500 new structures per year [49,50]. While most households have access to public piped water, accessibility to electricity, private toilets, and garbage removal is much more limited [51].

Table 1. Characteristics of constituencies with informal settlements, 2011 [47].

	Moses Garoëb	Samora Machel	Tobias Hainyeko
No. of Households	13,800	13,200	12,600
Population	45,500	49,700	45,800
Age 0–14 (%)	25	29	27
Age 15–59 (%)	72	68	70
Age 60+	1	1	1
Employed (%)	62	63	62
Unemployed (%)	38	37	38
Public piped water (% of HH)	99	99	98
Private toilet (% of HH)	44	77	33
Electric lighting (% of HH)	28	69	20
Regular garbage collection (% of HH)	28	69	20
Shacks (%)	64	37	71
Brick houses (%)	36	63	29

Formal unemployment in all three areas was close to 40% in 2011. Levels of unemployment were highest for females and poverty is most severe for female-headed households [47]. Males have higher rates of formal employment than females, but work primarily as manual laborers in sectors like construction [52]. Jobs in the formal sector are sparse for women, so many turn to the informal sector to earn income. Previous studies of the quality of life in the informal settlements indicate that levels of absolute and lived poverty are extremely high and that this, in turn, is related to poor health outcomes (including child stunting and underweight) and a high incidence of food insecurity including a diet deficient in both quantity and quality [52–54]. A survey in 2007–2008, for example, found that

three-quarters of households in the city's low-income areas were severely food insecure and only 6% were food secure [52]. Dietary diversity was also very low with foods eaten from an average of less than 5 of 12 possible food groups in the 24 h prior to the survey. A more recent survey of a sample of over 400 households in various informal settlements found that two-thirds were food insecure [53].

Windhoek's burgeoning informal settlements certainly qualify as urban food deserts in terms of the revised Africa-specific definition provided above: i.e., they are poor, informal, urban neighborhoods characterized by high food insecurity and low dietary diversity. What is less clear is whether they have multiple market and non-market food sources as per the definition. In terms of the main food sources, previous studies suggest that low-income households in Windhoek purchase most of their food from a combination of formal and informal retail outlets—including supermarkets, informal markets, street vendors, and tuck shops [52]. With urban agriculture almost non-existent, the primary non-market source of food is rural-urban food transfers [55].

3. Research Methods

The data for this study comes from a city-wide household survey of the City of Windhoek conducted in August 2016 as part of the ongoing research program of the African Urban Network (AFSUN) and the Hungry Cities Partnership (HCP). The survey instrument was developed by AFSUN and HCP and mounted on tablets through a modified computer-assisted personal interviewing open data toolkit (ODK). The city-wide survey interviewed a total of 863 households, drawn from all 10 constituencies, using a two-stage cluster sampling design. First, a total of 35 primary sampling units (PSU) were randomly selected with probability proportional to size (PPS). The PSUs were selected from a master frame developed and demarcated for the 2011 Population and Housing Census. The second stage involved systematic sampling of 25 households in each of the selected PSUs. In each household, the head or their representative was interviewed after informed consent. For the purposes of this paper, a sub-sample of 431 households in informal settlements was extracted from the overall sample of over 800. All these households were resident in informal (shack) housing in the relevant constituencies.

The survey collected data on household demography and economics, levels of food security, the type and location of food sources, and the purchasing strategies of households. To assess the prevalence and levels of household food insecurity, the survey used three indicators developed by the Food and Nutrition Technical Assistance (FANTA) project [28] as follows: (a) the Household Food Insecurity Access Score (HFIAS) which is a continuous measure of the degree of food insecurity in the household [32]. An HFIAS is calculated based on answers to nine frequency-of-occurrence questions and ranges from 0 (completely food secure) to 27 (completely food insecure); (b) the Household Food Insecurity Access Prevalence (HFIAP) measure uses a scoring algorithm to categorize households into one of four categories: food secure, mildly food insecure, moderately food insecure, and severely food insecure (Coates et al. 2007); and (c) the Household Dietary Diversity Score (HDDS) which captures how many food groups from 0 to 12 were consumed within the household in the previous 24 h [33]. Household food purchasing patterns were identified using the Hungry Cities Food Purchase Matrix (HCFPM) which identifies where households normally purchase a range of up to 30 common food items, the frequency of purchase, and the geographical location of the source [56].

4. Food Insecurity in Windhoek's Food Deserts

4.1. Levels of Food Insecurity

The survey results reveal extremely high rates of food insecurity amongst households living in shack housing in Windhoek's informal settlements. The mean household HFIAS score was 15.4 which is very high by most standards. For example, a study of over 6000 households in low-income neighborhoods in 11 African cities by AFSUN found an average HFIAS of 10.0. Even Harare in Zimbabwe which was in the middle of a severe economic crisis at the time had a mean HFIAS of 14.7 [57]. In Windhoek, the mean HFIAS was 9.3. In another study of Lilongwe in Malawi also focused

exclusively on informal settlements, the mean HFIAS was only 10.3 [58]. Two-thirds of the households in the Windhoek informal settlements had an HFIAS of 15 or greater, and a quarter an HFIAS of 20 or greater (Figure 1).

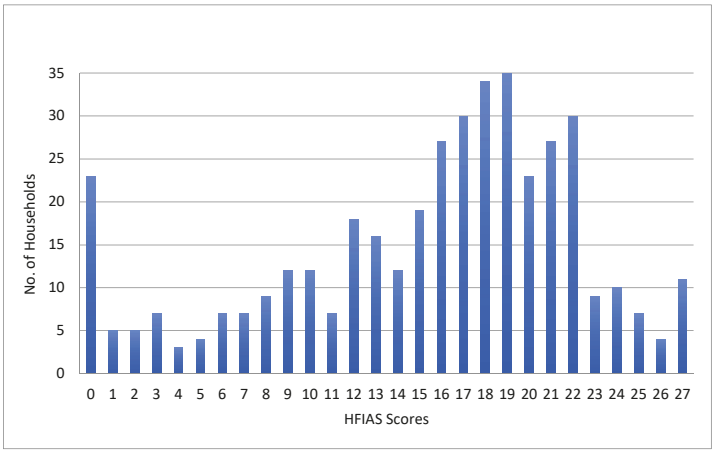

Figure 1. Distribution of household HFIAS scores.

The high HFIAS scores translate into very high prevalence of food insecurity on the HFIAP classification. Only 6.2% of households classified as completely food secure, while 81.2% were severely food insecure. To put these extremely high levels of food insecurity into context, Table 2 compares the Windhoek findings with those for the whole Windhoek sample (including the informal settlements) which found that 16.4% were food secure and 67.1% were severely food insecure. Other comparative benchmarks include the AFSUN study in which 57% of low-income households were food insecure [21]. The Lilongwe informal settlements study also found high levels of severe food insecurity, but the proportion of severely food insecure households was lower (at 72%) [58].

Table 2. Windhoek informal settlement HFIAP in comparative context.

	% of Households in Informal Settlements in Windhoek, 2016	% of all Households in Windhoek, 2016	% of Households in Low-income Areas of 11 SADC Cities, 2007–2008	% of Households in Informal Settlements in Lilongwe, Malawi, 2015
Food secure	6.2	16.4	17.0	3.0
Mildly food insecure	1.2	3.4	7.0	6.0
Moderately food insecure	8.4	13.1	19.0	19.0
Severely food insecure	81.2	67.1	57.0	72.0

Of the four basic types of household structure, nuclear households were the most food insecure with an HFIAS = 16.9, followed by female-centered households (HFIAS = 15.6), extended households (HFIAS = 14.9), and finally male-centered households (HFIAS=13.9) (Table 3). Nuclear households are the most food insecure because they tend to be larger in size with more young dependents. However, while there are variations in the prevalence of food security by household type, the overall picture is of ubiquitous food insecurity with well over 80% of households severely food insecure in each category. As many as 77% of the household heads said that they worry about not having sufficient food and 60% that in the previous month there had been times when there was no food of any kind in the house due to a lack resources to purchase it. Nearly half had experience of going to bed hungry because there was no food in the house and 40% had gone a whole day and night without eating anything. Food shortages led to eating fewer meals (71%) and eating smaller meals (70%).

Table 3. Levels of household food insecurity in Windhoek informal settlements by household type.

	Households		HFIAS	HFIAP				HDDS
	No.	**%**	**Mean**	**Food Secure (%)**	**Mildly Food Insecure (%)**	**Moderately Food Insecure (%)**	**Severely Food Insecure (%)**	**Mean**
Female-centred (no husband/male partner, may include relatives, children, friends)	114	28.2	15.6	5.1	0.8	7.6	86.5	2.5
Male-centred (no wife/female partner, may include relatives, children, friends)	100	24.8	13.9	9.9	2.0	6.9	81.2	2.6
Nuclear (husband/male partner and wife/female partner with or without children)	105	26.0	16.9	4.0	0.0	7.6	88.4	2.3
Extended (husband/male partner and wife/female partner and children and other relatives)	85	21.0	14.9	4.7	2.4	11.8	81.1	3.0
Total	404	100.0	15.4	6.2	1.2	8.4	84.2	2.6

4.2. Quality of Household Diets

In addition to insufficient food, the quality of the diet in the informal settlements is very poor. The mean HDDS for all the households in the informal housing sub-sample was only 2.6, meaning that on average households had eaten food from less than three food groups in the previous 24 h. A total of 63% of the households had an HDDS of 2 or less and 97% had an HDDS of 5 or less (Table 4). An HDDS of 5 is generally considered the absolute minimum for a nutritionally adequate diet. While there was some variation by household structure, from a low of 2.5 for female-centered households to 3.0 for extended households, the values for all four groups indicate extremely limited dietary diversity (Table 3).

Table 4. Distribution of HDDS scores in Windhoek informal settlements.

No. of Food Groups	No. of Households	% of Households	Cumulative % of Households
0	11	2.6	2.6
1	33	7.9	10.5
2	220	52.5	63.0
3	68	16.2	79.2
4	43	10.3	89.5
5	24	5.7	95.2
6	8	2.9	98.1
7	4	1.0	99.1
8	3	0.7	99.8
9	1	0.2	100.0
10	0	0.0	
11	0	0.0	
12	0	0.0	
	411	100.0	

Table 5 shows which food groups had been accessed by the households. The overwhelming majority (95%) had consumed one of the staple cereals that are core to the daily diet—maize meal, rice, pearl millet, pasta, or wheat (in the form of bread). Around a third were able to supplement the staple with meat (beef, chicken, or offal) and nearly a third had eaten some fish. Around 22% had been able to consume some vegetables but apart from non-nutritious commodities such as sugar and tea/coffee and food made with oil, little else had been consumed by many households. Dairy had only been consumed in 8% of households and fruit in only 2%.

Table 5. Food groups consumed in Windhoek informal settlements.

Food Groups	No. of Households	% of Households
Cereals and food made from grains	398	95.0
Meat including beef, chicken, offal	141	33.7
Fresh or dried fish	121	28.9
Foods made with oil, fat, or butter	101	24.1
Vegetables	93	22.2
Sugar or honey	89	21.2
Other foods such as condiments, coffee, tea	57	13.6
Dairy products including milk and cheese	33	7.9
Foods made from beans, peas, lentils, or nuts	19	4.5
Potatoes and other tubers	11	2.6
Eggs	10	2.4
Fruit	5	1.2

Note: Multiple-response question.

5. Sources of Food in the Deserts

5.1. Supermarkets

A classic western city food deserts argument would implicate the absence of supermarkets as a key culprit in the state of food insecurity and poor diets of households in the informal settlements of Windhoek. However, the city has undergone a mini-supermarket revolution in the last two decades and there are now over 30 supermarkets (Figure 2) [59]. The majority of the supermarkets are owned by companies from the neighboring country of South Africa, with one local chain, Woermann Brock (WB Supermarkets). While most supermarkets are located in higher-income areas in the center and south of the city, there are a number of budget outlets towards the north of the city. There are no supermarkets within the informal settlements per se but this does not necessarily mean that they are inaccessible to residents of these areas.

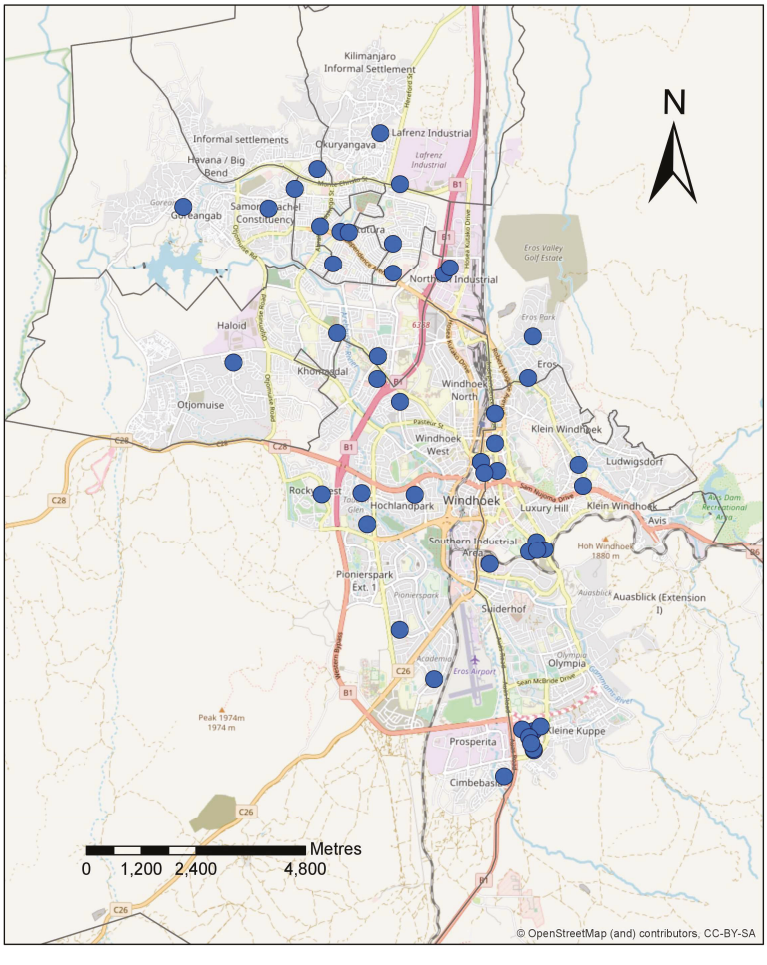

Figure 2. Location of supermarkets in Windhoek.

As Table 6 shows, the vast majority of households in the informal settlements purchase food at supermarkets (at 93% of surveyed households, far more than for any other type of formal or informal outlet). The importance of spatial proximity is confirmed by the fact that the most patronized

supermarkets are virtually all located in the northern part of the city. The spatial accessibility of supermarkets to residents of Windhoek's food deserts suggests that their presence is having little impact on the high levels of food insecurity and dietary diversity. The reasons for this are threefold. First, budget supermarkets close to low-income areas carry a very limited range of products including minimal fresh produce. Second, while supermarkets are spatially accessible, their products may be economically inaccessible to the majority of households on limited income. Third, households tend to target shop at supermarkets on an infrequent basis. Nearly three-quarters of the surveyed households patronize supermarkets on a monthly basis. Only 10% of households shop at supermarkets with any regularity (weekly or more frequently).

Table 6. Food outlets patronized by residents of informal settlements.

	No. of Households	% of Households	At Least Five Days per Week	At Least Once per Week	At Least Once per Month	Less Frequent
Formal Sources						
Supermarkets	389	93.1	1.0	10.0	72.8	16.2
Small shops	64	15.3	7.8	59.4	21.9	11.9
Fast food/takeaways	17	4.1	0.0	11.8	88.2	0.0
Purchase at commercial farm	4	1.0	0.0	25.0	75.0	0.0
Restaurant	2	0.5	0.0	50.0	50.0	0.0
Informal Sources						
Open markets	243	58.1	14.9	46.3	16.9	21.9
Street vendors	113	27.0	62.2	21.6	8.1	8.1
Tuck shops	60	14.4	47.5	35.6	16.9	0.0

Note: Multiple-response question.

This raises the question of what foodstuffs these informal settlement households are buying when they go to supermarkets. The HCFPM provides a product-by-product analysis which shows exactly where households purchase various foodstuffs [56]. Table 7 shows the top 10 food products (i.e., purchased by the greatest number of households in the month prior to the survey). What stands out is that all of these products were bought by at least 20% of purchasing households at supermarkets. Supermarkets were also the primary source for healthy foods such as fruit (76%) and vegetables (56%). However, the proportion of households buying these products is low. Supermarkets completely dominate the purchase of cereals—including mealie meal, rice, and pasta—with over 90% of households buying these staples at supermarkets. The pattern of monthly shopping suggests that they buy these products in bulk. Thus, most households rely on supermarkets for their staple food and while this may mean that they are more food secure than they might otherwise have been, the quantities purchased certainly do not ensure food security, and they certainly do not guarantee a diverse and nutritious daily diet.

Table 7. Foodstuffs purchased at different food retail outlets by residents of informal settlements.

		Formal Outlets			Informal Outlets		
	% of Households	Super Market	Small Shop	Butchery	Open Market	Tuck Shop	Street Seller
Mealie meal	80.5	92.5	2.3		1.2	1.2	0.3
Bread	79.3	39.7	19.0		2.7	31.5	1.1
Fish	41.1	20.9	5.2		24.4	2.9	42.4
Rice	37.8	98.8			1.2		
Pasta	35.0	98.6			0.7		
Meat	34.8	34.7	4.7	16.7	33.3	0.7	10.0
Vegetables	18.1	56.4	6.4		26.9	3.8	6.4
Mahangu	16.2	92.1	3.9		1.3	2.6	1.3
Offal	12.1	20.4	1.9	7.4		44.0	22.2
Fruit	6.7	75.9			17.2		6.9

5.2. Informal Food Sector

The informal food sector has been identified in many African cities as a playing a key role in delivering affordable food to low-income households [45]. In Windhoek, informal retailing has expanded in volume and complexity with the rapid growth of the city. The sector is characterized by several different types of enterprise including: (a) tuck shops which are small informal shops in fixed structures located primarily in informal settlements; (b) mobile vendors selling door-to-door or from the back of small trucks; (c) street vendors on sidewalks, at transport hubs, and outside supermarkets. Clusters of street vendors in various areas are known as informal markets; and (d) open markets which are formally established and approved by the city authorities. The municipality is responsible for fee collection from informal vendors who pay rent for market stands, security, cleaning, sanitation facilities, and maintenance.

Of these various sources, open markets were patronized by almost 60% of surveyed households in the informal settlements in the month prior to the survey, street sellers (including informal market vendors) by just over a quarter and tuck shops by 14% (Table 6). The city's nine open markets are located in close proximity to the informal settlements. One of them, Tukondjeni, is the preferred market for 46% of the informal households. Other well-patronized markets include Single Quarter (preferred by 25% of households), Soweto (by 10%) and Okahandja (by 8%). Almost half of those who shop at open markets do so on a weekly basis and another 15% almost daily. The main products bought at the open markets are meat, fish, and vegetables (Table 7). They therefore do play an important role in making more nutritious foods available for those households that can afford the products.

Street sellers and tuck shops are patronized much more frequently than either supermarkets or open markets, on an almost daily basis in many cases (Table 7). This is mainly because they make food available within walking distance in the informal settlements themselves, break bulk to sell in small and affordable quantities, and offer food on credit to trusted customers. Tuck shops meet local demand for bread and for offal, while street sellers provide fish, meat, and offal. Both of these informal retailers therefore play a role in making a greater range of food available and accessible within the informal settlements. However, their presence is insufficient to mitigate chronic food insecurity as households are only able to patronize these outlets when they have sufficient income or do not have enough income to purchase enough to lift themselves out of a situation of severe food insecurity.

5.3. Absent Urban Agriculture

In some African cities, poor households are able to mitigate food insecurity through non-market mechanisms such as urban agriculture, urban livestock, rural-urban food remittances, and food sharing. In theory, urban agriculture has the potential to mitigate food insecurity and diversify diets in Africa's urban food deserts. However, the evidence on the success of urban agriculture in achieving these goals is extremely mixed. In many Southern African cities, rates of participation in urban agriculture by the urban poor are extremely low [60,61]. In informal settlements, where land is at a premium, urban agriculture is even less feasible. An earlier study of urban agriculture in Windhoek gave the impression that the city was an exception [62]. However, the study only interviewed a small sample of households that were practicing urban agriculture. While this provided insights into some of the challenges faced by these households in growing food in the city, it provided no sampling frame and therefore no sense of how typical these households were. Other studies suggest that participation rates in urban agriculture are very limited in Windhoek due to land shortages, the arid climate, and lack of inputs [52].

In our 2016 survey of Windhoek's informal settlements, less than 10% said they grow any of their own food or keep livestock for food in the city. Seeking to understand why urban agriculture is not greening Windhoek's informal food deserts, respondents were asked to agree or disagree with a set of statements about the obstacles to growing their own food. Interestingly, as Table 8 shows, the threat of theft or produce proved to be the biggest impediment (with 69% in agreement). More conventional disincentives were also cited by most respondents including land shortage (68%), a lack of inputs

(64%) and poor soil quality (51%). Half of the respondents agreed that they lacked the skills to grow food and a similar proportion said it was easier to buy food than grow it. There was uncertainty about whether municipal regulations allowed them to practice urban agriculture. A significant minority (45%) had no interest in growing food or did not have the time or labor (39%).

Table 8. Reasons for not engaging in urban agriculture in Windhoek's informal settlements.

Reasons	Agree	Disagree	Neither
People would steal whatever we grow	68.9	19.4	11.6
We have no land on which to grow food	67.9	23.7	8.4
We do not have access to inputs	63.9	24.6	11.6
The soil is poor quality/rocky	51.2	36.6	12.3
We lack the skills to grow food	50.9	41.7	7.4
It is easier to buy our food than grow it	50.7	42.9	6.4
Municipal regulations do not allow us to grow food	49.4	37.5	13.1
We have no interest in growing food	45.5	46.5	8.0
We do not have the time or labor	39.0	49.0	12.0
Farming is for rural people only	35.2	49.3	5.5
The water is poor quality/brackish	32.7	53.0	14.3

A few households grew some food in rural areas or received food from relatives in rural areas. While there is some food sharing in the informal settlements, the number of beneficiaries is small (less than 10%). This may not be because households are unwilling to share but rather that they barely have enough for their own survival. None of these coping mechanisms have any significant impact on overall levels of food insecurity in Windhoek's informal urban food deserts.

6. Conclusions

Much of the literature on informal settlements in African cities focuses on housing, sanitation, and infrastructure. Food receives much less attention despite its central importance to daily survival. UN-Habitat's list of key urban challenges does not even mention food security as a concern, for example [63]. Similarly, while Sustainable Development Goal (SDG) 11 provides a list of targets for the achievement of sustainable cities by 2030, food security is absent. The reasons for the neglect of urban food deserts in the international food security agenda relates to the pervasive anti-urban bias in the global food security agenda [64]. Rapid urbanization in Africa is leading to the explosive growth of informal settlements which are particularly intense and chronic spaces of deprivation and vulnerability. They are also sites of high levels of food insecurity despite the ubiquitous presence of food. In terms of the Africa-appropriate definition used in this paper, informal settlements also qualify as food deserts.

The traditional conception of food deserts was developed to describe the lack of physical access to healthy food in poorer areas of UK and North American cities. The inaccessibility of supermarkets is seen as a key driver of food desertification. Critics of the food deserts concept have argued that it is inappropriate for Africa, not least because supermarkets have a marginal presence in most African cities. This characterization is not true of many cities in the southern part of the continent where urban food systems are dominated by supermarkets and their supply chains. In the case of Windhoek, Namibia, supermarkets command a majority share of the food retail market and are also physically accessible to the residents of the city's burgeoning informal settlements. However, as we show in this paper, supermarket patronage by households in the city's food deserts is targeted at monthly bulk purchase of key staples. Other healthier foods are available but are unaffordable for the majority.

In addition to the supermarkets, there are numerous formal and informal food outlets both within and near the informal settlements. However, urban agriculture is unviable, leaving households reliant on occasional transfers of food from the rural north to diversify their diet. The high levels of food insecurity in Windhoek's informal settlement food deserts documented here are therefore not a function of the lack or physical inaccessibility of food. Rather, they are due to economic inaccessibility

and the inability of most households to secure sufficient income to meet their basic needs, and to purchase food in sufficient quantity and of sufficient diversity to ensure a balanced and nutritious diet for all household members.

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Family Structure and Severe Food Insecurity in Maputo and Matola, Mozambique

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Abstract: The rapid growth of Maputo and Matola (neighbouring cities in Mozambique) has dramatically shifted the vulnerability profiles of these cities. Poor neighbourhoods across these two cities may now face the prospect of becoming food deserts. Scholars have defined African urban food deserts by the co-occurrence of poverty and food insecurity. This study aims to assess the assumed relationship between resource poverty and food insecurity in the African urban food desert concept and to assess the contribution of household demographics to this relationship. Using household survey data collected in 2014 across Maputo and Matola, this investigation demonstrated that inconsistent access to water, electricity, medical care, cooking fuel, and cash was associated with increased odds of severe household food insecurity across both cities. In addition, a nuclear household family structure was associated with reduced odds of severe food insecurity in both cities (even when taking limited resource access into account). These findings suggest that the severe food insecurity vulnerabilities associated with African urban food deserts may differ according to the family structure of households in Maputo and Matola.

Keywords: food deserts; food security; urbanization; urban poverty; social networks

1. Introduction

Africa is experiencing rapid urbanization [1,2]. While the global urban transition is estimated to have occurred around 2010, this region will continue to host a dramatic shift from rural to urban livelihoods in the coming years [3]. Megacities and secondary cities across Africa are both expected to grow rapidly (with the latter receiving the lion's share of growth) [3]. These rapid changes represent opportunities and challenges, particularly for cities in Sub-Saharan Africa [4], where the urban transition has been matched by technological, economic, and public health innovations [5]. Alongside this rapid urbanization, diets in this region (and across the developing world) have also favoured increasing sugar and saturated fat consumption [6]. Under this nutrition transition, many cities have come to host public health challenges resulting from both under-nutrition and over-consumption [7]. Popkin et al. [8] draw attention to the dietary challenges faced by the urban poor as urban food systems are overwhelmed by cheap and easily accessible processed foods. As a result, urban growth, poverty and nutrition have become intertwined causal factors in a damaging prognosis for future generations in Sub-Saharan Africa.

These intertwined hazards have been framed as sustainability challenges in the Sustainable Development Goals (SDGs) adopted by the United Nations on 25 September 2015 [9]. Among the 17 goals adopted in this resolution, SDG 1 (No Poverty), SDG 2 (Zero Hunger) and SDG 11 (Sustainable Cities and Communities) highlight the interwoven dietary and demographic shifts described so far. While other authors have theorized the network of relationships connecting these SDGs [10],

the concept of the urban food desert has provided a helpful theoretical anchor for the intersection of SDGs 1,2, and 11. Early conceptions of the term focused almost exclusively on the spatial availability of supermarkets [11–13]. Recently, however, the term has evolved to incorporate the accessibility of a broader range of food retail outlets and specific food items [14]. Current work on the topic has embraced the complexity of modern urban food systems, integrating both economic and political concerns [15,16].

In a novel approach to the urban food desert concept, Battersby and Crush [17] defined the African urban food desert as "poor, often informal, urban neighbourhoods characterised by high food insecurity and low dietary diversity, with multiple market and non-market food sources but variable household access to food" (p. 149). This definition was situated in contrast to predominantly Euro-American conceptualizations of the term that often left out the unique contributions of informal food retail (for example, street vending and unregulated food markets) and non-market food sources (for example, food remittances and urban agriculture) in determining household food insecurity in the African context. Battersby and Crush note that, while these food system activities are difficult to define and measure, they are frequently relied upon by poor urban households in the southern African context. This definition also recognizes the contribution of poverty and informality to urban household food insecurity. While the consideration of poverty in the development of food deserts has been previously highlighted through investigations into redlining (the spatial avoidance of poor areas for profit-driven food retailing) [13], the causal structure is different in the Battersby and Crush definition. Instead of focusing on the availability of food, Battersby and Crush re-focus the definition of urban food deserts towards the accessibility of food and thus open the concept to the broader poverty contexts that constrain food access [18]. In defining food deserts by access, Battersby and Crush have shifted the term from a primarily spatial measure to a conceptual framework. While both the concept of the urban food desert and the informal sector are contested in the literature, the Battersby and Crush definition is a conceptually helpful tool for understanding grounded realities of urban food security in the Global South.

Despite the adoption of the SDG goals, and the extensive literature on urban food deserts, urban food insecurity in developing countries is relatively under-studied. Those studies that have been undertaken tend to focus more on food production and the availability dimension of food insecurity [19]. In Mozambique, there is also a public policy tendency to respond to food insecurity with food production programs. That said, there has been growing research interest in other dimensions and drivers of urban food security in Mozambican cities [20–22]. This paper takes a broader, non-productionist approach to urban food insecurity through a study of the adjoining mainland cities of Maputo and Matola in southern Mozambique. These cities have been selected as case studies for this investigation because of the widespread challenge of food insecurity faced by households in both cities. Preliminary studies have also indicated that, as the Battersby and Crush urban food desert definition highlights, there may be an intersection between resource poverty and food insecurity in Maputo [20–22]. As a result, these cities are a fertile ground for testing this definition of urban food deserts empirically.

This paper provides an analysis and comparison of the predictors of severe food insecurity in Maputo and Matola based on data from a Hungry Cities Partnership (HCP) household survey conducted in 2014. To achieve this aim, the investigation assesses the predictive relationship between household family structure and severe food insecurity in Maputo and Matola. This relationship is then tested against household resource poverty (defined by limited access to water, electricity, cash, medical care, and cooking fuel) to determine whether any observed relationships between household family structure and severe food insecurity change when resource poverty is controlled. The results of this investigation assess the contribution of household demographics to the severe food insecurity vulnerabilities associated with urban food deserts. Through this analysis, this investigation will assess the validity of the assertion in the Battersby and Crush definition that resource poverty is associated with urban food insecurity and whether that relationship is further nuanced by broader

systems of social support. If that is the case, then the urban food desert definition may need to evolve further to include considerations of social structure and support when assessing and explaining urban food security.

Background on Maputo and Matola

The City of Maputo is the capital of Mozambique and is in the south of the country on the western shore of Maputo Bay (Figure 1). Administratively, the city is divided into seven municipal districts, namely KaMavota, KaMaxaqueni, Kampfumo, KaMubucuane, KaNyaka, KaTembe, and Lhamankulu, To the west is the City of Matola, the capital of the province of Maputo. Matola is divided into three administrative posts (corresponding to Maputo's municipal districts)—Infulene, Machava and Matola Sede). According to the preliminary results of the population census of 2017 by the National Institute of Statistics, Maputo City has a total population of about 1,101,170 persons (48% male and 52% female). The City of Matola has a total population of 1,616,267 (47% male and 53% female) (Figure 2). Maputo has 242,254 households and Matola has 374,546 households [23].

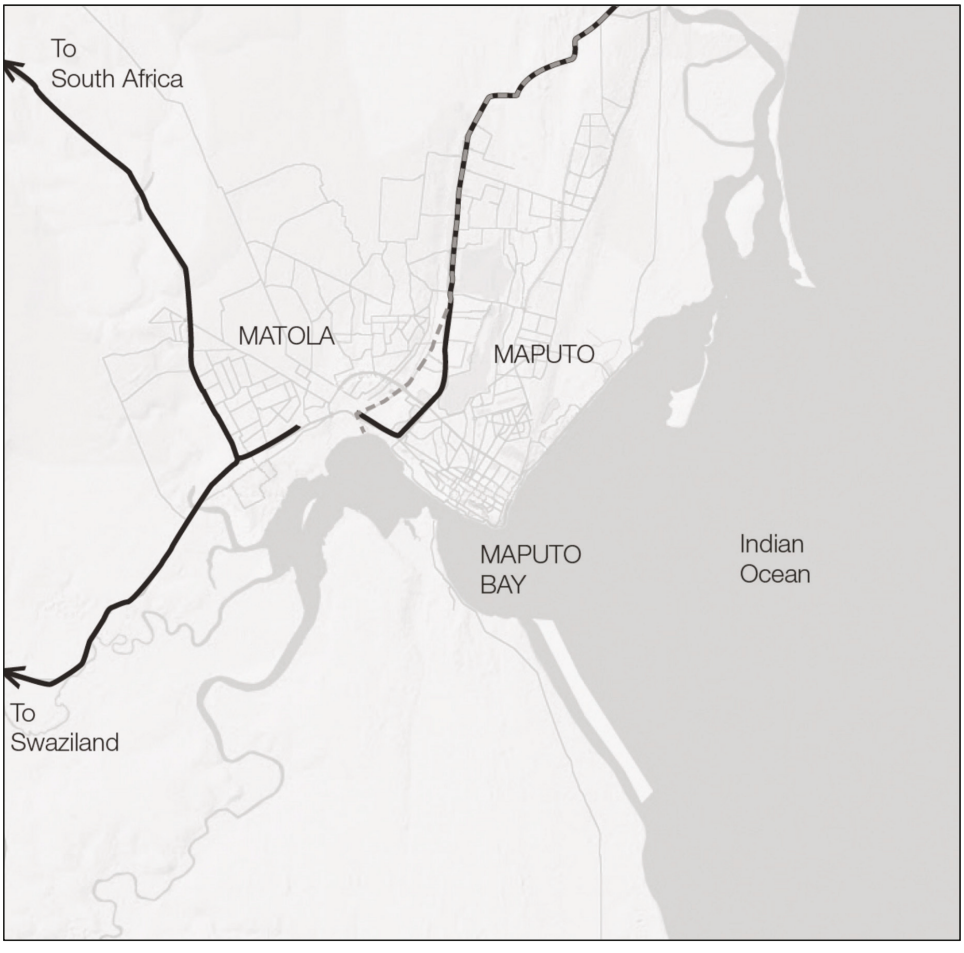

Figure 1. Map of Maputo and Matola, 2014 [20].

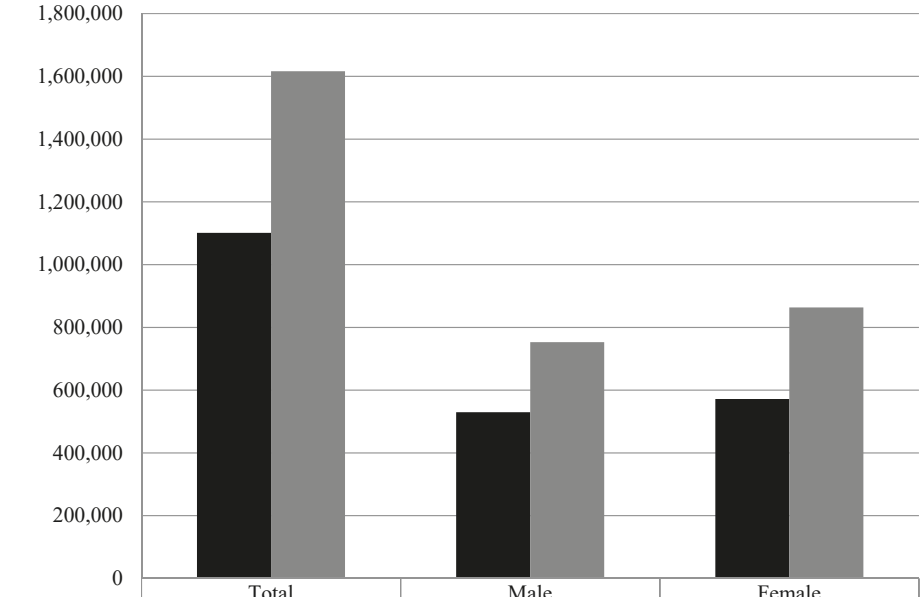

Figure 2. Population of Maputo and Matola, 2017 [23].

According to surveys carried out by the Hungry Cities Partnership, both the city of Maputo and Matola experience severe, and similar, degrees of food insecurity. Only around 30% of the sampled households in both cities were categorized as food secure in these surveys (Table 1). At the same time, almost 40% of the sampled households in both cities were categorized as severely food insecure. These frequency distributions indicate significant inequality in the household experience of food security in Maputo and Matola. About 70% of the surveyed households were categorized as either food secure or severely food insecure, while only 30% of the sampled households experienced mild to moderate forms of food insecurity. When household food security scores were calculated as scaled scores from 0 to 27 (where 0 represented complete food security and 27 represented complete food insecurity), the sampled households in these cities differed only marginally. The sampled households in Maputo received an average score of 6.48 while the sampled households in Matola received an average score of 6.11 on this scale.

Table 1. Household food security in Maputo and Matola.

Household Food Security	**Maputo**		**Matola**	
	n	**%**	**n**	**%**
Food Secure	589	28.6%	166	32.9%
Mildly Food Insecure	227	11.0%	53	10.5%
Moderately Food Insecure	453	22.0%	98	19.4%
Severely Food Insecure	787	38.3%	187	37.1%
Total	2056	100.0%	504	100.0%

Source: Author's own calculations.

The Hungry Cities Partnership surveys also indicate that, in the 24 h leading up to the survey, sampled households in Maputo consumed an average of 4.14 food groups and the sampled households in Matola consumed an average of 4.26 food groups. These statistics indicate very limited dietary diversity with marginal difference between the two cities. That said, there does appear to be a slight difference in the distribution of this dietary diversity between the two cities (Figure 3). In the 24 h leading up to the survey, the sampled households in Maputo were more likely to consume 3 or fewer food groups while the sampled households in Matola were more likely to consume 4 or more food groups. These differences amounted to only a slight difference in the average dietary diversity of the sampled households in these two cities.

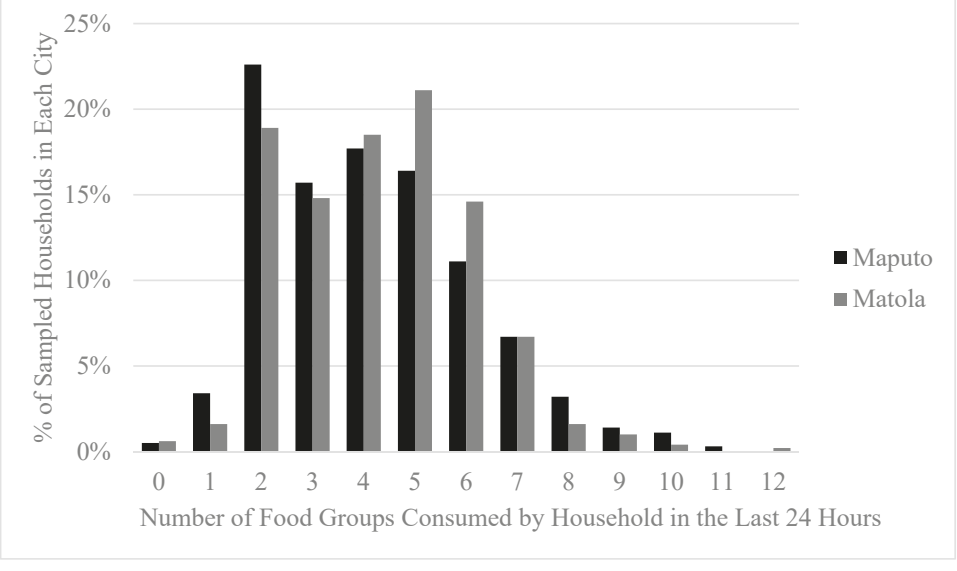

Figure 3. Household dietary diversity in Maputo (n = 2071) and Matola (n = 507) (author's own calculations).

Much of the insecurity experienced by vulnerable households in Maputo and Matola is an outcome of Mozambique's unique pathway towards urbanization. Urban development in Mozambique has historically been centralized in Maputo. However, recent trends indicate that urbanization has become more diffuse, with the rapid development of many secondary cities in the country [24]. Over the previous few decades, there have been several piecemeal infrastructure development projects in both Maputo and Matola [25]. These projects were historically hampered by the country's civil war which redirected funding towards national security at the cost of urban planning [26]. Following the end of colonial rule, urban infrastructure development continued to be obstructed by the limited availability of funding [25]. The resulting distribution of infrastructure across Maputo tends to fall along broad lines of formality and informality [27]. Access to these key infrastructure resources has been complicated by land tenure policies which have tended to regard rural–urban migrants in the city as temporary residents [25,28,29].

The distribution of infrastructure in Maputo and Matola is pertinent to the existence of food deserts because of its predictive relationship with food security [30]. Urban infrastructure provides access to the basic resources and services that are required for urban livelihoods. Interruptions in household access to those resources and services has significant and negative impacts on human security [31,32]. Within the context of Maputo, McCordic [33] demonstrated that household access to cash, medical care, electricity, and water significantly predicted levels of household food security.

McCordic and Frayne [34] also found that household access to cooking fuel was a significant predictor of food security among poor urban households across Southern Africa.

There are theoretical explanations for the relationship between resource poverty and food insecurity. Household food access in cities is chiefly negotiated through retail rather than production. Secure food access is therefore predominantly a function of household assets and food prices. Limited household access to basic resources can indicate the availability of disposable household assets, since going without these goods and services demonstrates a limited capacity to purchase those resources. It is important to note, however, that households are not passive agents of their circumstances. Households secure access to key resources through adaptive coping strategies (including remittances, self-limiting food consumption, and resource trade-offs). In this context, household family structure can indicate a household's ability to adapt to hazards via the extent and quality of supports available within that household.

There is also evidence that social support systems can mitigate the impact of food insecurity. Morton et al. [35] found that food transfer arrangements in rural areas of Iowa were associated with greater resiliency in food deserts. Using survey data collected in the United States, Garasky et al. [36] found that social support systems were a beneficial coping mechanism for dealing with food insecurity. Using large-scale survey data collected in the United States, Balistreri [37] also found that children living in complex family structures were more vulnerable to food insecurity. The challenge is that many of these studies have been undertaken in a North American context. This investigation assesses whether these conclusions are relevant to urban food deserts in Maputo and Matola.

2. Materials and Methods

This investigation assesses the predictive relationship between household family structure, resource poverty and severe food insecurity in City of Maputo (with KaNyaca and Katembe districts excluded) and Matola, using household survey data collected in 2014. To achieve this aim, this investigation has the following objectives: (a) to determine the predictive relationship between household family structure and severe household food insecurity in Maputo and Matola, (b) to determine the predictive relationship between household resource poverty and severe household food insecurity in Maputo and Matola, and (c) to assess whether the predictive relationship between household family structure and severe household food insecurity changes when adjusted for household resource poverty in Maputo and Matola.

The data is drawn from a household food security survey of Maputo and Matola completed in 2014. The survey was administered by the HCP in collaboration with the Centre for Policy Analysis at Eduardo Mondlane University (EMU) in Maputo, Mozambique. All household respondents in this survey provided free and informed consent before participation in the study. This survey was completed according to the Tri-Council Policy Statement on Ethical Conduct for Research Involving Humans. The survey administration procedures were approved by the Wilfrid Laurier University Research Ethics Board. The HCP household survey instrument measured food security, food access, and household economic and social demographic characteristics. The household survey was administered using android tablets by researchers and students from EMU. In Maputo, 19 wards were randomly selected, and the total sample size was stratified across these wards using approximate proportionate allocation based on the most recent census records for the city. A systematic sampling strategy was used to select households within each ward. The same sampling strategy was used in Matola, where 10 wards were randomly selected. The total Maputo household sample size was 2071 households and the total Matola household sample size was 507 households.

This paper drew three sets of variables from the household survey: household food security, household family structure, and household resource poverty (Table 2). Household food security was measured using the Household Food Insecurity Access Scale (HFIAS) [38,39]. This scale is based on 9 Likert style questions that assess the frequency with which households have experienced different food access challenges in the previous four weeks. The answers to these questions are then summed up

using a scoring algorithm to categorize each household into one of the following four categories: food secure, mildly food insecure, moderately food insecure, and severely food insecure. For the purposes of this investigation, the HFIAS categories were binned into a binary variable representing whether a given household is severely food insecure.

Table 2. Investigation variable descriptions.

Variable	Level	Values	
Dependent Variable			
Household Food Insecurity Access Scale (HFIAS)	Binary	Not Severe	Severe Food Insecurity
Household Family Structure			
Female-Centred	Binary	No	Yes
Male-Centred	Binary	No	Yes
Nuclear	Binary	No	Yes
Extended	Binary	No	Yes
Household Resource Poverty			
Water Access	Binary	Consistent	Inconsistent/No Access
Medical Access	Binary	Consistent	Inconsistent/No Access
Electricity Access	Binary	Consistent	Inconsistent/No Access
Fuel Access	Binary	Consistent	Inconsistent/No Access
Cash Access	Binary	Consistent	Inconsistent/No Access

To predict this HFIAS dependent variable, this investigation relied on two sets of independent variables: (a) household family structure and (b) household resource poverty. The household family structure variable reflects the internal social arrangement of the household and is divided into four categories: male-centred, female-centred, nuclear and extended. Male-centred households contain a single male head without a partner/spouse; female-centred households contain a single female head without a partner spouse; nuclear households contain a married or common law couple with or without children; and extended households contain a married or common law couple with immediate and extended relatives or non-relatives living in the household. This variable was binned into four dummy variables which indicate whether any given household is categorized in any one of these household family structures. The set of household resource poverty variables measure whether households have consistent or inconsistent (including no) access to water, medical care, electricity, cooking fuel, and cash in the year prior to the survey. These variables are drawn from the Afrobarometer Live Poverty Index and represent important and basic resources needed to support life and overall household food security [33].

To assess whether these sets of independent variables have a predictive relationship with severe household food insecurity in Maputo and Matola, this investigation relied on odds ratios to assess whether a change in the value of any of the independent variables is associated with a change in the odds of the dependent variable (severe household food insecurity). These calculations were paired with Pearson's chi-square tests and Fisher's exact tests to assign a *p*-value to assess the statistical significance of the relationships. These odds ratios are calculated independent of the influence of any other variable. In other words, it is difficult to assess whether the relationship is mediated or moderated by other variables in the data set. In order to assess this aspect of the relationship, this investigation relied on binary logistic regression to control for the influence of the resource poverty variables while assessing the relationship between household family structure and severe food insecurity.

This research approach has inherent limitations. First, given the challenges in developing an accurate sampling frame (due to the limited availability of recent, accurate and relevant maps and census data), it is difficult to establish the generalizability of the household survey to all households in either Maputo or Matola. Second, the thresholds used to bin variables in this investigation may mask variations in the variable measurements and therefore may miss more important thresholds for predicting household food security. Third, given the observational nature of this data, the lack of a control group and the limited statistical ability to control all significant variables, it is not possible to use this research to make causal arguments. Instead, this research approach can highlight predictive relationships and changes in the quality of those relationships when other factors are controlled. Finally, as is the case in all survey research, the variables measured in this investigation are open to the subjectivity, interpretation, and recall of the survey respondents. As a result, deeper and more qualitative insights are not feasibly captured in this analytical approach. While this investigation can statistically control the influence of a few variables, further qualitative research will be needed to gain insight into the broader socio-cultural systems in which the findings from this investigation are embedded.

3. Results

The distribution of households across the independent and dependent variables reveal some interesting preliminary trends (Tables 3 and 4). Within the sample, only about 28% of severely food insecure households in Maputo and Matola maintained consistent access to medical care in the previous year. Similarly, only about 25% of severely food insecure households in these cities maintained consistent access to cash or cooking fuel in the previous year. Among the different household family structures, over 40% of the sampled male-centred and extended households were severely food insecure in Maputo and Matola.

Table 3. Cross-tabulation of variables against severe household food insecurity in Maputo.

Variables	Values	Not Severe		Severe F.I.		Total	
		n	%	n	%	n	%
Female-Centred	Not a Female-Centred Household	893	63.4	516	36.6	**1409**	**100**
	Female-Centred Household	365	57.8	266	42.2	**631**	**100**
Male-Centred	Not a Male-Centred Household	1081	61.7	670	38.3	**1751**	**100**
	Male-Centred Household	177	61.2	112	38.8	**289**	**100**
Nuclear	Not a Nuclear Households	857	59.0	595	41.0	**1452**	**100**
	Nuclear Households	401	68.2	187	31.8	**588**	**100**
Extended	Not an Extended Household	991	62.6	592	37.4	**1583**	**100**
	Extended Household	267	58.4	190	41.6	**457**	**100**
Water Access	Consistent Access to Water	927	69.0	416	31.0	**1343**	**100**
	Inconsistent Access to Water	329	47.8	360	52.2	**689**	**100**
Medical Access	Consistent Access to Medical Care	1105	71.8	435	28.2	**1540**	**100**
	Inconsistent Access to Medicine	154	30.9	345	69.1	**499**	**100**
Electricity Access	Consistent Access to Electricity	711	73.4	258	26.6	**969**	**100**
	Inconsistent Access to Electricity	542	51.2	516	48.8	**1058**	**100**
Fuel Access	Consistent Access to Cooking Fuel	1023	75.0	341	25.0	**1364**	**100**
	Inconsistent Access to Cooking Fuel	236	35.1	436	64.9	**672**	**100**
Cash Access	Consistent Access to Cash	1031	75.9	327	24.1	**1358**	**100**
	Inconsistent Access to Cash	225	33.2	452	66.8	**677**	**100**

Table 4. Cross-tabulation of variables against severe household food insecurity in Matola.

Variables	Values	Not Severe		Severe F.I.		Total	
		n	%	n	%	n	%
Female-Centred	Not a Female-Centred Household	239	64.6	131	35.4	**370**	**100**
	Female-Centred Household	76	58.5	54	41.5	**130**	**100**
Male-Centred	Not a Male-Centred Household	285	64.2	159	35.8	**444**	**100**
	Male-Centred Household	30	53.6	26	46.4	**56**	**100**
Nuclear	Not a Nuclear Households	187	56.7	143	43.3	**330**	**100**
	Nuclear Households	128	75.3	42	24.7	**170**	**100**
Extended	Not an Extended Household	240	65.2	128	34.8	**368**	**100**
	Extended Household	75	56.8	57	43.2	**132**	**100**
Water Access	Consistent Access to Water	237	72.5	90	27.5	**327**	**100**
	Inconsistent Access to Water	76	43.9	97	56.1	**173**	**100**
Medical Access	Consistent Access to Medical Care	279	72.8	104	27.2	**383**	**100**
	Inconsistent Access to Medicine	31	27.7	81	72.3	**112**	**100**
Electricity Access	Consistent Access to Electricity	169	71.6	67	28.4	**236**	**100**
	Inconsistent Access to Electricity	143	54.4	120	45.6	**263**	**100**
Fuel Access	Consistent Access to Cooking Fuel	259	73.4	94	26.6	**353**	**100**
	Inconsistent Access to Cooking Fuel	54	37.0	92	63.0	**146**	**100**
Cash Access	Consistent Access to Cash	253	74.2	88	25.8	**341**	**100**
	Inconsistent Access to Cash	59	37.6	98	62.4	**157**	**100**

3.1. Odds Ratios

The odds ratio calculations for these relationships indicate the statistical significance of the trends observed in these descriptive statistics (Table 5). All the resource poverty variables were associated with a statistically significant increase in the odds of severe household food insecurity. Sampled households with inconsistent access to medical care, cooking fuel or cash over the past year had at least 4 times the odds of being severely food insecure in Maputo and Matola when compared to households that maintained consistent access to these resources. Among the household family structures, only nuclear households shared a statistically significant relationship with severe food insecurity in both cities. In this case, the sampled nuclear households in Maputo had 30% lower odds of being severely food insecure while the sampled nuclear households in Matola had 50% lower odds of being severely food insecure when compared to other household family structures. In Maputo, female-centred households also had 26% higher odds of being severely food insecure when compared to other household family structures. That said, this relationship indicated limited statistical significance and the sampled households in Matola did not show the same relationship. This analysis indicates that, except for female-centred households, the same relationships are observed between severe food insecurity, household family structure, and resources access across both cities.

Table 5. Household food security in Maputo and Matola.

	Maputo				Matola			
	95% C.I.				95% C.I.			
Variables	**O.R.**	**Lower**	**Upper**	**N**	**O.R.**	**Lower**	**Upper**	**N**
Female-Centred	1.261 *	1.041	1.528	2040	1.296	0.861	1.951	500
Male-Centred	1.021	0.791	1.318	2040	1.553	0.887	2.719	500
Nuclear	0.672 **	0.548	0.823	2040	0.429 **	0.284	0.647	500
Extended	1.191	0.964	1.473	2040	1.425	0.95	2.138	500
Water Access	2.438 **	2.018	2.946	2032	3.361 **	2.285	4.945	500
Medical Access	5.691 **	4.567	7.091	2039	7.01 **	4.376	11.229	495
Electricity Access	2.624 **	2.177	3.162	2027	2.117 **	1.458	3.073	499
Fuel Access	5.542 **	4.536	6.771	2036	4.694 **	3.113	7.078	499
Cash Access	6.334 **	5.172	7.756	2035	4.775 **	3.189	7.152	498

* ($p < 0.05$ on Chi-Square and Fisher's Exact Test), ** ($p < 0.01$ on Chi-Square and Fisher's Exact Test). O.R.: Odds Ratio, C.I.: Confidence Interval.

3.2. Adjusted Odds Ratios

All binary logistic regression models of severe household food insecurity in this analysis had insignificant Hosmer and Lemeshow tests with Nagelkerge R^2 values over 0.25. In addition, multicollinearity was ruled out as a confound for any of these models via Pearson's r correlation matrices of the independent variables in the models. Finally, all models indicated an increase in predictive accuracy by at least 7 percentage points over their null models.

These binary logistic regression models indicate some interesting characteristics. First, when other resource poverty and household structure variables are controlled, the consistency of household access to water and electricity no longer shares a statistically significant relationship with severe household food insecurity in Maputo. In Matola, however, inconsistent access to water remains a statistically significant predictor of severe food insecurity, while electricity access does not maintain such a relationship when these same variables are controlled. Second, controlling for the resource poverty variables, male-centred households demonstrate a statistically significant increase in the odds of severe food insecurity in both Maputo and Matola when compared to other household family structures. Under the same conditions, nuclear households in both cities demonstrate a statistically significant reduction in the odds of severe household food insecurity when compared to other household family structures (Table 6).

Table 6. Binary logistic regression models of severe household food insecurity.

Maputo								
Variables	**O.R.**	**Sig.**	**O.R.**	**Sig.**	**O.R.**	**Sig.**	**O.R.**	**Sig.**
Female-Centred	1.198	0.11						
Male-Centred			1.457	0.013				
Nuclear					0.608	<0.001		
Extended							1.125	0.348
Water Access	1.194	0.158	1.223	0.11	1.176	0.2	1.211	0.126
Medical Access	2.445	<0.001	2.418	<0.001	2.459	<0.001	2.394	<0.001
Electricity Access	1.07	0.587	1.107	0.416	1.123	0.357	1.087	0.505
Fuel Access	2.139	<0.001	2.181	<0.001	2.151	<0.001	2.179	<0.001
Cash Access	3.099	<0.001	3.123	<0.001	3.089	<0.001	3.066	<0.001
Nagelkerke R^2	*0.291*		*0.292*		*0.298*		*0.29*	
HL p-Value	*0.49*		*0.134*		*0.721*		*0.641*	
Matola								
Variables	**O.R.**	**Sig.**	**O.R.**	**Sig.**	**O.R.**	**Sig.**	**O.R.**	**Sig.**
Female-Centred	1.064	0.798						
Male-Centred			2.356	0.009				
Nuclear					0.51	0.004		
Extended							1.223	0.398
Water Access	2.027	0.004	2.098	0.002	1.989	0.005	2.032	0.004
Medical Access	3.471	<0.001	3.353	<0.001	3.459	<0.001	3.465	<0.001
Electricity Access	0.869	0.573	0.973	0.914	0.903	0.681	0.878	0.601
Fuel Access	1.718	0.05	1.687	0.06	1.675	0.063	1.69	0.058
Cash Access	2.211	0.003	2.369	0.001	2.09	0.006	2.18	0.003
Nagelkerke R^2	*0.268*		*0.283*		*0.286*		*0.269*	
HL p-Value	*0.454*		*0.297*		*0.084*		*0.054*	

O.R.: Odds Ratio, Sig.: Statistical Significance (*p*-value).

4. Discussion

4.1. Resource Poverty and Severe Food Insecurity

While the importance of resource access for household food security in Maputo has been demonstrated elsewhere [33], this investigation demonstrates the importance of impoverished resource

access in the prediction of severe food insecurity in both Maputo and Matola. The analysis also found that, compared to other household family structures, male-centred households had significantly increased odds, and nuclear households significantly reduced odds, of severe food insecurity when access to water, electricity, medical care, cooking fuel and cash are controlled in both Maputo and Matola. Maputo and Matola, therefore, appear to share similar predictive relationships between household family structure, impoverished resource access, and severe household food insecurity. Given the unique histories and current challenges faced by Maputo and Matola, this case study should be assessed in other cities to determine whether the observations made in this study are truly the result of the unique socio-cultural environment of these cities.

The mounting evidence of a predictive relationship between resource access and food insecurity (in addition to [30,33]), suggests the importance of physical infrastructure and social institutions to human security in cities of the Global South. This finding also reiterates the importance of research into the network relationships among the SDGs [10]. By better understanding how these network relationships occur in cities, it may be possible to inform more targeted policy interventions into poverty and food insecurity.

4.2. Household Family Structure and Severe Food Insecurity

These findings also indicate the importance of social networks, as exemplified in household family structure, in predicting the severity of household food insecurity in Maputo and Matola. These findings support the conclusions of Balistreri [37], who found that children living in complex family structures in the United States were more vulnerable to food insecurity. The family structure of households may indicate the kind of social support available within a given household, which may in turn influence the severity of food insecurity experienced by the household. Given that only nuclear households were found to decrease the odds of severe food insecurity, this household family structure may represent a balance between the negative food impacts on large household size and improved social support than would be available to male-headed households. That said, Miller et al. [40] found in a longitudinal study that the risk of child food insecurity in the United States did not vary by household structure when other social vulnerability indicators (such as income, education and family size) were controlled. As a result, further research is necessary to understand the exact causes of this relationship.

These findings also contribute to ongoing research into urban food deserts in the Global South. Based on this investigation, it appears that the vulnerabilities highlighted by Battersby and Crush [17] in African urban food deserts may be differentiated by household family structures. This research indicates that, in addition to the spatial accessibility of food retailers and food items [14], social support networks (like family structure) may influence the vulnerabilities associated with urban food deserts. Further research will be needed to determine the extent to which these findings may be applicable in other cities in the Global South. If this is the case, then the entire concept of the urban food desert may need to evolve beyond the Battersby and Crush definition to incorporate unique contributions of social support systems in the understanding of urban food insecurity. As a result, the urban food desert may need to evolve into a more conceptual rather than spatial framework for understanding urban food insecurity.

5. Conclusions

This investigation found very similar rates of food insecurity across both Maputo and Matola, suggesting that these two cities may in fact share a similar vulnerability profile regarding food insecurity. This finding indicates that, while Maputo is the national capital, the city may share similar food insecurity challenges to Matola. Given the widespread food insecurity observed in Maputo over the course of this investigation, future food security and social welfare programs in Mozambique should consider the inclusion of Maputo in their programming.

The predictive relationship between resource poverty, household family structure, and severe food insecurity in Maputo and Matola supports more targeted vulnerability assessments. In other words, the

characteristics of households that experience severe food insecurity can be used to identify households in danger of falling into this form of insecurity. If these findings are validated by future research, future food security policies in programs should aim to bolster support networks for vulnerable family structures. By bolstering programs targeting remittances of food and goods among families, there may be additional support provided to households that are vulnerable to food insecurity. Community support programs may also be able to provide support networks that limit the shocks experienced by households experiencing resource deprivation.

There is mounting evidence for the importance of public resources (like water, electricity, and medical care) for household vulnerability to food insecurity. This observation provides an additional explanation for the network relationships between SDGs 1, 2, and 11. Beyond representing a potential compounded vulnerability, the interaction of these factors may also identify policy efficiencies. Planning and subsidizing infrastructure access may have knock-on implications for household poverty and insecurity. As a result, social welfare programs in Maputo and Matola may benefit from subsidizing household infrastructure access.

That said, given the observational nature of this study, the lack of a control group, the reliance on self-report, and the dichotomizing of investigation variables, further research will be needed to assess any causal interpretations and to test the replicability of these findings. The policy implications of this relationship highlight a potential role for urban planning in mitigating urban poverty and insecurity while also highlighting the nuance that social networks can bring to these contributions.

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Food Purchasing Characteristics and Perceptions of Neighborhood Food Environment of South Africans Living in Low-, Middle- and High-Socioeconomic Neighborhoods

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Abstract: Using intercept surveys, we explored demographic and socioeconomic factors associated with food purchasing characteristics of supermarket shoppers and the perceptions of their neighborhood food environment in urban Cape Town. Shoppers (N = 422) aged ≥18 years, categorized by their residential socioeconomic areas (SEAs), participated in a survey after shopping in supermarkets located in different SEAs. A subpopulation, out-shoppers (persons shopping outside their residential SEA), and in-shoppers (persons residing and shopping in the same residential area) were also explored. Fruits and vegetables (F&V) were more likely to be perceived to be of poor quality and healthy food not too expensive by shoppers from low- (OR = 6.36, 95% CI = 2.69, 15.03, $p < 0.0001$), middle-SEAs (OR = 3.42, 95% CI = 1.45, 8.04, $p < 0.001$) compared to the high-SEA shoppers. Low SEA shoppers bought F&V less frequently than high- and middle-SEA shoppers. Purchase of sugar-sweetened beverages (SSBs) and snacks were frequent and similar across SEAs. Food quality was important to out-shoppers who were less likely to walk to shop, more likely to be employed and perceived the quality of F&V in their neighborhood to be poor. Food purchasing characteristics are influenced by SEAs, with lack of mobility and food choice key issues for low-SEA shoppers.

Keywords: shopping behaviors; food environment; food insecurity; food purchasing characteristics; socioeconomic area; obesity; out-shoppers

1. Introduction

Obesity and food insecurity (i.e., lack of sufficient physical and economic access to enough quality and nutritious food for an active and healthy life) [1], often co-exist in South Africa, and are associated with poor diet and health outcomes [1]. Food choice behaviors are considered to be largely influenced by the food environment and socioeconomic status [1]. The retail food environment, which is defined as food outlets within a person's neighborhood [2] has been linked to diet quality [3]. Socioeconomic status of individuals has also been associated with diet quality in several studies in both developed and developing countries, although with varying predictors of socioeconomic status, such as education, occupation, income and area of residence [4–6]. However, there is limited evidence from lower- and middle-income countries and the Global South.

Only a small number of studies have examined informal food retail outlets, such as 'spaza shops' (an informal convenience shop in residential neighborhoods [7]) and street vendors in relation to shopping decisions and dietary choices. However, although more is known about the geospatial distribution of supermarkets in South Africa [8–11], there is limited evidence on the association between supermarket locations and food purchasing characteristics in low-, middle- and high-socioeconomic areas. In South Africa, formal retailers, such as supermarkets and fast food outlets and less formal retailers, such as street vendors, convenience stores, and in certain areas, food/community markets are the predominant source of food shopping [12]. There has however been a rapid expansion of supermarkets over the last decades and supermarkets have become a primary source for food shopping, accounting for more than 50% of food sales in South Africa [12,13]. Furthermore, most people in urban areas purchase their food items from supermarkets [14–16]. For instance, more than 90% of the population in Cape Town shop in supermarkets [17,18]. As such, supermarkets have been identified as a potential role player in curbing obesity and addressing food insecurity, by providing local access to healthy food, especially in urban communities [19,20].

Nevertheless, several studies have shown that access to supermarkets does not necessarily lead to healthy food choices, as they increase access to both healthy and unhealthy food choices [21,22]. Also, it has been documented that the expansion of supermarkets in South Africa is not evenly distributed, with a higher concentration in middle and high income areas [19]. Furthermore, the expansion of supermarkets in South Africa has been largely characterized by a movement of the more discount retail chains into low income areas, and associated foods of lower quality [19]. The results are a promulgation of "food deserts," when it becomes challenging to buy affordable and/or quality healthy foods and consequently, persons from these communities may lack access and sufficient economic resources to purchase healthy food [19]. In some cases, residents of an area may choose to purchase food in supermarkets outside of their neighborhood (out-shopping) as they are often dissatisfied with the quality or variety of foods in their local environment and may drive or travel a long distance for better access to healthy foods or better value at discount supermarkets [10,23]. Furthermore, car ownership, high level of education and higher socioeconomic status have been associated with outshopping in South Africa [10]. The underlying factors associated with "out-shopping" are varied and may be related to individual and demographic factors, or more broadly, related to the local food environment. This has not been widely studied in lower- and middle-income country settings [10,14].

Characterizing food purchasing decisions, as well as perceptions of the neighborhood retail food environments, in shoppers from different socioeconomic areas, may add to our understanding of factors that influence food choice behaviors, and that may impact, directly or indirectly on health. The overall goal of the present study is to advance our knowledge concerning those factors that leverage or impact on the food purchasing decisions of shoppers residing in low-, middle- and higher socioeconomic areas in urban suburbs of Cape Town, South Africa. The aims of the study are to better understand the shopping characteristics of supermarket shoppers from low, middle and high socioeconomic areas; to explore the perceptions of the low, middle and high socioeconomic area shoppers of their neighborhood food environment; and to unpack the food purchasing characteristics and neighborhood food environment perceptions of out-shoppers vs. in-shoppers.

2. Material and Methods

2.1. Study Design and Settings

The current cross-sectional analytical study is part of a larger study, STOP SA (Slow, Stop or Stem the Tide of Obesity in the People of South Africa), aimed at addressing the challenges of obesity in conjunction with food insecurity. Data for this study were collected between March and May 2017 in 11 major supermarkets located in purposively selected two high-, two middle- and two low-SEAs in Cape Town.

2.2. Socioeconomic Profile of Cape Town

The selected areas are based in Cape Town, the provincial capital of Western Cape, and second most populous city in South Africa with a population size of approximately four million people [24]. The selected areas were categorized into three categories (low, middle and high socioeconomic areas) based on the 2016 Socio-economic Profile: City of Cape Town [25] which was classified using the average household income.

In the current study, the selected low socioeconomic areas were Langa and Khayelitsha. Both areas are townships located in the Cape Flats, which is one of the poorest sections in Cape Town. The Langa population of approximately 52,500 has an average monthly household income of ZAR2144 [26]. Khayelitsha, the fastest growing township in Cape Town with a population of approximately one million people, has the highest poverty rate in Cape Town [17], with more than 60% of the population having an average monthly household income of ZAR1600 [27]. The townships areas (Khayelitsha and Langa) cover 38.71 and 3.09 square kilometers respectively [25]. The middle SEAs selected were Athlone with a population size of 237,000 and Mowbray with a population size of 5000. Both middle SEAs have an average monthly household income of ZAR5217 [28]. The high SEAs included Parklands, one of the fastest growing new residential areas covering 2.47 km^2 with a population size of about 43,000 and average monthly income of ZAR9500, and Claremont, an old residential area covering 5.21 square kilometers with a population size of 17,000 and average monthly income of ZAR12000 [24]. Based on the 2016 Socio-economic Profile: City of Cape Town [25], shoppers and the supermarkets were classified into low, middle and high socioeconomic categories by residential area and location respectively.

2.3. Supermarket Sample

Supermarkets in this study are major recognized retail store chains in South Africa that offer a broad selection of foods and household products. The managers of major supermarkets in the selected study areas were approached to obtain permission to conduct our study within their premises, but outside the supermarkets. Consent from supermarket managers was obtained from 11 supermarkets (four supermarkets in low SEAs, five in middle SEAs and only two supermarkets in the high SEAs) representing approximately 20% of the total supermarkets in these areas. The 11 supermarkets represented three of the four major recognized retail store chains in South Africa. We were unable to obtain consent from many of the managers of supermarkets in high SEAs as they did not wish their customers to be disturbed.

2.4. Intercept Survey

We intercepted shoppers that were coming out of pre-selected supermarkets and invited them to answer a short structured survey which was interview administered. Intercept surveys involve stopping target group (shoppers), screening them for eligibility of the study and administering a survey on the spot which is usually in a public or business place. The intercept survey was piloted in a preliminary test in two supermarkets using similar methods described in the current study. Each shopper was approached after shopping and briefed on the objective of the study, and after voluntarily consenting to participate, and signing an informed consent, he/she was interviewed. Only shoppers who were $\geq$18 years old and had purchased more than 10 different items confirmed by

their grocery receipts were eligible for the intercept survey. A total of 635 shoppers were approached, of which, 425 agreed to be part of the study. The remainder, of which more than 60% were from the high SEAs, cited time constraints as the major reason for non-participation. Overall, information on only 422 shoppers from the 11 supermarkets was used as three interviews were incomplete. Each intercept survey lasted 20–25 min and was conducted by a trained research assistant/fieldworker in either one, or a combination of the three major languages in Cape Town: English, Xhosa and Afrikaans, depending on the preference of the shopper. The intercept surveys were conducted between 10:00–17:00 on weekdays, and 10:00–14:00 on Saturdays in the beginning, middle and end of the month in each of the supermarkets to capture various categories of shoppers. The structured questionnaire included information concerning shopping patterns and practices, perceptions of the neighbourhood food environment, demographic characteristics and the food security status of the shopper. Participants were given a shopping voucher (ZAR50/≈$4) as compensation for their time after completing the intercept survey.

2.5. Out-Shoppers and In-Shoppers

Previous research has indicated that sometimes for various reasons, some people tend to shop outside their residential areas. They also indicated that these shoppers may have certain common factors or drivers that results in their out-shopping [10,23]. In the present study, we also looked at a sub-population based on their shopping socioeconomic area versus their residential socioeconomic area. This sub-population was classified into two groups; out-shoppers and in-shoppers. The proportion of shoppers shopping within their residential SEA are defined as in-shoppers and those shopping outside their residential SEA as out-shoppers. The aim is to explore this subpopulation to better understand the characteristics of in-shoppers and out-shoppers.

2.6. Measures

The 35-item intercept survey had six main sections:

2.6.1. Shopping Characteristics and Mode of Transportation to the Supermarket

This section of the questionnaire consisted of questions on self-reported frequency of shopping (daily, weekly, monthly), number of persons shopped for, the main person in the household responsible for shopping, main person in the household responsible for food preparation, to indicate by ranking the most important factors that influence their choice of supermarket (e.g., price, convenience, proximity, quality, value for money and variety), the major shopping place(whether the supermarket in which they were intercepted was their main shopping place), and the mode of transportation to supermarket.

2.6.2. Food Types and Frequency of Purchase

Questions in this section included the self-reported frequency of purchase of various foods, such as meat (fresh, frozen, dried, whole, portioned); fruits and vegetables (fresh and frozen), and snacks (chips, sweets, chocolates and cakes).

2.6.3. Self-Report on Bread and Sugar-Sweetened Beverages (SSBs)

Information on bread type preference and self-reported purchase of sugar-sweetened beverages (soft drinks/sodas, flavored juice drinks, non-alcoholic wine, flavored water with sugar, sports drinks, energy drinks and fruit juice blends, cordials, fruit nectar and all fruit juices) were elicited. Bread is generally purchased by the average South African [3], however, the knowledge gap is the bread type preference, which is important in this paper as the focus is on healthy food choice, affordability and availability.

The question about the purchase of SSBs varied from the other categories as the consumption of SSBs has increased significantly over the years and it was often something that most shoppers purchase

each time they shop [11]. Asking if they purchased SSBs will be more significant in the representative consumption of SSBs as opposed to asking how frequently they purchased SSBs.

2.6.4. Neighborhood Food Environment Perceptions

We measured the perceptions of shoppers' neighborhood food retail environment using adapted four statements from a previous study conducted in a low income neighborhood in the United States [29]. Each statement was designed to address a distinct dimension of the retail neighborhood food environment. One pertained to the general neighborhood retail food environment, two were specific to fruits and vegetables in the neighborhood and one to the affordability of healthy foods in their neighborhood (formal and less formal retail outlets). Representative statements included 'There are no supermarkets in my neighborhood', 'It is easy to purchase fruits and vegetables in my neighborhood', 'The healthy foods in stores in my neighborhood are too expensive' and 'The quality of fruits and vegetables in my neighborhood is poor'. Shoppers were asked these statements using a 5-item Likert scale coded 1–5 (1 strongly agree, 2 agree, 3 neither agree or disagree (neutral), 4 disagree, 5 strongly disagree).

2.6.5. Demographic Characteristics

Questions in this section of the intercept survey included self-reported sex, age in years, residential location and three indicators of an individual's socioeconomic position, specifically: Educational attainment, employment status and socioeconomic area. Age was categorized into three groups: Young adults early working age (18–30), prime working age (31–55), and mature working age and seniors (>55 years). Educational attainment and employment status were both self-reported. Educational level was grouped into three categories: Primary, high school, and tertiary education. Employment status was classified as employed, unemployed, homemaker or retired. Socioeconomic area was determined by categorizing the shopper's self-reported residential location according to the socioeconomic profile of the city of Cape Town 2016 [24].

2.6.6. Food Security Assessment

Three key food security questions were adapted from the U.S. Household Food-Security/Hunger Survey Module: 3-Stage Design [17]. The questions were: (i) In the last 12 months, did you eat less than you felt you should because there wasn't enough money for food? (ii) In the last 12 months, were you hungry but didn't have enough money for food? (iii) How often were you able to eat a balanced diet in the last 12 months? An affirmation to questions i and ii and "often" and "sometimes" to question iii were coded "yes" for food insecure. A negative response to question i and ii and "never true" to question iii were coded "no" for food insecure to create a binary variable for food insecurity (0 = insecure and 1 = secure).

2.7. Data Analysis

Descriptive analyses were undertaken. Pearson chi-square analysis was used to determine significant differences in demographics, shopping characteristics and purchase frequency of food categories between residential SEAs, and between out-shoppers and in-shoppers within the low and middle SEA groups. The Likert scale (1–5) for measuring neighborhood food environment perceptions were subsequently collapsed into three categories and recoded as: Strongly agree and agree = 1 (agree); somewhat agree or disagree = 2 (neutral); disagree and strongly disagree = 3 (disagree). Thereafter, multinomial regression analyses were conducted on the dependent variables (perceptions of the neighborhood environment) to understand the associations between individual-level factors (education level, employment, residential area, food security status) as independent variables. Food environment perceptions were controlled for individual-level effects, such as age, sex, education and employment. Multinomial regression is often used to predict the nominal dependent variable with more than two categories for one or more independent variables. We tested for multicollinearity between the

independent variables and found no substantial issues as no variation inflation factor (VIF) exceeded 3. The association of shopping characteristics and neighborhood food environment perceptions as independent variables and out-shopping as the dependent variable was also analyzed using logistic regression controlling for age and sex. Data were analyzed using IBM SPSS for Windows, version 24, Armonk, New York: IBM Corporation

3. Results

3.1. Demographic and Shopping Characteristics

The shoppers' demographics and shopping characteristics by shoppers' residential socioeconomic status are presented in Table 1. There were significant differences in age distribution, education level, employment and modes of transport between persons from the three SEAs. More than half (60%) of the shoppers were between the ages of 30–55 years and 82.5% (N= 344) were women. Just over half of the participants from the low SEAs had a primary school education while a similar proportion of participants from the high SEAs had tertiary education. Unemployment was more common in the participants from low SEAs than in shoppers from high SEAs (36.3% vs. 13.0%). Most respondents from the low SEAs walked to shop (67.2%) and more than half (62.1%) spend more than 10 min to get to the supermarkets from their home, while most participants from the high SEAs used a private car (73.2%) and spent less than 10 min or less (88.7%) to get to the supermarket. According to the food security assessment, food insecurity status was inversely associated with SEAs ($p < 0.001$).

Of the people interviewed, most were the household member primarily responsible for grocery shopping (78.9%) and food preparation (79.6%). When compared to residents from high SEAs, a higher proportion of residents from low and middle SEAs were mostly responsible for major grocery shopping (81.7% and 83.3% vs. 62%, $p = 0.01$). Similarly, more persons from the low and middle SEAs than from high SEAs were responsible for food preparation in their households (79% and 89.6% vs. 70.4%, $p = 004$). For most (85.1%) of shoppers, the supermarket in which they were interviewed was the one in which they mostly shopped. Sales/promotions were not indicated as an important factor for choice of supermarket in any of the SEAs. The highest proportion of the respondents (46.7%), irrespective of their residential SEAs were weekly shoppers compared to daily (28.4%) and monthly (24.9%) shoppers, with most (74.4%) purchasing specifically for their own households. Price and convenience were two factors that were most frequently indicated as important in the choice of supermarkets, however the most common factor differed significantly between the groups ($p < 0.001$), with price being the most common selected factor of shoppers from the low and middle SEAs, and convenience in the high-SEA group (Table 1). None of the high-SEA residents were classified as out-shopper (persons shopping outside their residential socioeconomic area) compared to 12.0% from middle SEAs and 23.7% from low SEAs. Therefore, in this study, we will be exploring more on the characteristics of out-shoppers and in-shoppers from only the low and middle socioeconomic areas for further comparative analysis.

3.2. Purchase Frequencies and Preferences

Self-reported purchase frequencies of food categories according to the respondent's residential SEAs are presented in Table 2. Persons living in low SEAs were likely to purchase fruits and vegetables and meat less frequently than persons from high and middle socioeconomic areas, but there was no difference in the frequency of purchasing snacks and SSBs between the shoppers from different SEAs. Brown bread was the most preferred bread type by all the shoppers. However, more low-SEA shoppers (69.6%) preferred brown bread compared to 40.5% middle-SEA and 52.1% high-SEA shoppers ($p < 0.001$).

Table 1. Demographic and shopping characteristics of participants by residential socio-economic areas.

Variables	Residential SEAs				
	High *SEAs* *n* (%)	**Middle SEAs, *n* (%)**	**Low SEAs, *n* (%)**	**Total**	***p*-Value**
N (%)	71 (16.8) (%)	132 (31.3) (%)	219(51.9) (%)		
Demographics	(%)	(%)	(%)	(%)	
Age					
18–30 years old	18.3	16.0	22.6	19.8	0.003
30–55 years old	54.9	58.8	66.4	62.1	
>55 years old	26.8	25.2	11.1	18.1	
Gender					
Male	26.8	15.4	15.7	17.5	0.08
Female	73.2	84.6	84.3	82.5	
Education					
Primary	5.8	37.4	52.1	39.7	
High school	43.5	39.8	36.6	38.8	<0.001
Tertiary	50.7	22.2	11.3	21.5	
Employment status					
Employed	66.6	44.7	48.6	50.4	
Unemployed	13.0	23.1	36.3	28.2	<0.001
Homemaker	8.7	14.6	6.1	9.2	
Retired	11.6	17.7	9.0	12.1	
Transportation mode					
Walk	11.3	41.7	67.2	49.8	
Public transport	15.5	23.5	26.0	23.5	<0.001
Private car	73.2	34.8	6.8	26.7	
Distance to supermarket (min)					
0–10	88.7	52.7	37.9	51.1	
11–30	8.5	38.2	50.2	39.4	
More than 30	2.8	9.2	11.9	9.5	<0.0001
Food security status					
Food secure	57.7	36.7	30.1	40.0	<0.001
Food insecure	42.3	53.0	69.9	60.0	
Shopping Characteristics					
No of people shopped for: Mean (SD)	3.68 (2.4) (%)	4.48 (4.8) (%)	3.91 (1.9) (%)	4.05 (2.8) (%)	0.84
Shopping pattern					
Daily	32.4	32.6	24.7	28.4	<0.001
Weekly	60.6	41.7	45.2	46.7	
Monthly	7.0	25.8	30.1	24.9	
Shopping for					
Self	28.2	22.0	26.9	25.6	0.51
Household	71.8	78.0	73.1	74.4	0.60
Main household shopper (Yes)	62.0	83.3	81.7	78.9	0.01
Responsible for food preparation (Yes)	70.4	85.6	79.0	79.6	0.04
Factors affecting supermarket choice					
Price	35.2	50.0	48.9	46.9	<0.001
Convenience	49.3	25.8	18.7	26.1	
Value for money	4.2	7.6	11.4	9.0	
Quality	4.2	4.5	7.8	6.2	
Others	7.1	12.1	13.2	11.8	
Shopping area (outshopping)					
High SEA	100	8.3	3.7	21.3	<0.001
Middle SEA	0	87.9	20.0	37.9	
Low SEA	0	3.8	76.3	40.8	
Main supermarket (Yes)	85.9	78.8	88.6	85.1	0.05
Shopping for promotions/sales (Yes)	18.3	18.2	8.7	13.3	0.02

SEAs: Socioeconomic areas. Data is presented as proportions (%) based on indicated numerator (N), except when stated otherwise (e.g., Mean, (SD); *p*-values determined based on Chi-Square (X^2).

Table 2. Self-reported purchase frequency and preference of food categories classified by residential SEAs.

Variables	Residential SEAs			
	High SEAs	**Middle SEAs**	**Low SEAs**	***p*-Value**
N (%)	71 (16.8)	132 (31.3)	219 (51.9)	
Frequency	%	%	%	
Fruits and vegetables				
More than once a week	41.1	40.0	33.1	
Once a week	42.2	43.1	29.1	<0.001
Once/twice a month	16.7	16.9	37.8	
Meat				
More than once a week	27.8	21.9	22.7	
Once a week	37.8	33.1	24.4	0.05
Once/twice a month	34.4	45.0	52.9	
Snacks				
More than once a week	21.1	32.5	33.1	
Once a week	27.8	29.4	22.1	0.20
Once/twice a month	51.1	38.2	44.7	
Purchased SSBs (Yes)	66.2	55.3	62.1	0.30
Preferred bread type				
White	28.2	36.6	20.5	
Brown	52.1	40.5	69.9	<0.001
Whole wheat	15.5	13.0	3.7	
No preference	4.2	9.9	5.9	

SEA: Socioeconomic area; SSBs: Sugar-sweetened beverages; Data is presented as proportions (%) based on indicated numerator (N), except when stated otherwise (e.g., Mean, (SD)). *p*-values determined through Chi-Square (X^2) Tests.

3.3. Neighborhood Food Environment Perceptions

Factors associated with perceptions of the neighborhood food environment are presented in Table 3. When compared to respondents with a tertiary education, shoppers with a primary and high school education had 24% and 50% lower odds respectively of concurring that healthy foods were too expensive. In addition, those with primary education had 3.5 times higher odds of agreeing that the quality of fruits and vegetable in their environment was poor ($p < 0.05$) and approximately twice the higher odds of perceiving that supermarkets were not adequate ($p < 0.05$) in their neighborhood. The retired shoppers had approximately five times higher odds compared to the employed of being neutral on the affordability of healthy foods in their neighborhood. Conversely, low-SEA shoppers were less likely to be neutral compared to high-SEA shoppers in their perception that healthy foods are too expensive.

Shoppers who were food insecure and from low SEAs were less likely to consider healthy foods expensive. However, they were less likely to agree that fruits and vegetables were available in their local neighborhoods and had higher odds of considering the quality of fruits and vegetables in their neighborhoods to be poor.

3.4. Out-Shopping

Characteristics of out-shoppers and in-shoppers from the low and middle SEAs are presented in Table 4. Out-shoppers were 33% less likely to be unemployed and to walk to the supermarket in which they were intercepted, and they had 5.1 and 2.3 times higher odds of relying on public transport or private motor vehicles respectively compared to in-shoppers. Furthermore, out-shoppers were less likely to travel less than 30 min to shop compared to the in-shoppers.

Table 3. Adjusted multinomial regression results of the associations of individual-level factors with food environment perceptions.

	Perceptions about Neighborhood Food Environment															
	The Healthy Foods in Stores in My Neighborhood Are too Expensive				*It is Easy to Purchase Fruits and Vegetables in My Neighborhood*				*The Quality of Fruits and Vegetables in My Neighborhood Is Poor*				*There Are No Supermarkets in My Neighborhood*			
Variables	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
	Agree		**Neutral**		**Agree**		**Neutral**		**Agree**		**Neutral**		**Agree**		**Neutral**	
Education (Tertiary) [a]																
Primary level	**0.24** *	**0.12, 0.45**	0.54	0.24, 1.22	0.69	0.36, 1.30	**1.81**	**0.66, 4.94**	3.45 **	1.78, 6.47	1.50	0.73, 3.11	2.02 *	1.08, 4.09	1.73	0.76, 3.92
High school level	**0.50** *	**0.28, 0.92**	0.61	0.27, 1.39	0.91	0.48, 1.71	**1.73**	**0.63, 4.75**	1.59	0.86, 2.96	0.92	0.46, 1.84	1.59	0.83, 3.09	1.02	0.48, 2.32
Employment (Employed) [b]																
Retired	0.16	0.91, 5.12	**4.67** *	**1.62, 13.44**	0.01	0.43, 2.39	0.37	0.11, 1.26	0.71	0.31, 1.69	1.15	0.42, 3.12	0.64	0.28, 1.52	0.44	0.14, 1.44
Unemployed	0.78	0.48, 1.29	1.26	0.65, 2.45	0.35	0.80, 2.27	1.08	0.53, 2.21	0.72	0.43, 1.18	0.94	0.52, 1.72	1.27	0.77, 2.11	0.62	0.32, 1.21
Residential area (High SEAs) [c]																
Low SEAs	**0.04** *	**0.02, 0.11**	**0.19** *	**0.06, 0.63**	**0.35** *	**0.15, 0.81**	**0.29** *	**0.09, 0.90**	6.36 ***	2.69, 15.03	0.68	0.31, 1.51	1.69	0.80, 3.55	1.61	0.59, 4.40
Middle SEAs	**0.11** *	**0.04, 0.28**	0.33	1.00, 1.14	**0.42** *	**0.18, 0.99**	0.48	0.16, 1.49	3.42 **	1.45, 8.04	0.74	0.34, 1.61	0.86	0.40, 1.88	1.46	0.53, 3.96
Food security (food Secure) [c]																
Food insecure	**0.55** *	**0.34, 0.87**	0.68	0.37, 1.25	0.68	0.37, 1.25	0.72	0.44, 1.86	1.71 *	1.05, 2.77	1.12	0.64, 1.95	0.91	0.56, 1.47	0.86	0.46, 1.59

Reference categories are in parenthesis. Variables of interest considered were: Education, employment, OR: Odd ratio was estimated at 95% confidence intervals (CI); ref: Reference. Perceptions about food and food environment were taken as affirmative (Agree). [a] adjusted for age, sex, and employment; [b] adjusted for age, sex and education; [c] adjusted for age, sex, employment and education. * p-values of <0.05, ** p-values of <0.001, *** p-values of <0.0001.

Table 4. Adjusted logistic regression results of the associations of individual-level factors of out-shopping vs. in-shopping in the low- and middle-socioeconomic areas.

	Outshopping	
Variables	OR	95% CI
[a] Education (ref: Tertiary level)		
Primary level	0.60	0.27, 1.33
High school level	0.70	0.31, 1.57
[a] Employment (ref: Employed)		
Retired	0.27	0.17, 1.82
Unemployed	0.31 *	0.24, 0.88
[a] Transportation to shop (ref: Walk)		
Private car	2.16 *	1.0, 4.68
Public transport	5.04 *	2.64, 9.70
[a] Distance to supermarket from home (ref: More than 30 min)		
0–10 min	0.12 *	0.05, 0.28
11–30 min	0.26 *	0.12, 055
[a] Food security (ref: Food secure)		
Food insecure	0.85	0.49, 1.50
[a] Food environment perceptions (ref: Disagree)		
The healthy foods in stores in my neighborhood are too expensive	0.77	0.41, 1.45
It is easy to purchase fruits and vegetables in my neighborhood	0.81	0.43, 1.53
There are not enough supermarkets in my neighborhood	1.33	0.73, 2.42
The quality of fruits and vegetables in my neighborhood is poor	3.05 ***	1.53, 6.08
[a] Self-reported frequency of food purchase (ref: Once-twice a month)		
Fruits and vegetable		
More than once a week	2.30 *	1.08, 4.90
Once a week	1.98	0.91, 4.27
Snacks		
More than once a week	2.34 *	1.18, 4.65
Once a week	3.16 *	1.57, 6.36
Meat		
More than once a week	1.32	0.62, 2.64
Once a week	1.40	0.75, 2.64
[a] Purchased SSB (ref: no)	0.94	0.54, 1.64
[a] Factor influencing supermarket choice (ref: Convenience)		
Price	1.29	0.60, 2.74
Value for money	0.99	0.30, 3.07
Quality	3.19 *	1.08, 9.40

[a] Adjusted for age and sex; OR: Odd ratio was estimated at 95% confidence intervals (CI); ref: Reference. Perceptions about food and food environment were taken as affirmative (Agree). * p-values of <0.05.

Furthermore, out-shoppers had approximately three times higher odds of perceiving the quality of the fruits and vegetables in their neighborhoods as poor. Similarly, they were also three times more likely to shop in supermarkets that they perceive sell quality food than shop because of convenience when compared to in-shoppers (Table 4).

There were significant differences between the groups in the self-reported purchase frequencies of snacks and fruits and vegetables. Out-shoppers reported having higher odds of purchasing snacks and fruits and vegetables more frequently compared to in-shoppers. However, the frequency of meat, and SSBs purchases were not significantly different between in-shoppers and out-shoppers.

4. Discussion

This study highlights the low and middle SEA shoppers' perceptions of the lack of available quality fruits and vegetables in their retail food environment. Fruits and vegetables were less frequently consumed in lower SEAs. Notwithstanding, the frequent purchase of snacks and SSBs is clearly evidenced in all the neighborhoods. The study also shows the high prevalence of food insecurity, unemployment, and low level of education of shoppers from low SEAs. It further indicates that

shoppers of lower educational status, food security and socioeconomic status did not perceive healthy food as expensive. It demonstrates differing perceptions of the neighborhood food environment between in-shoppers and out-shoppers, and because the latter generally have better access to transportation, they have access to a greater range of food choices.

4.1. Food Choice

Our data on consumption frequency patterns conform to findings that the socioeconomic status of one's residential location influences the consumption of healthy foods, especially fruits and vegetables. According to a study on food consumption done in an informal low-income area in Cape Town using a food frequency questionnaire and 24-h recall, only about a third of people consume fruits, and six out of every ten people consume vegetables on a daily basis [30]. Conversely, persons from high SEAs in our study, similar to reports by other studies in Africa, purchase meat more frequently than shoppers from middle and low SEAs [11,31,32]. In South Africa, there is a general partiality for meat. Persons from a higher socioeconomic group purchase meat slightly more frequently than persons of low socioeconomic status, as the poor often opt for cheaper, lower quality and less nutritious meat rather than not buying meat at all [33].

The high frequency purchase of SSBs and snacks by shoppers from all the socio-economic areas is in line with reports on their general consumption in South Africa [32]. A recent study conducted in similar economically disadvantaged communities of South Africa, had shown that more than a third of the study population had consumed 10 and more servings of SSBs per week (an average of one and half cans of soda of 330 mL per day) [34]. The consumption of SSBs and snacks has been attributed to be a major factor in the increasing weight gain worldwide, a fact which is evident in South Africa [35].

4.2. Neighborhood Food Environment Perceptions of Shoppers from High, Middle and Low Residential SEAs

Consumer perceptions regarding the availability, affordability and diversity of choices of nutritious food in their neighborhood food environment have been known to play a significant role in purchase and food choice, and consequently eating a balanced and nutritionally adequate diet [36,37]. The perceived lack of availability of quality fruits and vegetables in lower SEAs who are more food insecure in the current study was consistent with the results of a study that reported that supermarkets in low SEAs i. South Africa stock less healthy and lower quality foods compared to supermarkets in high SEAs [18]. Moreover, the quality, packaging and safety of fresh produce in less formal retail outlets in South Africa, such as the spazas, street vendors and convenience stores, which often located in low and middle SEAs, are often questionable [38]. Additionally, residents in low SEAs often have greater access to high-calorie and nutritionally poor foods, than fresh fruits and vegetables [3]. For example, the low consumption of fruits and vegetables in low-income areas from studies conducted in Seychelles and South Africa were attributed to financial constraints often leading to the substitution of the purchase of fruits and vegetables for cheaper high energy-dense, but low nutrient foods [5,31].

Contrary to reviews from both high- and low- and middle-income countries, a high percentage of shoppers from low SEAs, educational status and food security status indicated that healthy foods were not expensive. This is despite evidence that in fact, healthier foods are often more expensive, both in South Africa, and in other countries [3,39]. In our study, this is also confirmed by most of the shoppers from low and middle SEAs indicating that price was the main influential factor in their supermarket choice. Therefore, we can assume that one of the barriers to purchasing "healthy" foods for low-income individuals is cost. However, it is possible that the reason for low SEA shoppers' perception that healthy foods are not expensive is that the contradictory it is likely that there are different definitions of "healthy" food in low, middle and high SEAs in South Africa. For example, a study conducted in Kanana in Guguletu, a low-income area in Cape Town [11] showed that most of the population classified foods, such as maize meal *(Isidudu*), snacks, such as chicken crisps, sweets, puffed corn, and imported SSBs, such as Fanta and Lemon Twist, as "healthy". The low level of

education of low- and middle-socioeconomic persons in the study, may also be a contributory factor to health and nutrition knowledge. Education level influences food choices as people with increasing higher level of education are more aware of the nutritional quality of foods [4]. Further studies on the neighborhood food environment and the understanding of the definition of healthy foods are needed to better understand the challenges of access to healthier food, particularly in low-socioeconomic communities in South Africa. Such studies should include actual grocery receipts analysis or measures of expenditure, household ethnography and formal and informal retail environment surveys.

4.3. Outshopping

Our findings that out-shoppers were only from middle and low SEAs and predominantly from low-SEAs is in line with other studies in LMICs that indicate that individuals from low SEAs often shop outside their neighborhood [40,41]. However, the relatively small number of out-shoppers (12.0% and 23.7% middle and low SEAs respectively) in our study could be due to the increased presence of supermarkets and/or less formal retail stores in their communities and the lack of mobility of shoppers from the low SEAs. Previous studies in South Africa have found that most respondents from low SEAs walk to their shopping destinations, due to the high rates of unemployment, consequently being financially constrained and unlikely to own a car or able to afford frequent transport fare to shop [11,42]. The out-shoppers in this study were more likely to be employed and primarily used public transport compared to walking (49.3% vs. 31.3%) to get to their shopping location. It is therefore a possibility that the out-shoppers, as supported by a study from Soweto (a low-income neighborhood in Johannesburg, South Africa), were often employed outside their residential areas. Consequently, they tended to shop in proximity to their workplace after work or along their travel route and transportation hubs [9], where supermarkets are often strategically located for convenience [9,20]. Quality is also notably one of the key factors reported to influencing out-shopper's supermarket choice. As they perceive the quality of fruits and vegetables to be poor in their neighborhood, out-shoppers were more likely and able to travel outside their neighborhood for better quality produce compared to in-shoppers. Further, as there were no out-shoppers from high SEAs, it is most likely that the shoppers from high SEA also work in a high SEA. As shown in the study, they are satisfied with the number of supermarkets and quality of fruits and vegetables in their neighborhood and consequently have no reason to shop far from home, despite that most of them have private cars to transport their groceries if they shop outside their neighborhood. The findings in our study when assessing the high-, middle- and low-SEA shoppers is somewhat contrary to the findings in Soweto where high socioeconomic status, car ownership and a higher level of education were associated with outshopping [10]. However, looking into the subpopulation of in-shopper vs. out-shoppers within the low and middle SEAs, there are similarities with the findings in the Soweto study.

4.4. Demographics and Shopping Patterns of Shoppers from Low-, Middle- and High-Residential SEAs

Most of the respondents in this study from three different socioeconomic areas shopped in supermarkets, in agreement with studies conducted in low-income households in urban and peri-urban areas of Msunduzi municipality, KwaZulu-Natal province, South Africa [43,44]. The rapid expansion and distribution of supermarkets in South Africa appear to have greatly formalized shopping behavior, despite the increase of other less formal retail outlets, such as spaza shops, convenience stores and street vendors [19,45]. For instance, the number of supermarkets in Cape Town increased by 164% from 1994 to 2012 with the highest increase in low socio-economic areas [45]. Furthermore, the availability of more food varieties, both healthy and unhealthy, and lower prices are advantages that supermarkets have over spaza shops and convenience stores [43,44].

All the respondents from high SEAs, and most respondents from low and middle SEAs (>75%) do their major shopping in their neighborhood. Weekly shopping was a general norm in all the neighborhoods. Contributing to the cause of this shopping pattern for their major shopping in the study might be the proximity of supermarkets to homes as most were in-shoppers. Lack of access

to transportation and storage facilities are other factors that might contribute to the major weekly shopping pattern for shoppers residing in the low and middle SEAs. This is because walking might hinder them from purchasing more than they can carry. Additionally, many may not have adequate storage and preservation facilities, such as refrigerators to store fresh produce that will last them more than a week. This was recently confirmed by a study done in Langa, a low socio-economic area in Cape Town [46]. Approximately only a third of the population in Kanana, Gugulethu, another low SEAs in Cape Town has either refrigerator (31%) or a freezer (2%) [11]. Furthermore, according to South Africa Community Survey, 2016, approximately 20% of South African population, especially in the low SEAs, do not have a refrigerator.

As expected, shoppers in our study were predominantly women who were mostly responsible for household food decisions, including the purchase and preparation of food. This is a very typical scenario in an African setting where women primarily make decisions related to food consumed in the household [11,47]. The fact that the shoppers from high SEAs were significantly less likely to be responsible for food preparation, may reflect a gender bias, in that men were more well-represented in our intercept interviews in the high SEAs compared to those in the low and middle SEAs. It could also be due to the possibility that high-SEAs households employed more domestic help. Modernization, urbanization and influence of education are resulting in slight changes in the typical African settings, especially in the high income households, where the division of households and domestic chores, such as grocery shopping and food preparation are embraced jointly to an extent, or out-sourced even though women are still mostly responsible for food decision [48]. As anticipated, price was reported as an important factor influencing the supermarket choice of shoppers from low- and middle-SEAs as they seemingly have less disposable income and will shop where they will pay less for more. It is however surprising that even though price seems to be important in the supermarket choice of these socio-economic groups, sales/promotions did not influence their supermarket choice. This could be due to regular price reductions and promotions by most supermarkets for profit maximization [49].

5. Study Strengths and Limitations

The study captured the shopping characteristics of the high-, middle- and low-SEA urban South African as supermarkets have been shown to be the main retail food environment for most households. In addition, the study highlighted shopping characteristics and neighborhood food environment perceptions that vary socioeconomically which are key for intervention strategies to alleviate food insecurity and obesity.

The study only focused on shoppers in supermarkets and did not intercept shoppers from less formal food purchasing outlets, such as spazas and convenience stores. The frequency of purchase of the food types was self-reported and did not give details on the quantity and quality of the food bought. The understanding of what defined "healthy" foods was not assessed, and as such, may itself have varied according to SEAs, food security status and/or education. The measures (statements) for assessing the different dimensions of the neighborhood food environment used mostly one question to assess each dimension as opposed to multiple questions which can be summed, and the scores weighted thereby making them sometimes more reliable for statistical calculations. Height and weight of the participants were not measured and therefore, the body mass index (BMI) of the participants could not be assessed to provide context concerning body weight status (obesity) and food choices.

6. Conclusions

Food choice may be influenced by both neighborhood food environment and socioeconomic factors. Persons living in settings, such as low SEAs compared to high SEAs may only have access to foods of poor quality, with fewer choices, which is an indication of the differences in their food environment in the study setting. Notwithstanding, the frequent purchase of snacks and SSBs is clearly evidenced in all the neighborhoods. Sustainable intervention strategies to improve the quality of fruits

and vegetables in lower socioeconomic areas and reduce the consumption of snacks and SSBs in South Africa are paramount to reduce the prevalence of obesity and food insecurity.

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Food Swamps and Poor Dietary Diversity: Longwave Development Implications in Southern African Cities

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Abstract: While the literature on food deserts focuses on limited availability of food in urban settings, 'food swamps' may better characterize the extensive prevalence and accessibility of cheap, highly processed foods. For urban populations, access to nutritionally inadequate poor-quality food has dire developmental consequences. The long-wave impacts of malnutrition at gestational and early childhood stages are negative and can be non-reversible. Moreover, those who survive into adulthood may face a lifetime of sub-optimal physical and mental development that undermines the second and third UN Sustainable Development Goals—to end hunger and to ensure healthy lives. This paper assesses the long-term health vulnerability of children with limited access to adequate and nutritious food in rapidly urbanizing cities. The analysis focuses on the African Urban Food Security Network (AFSUN) data drawn from 6453 household surveys in 11 cities and nine countries in Southern Africa. The results indicate that children in these households are consuming a limited diversity of food, have limited access to resources and have greater odds of experiencing both short-term and long-term food and nutrition insecurity. These findings demonstrate an underlying vulnerability to long-term health impacts stemming from nutritionally inadequate diets, with potentially significant costs to human capital.

Keywords: food deserts; food security; malnutrition; children; urbanization; Southern Africa

1. Introduction

The United Nations' 2030 Agenda poses two direct development challenges that pivot on Sustainable Development Goal (SDG) 11: Sustainable Cities. These challenges are captured under SDG 2: Zero Hunger, and SDG 3: Good Health and Well-Being. Cities of the Global South have become a "ground zero" for these compounding challenges. This investigation assesses the poverty, food security and food consumption characteristics of poor urban households in Southern Africa containing children aged 5 years old and younger. The findings identify household vulnerabilities to longwave nutrition-related health hazards faced by the children growing up in these environments.

The urban transition unfolding across the Global South has the potential to create great prosperity and provide the means by which these SDGs can be achieved. Cities provide economies of scale that make global sustainability possible [1]. However, accessible, nutritious food is a key component without which hunger cannot be eliminated, nor can good health and well-being be achieved [2]. Yet the promise of ending hunger and achieving good health for all is a major challenge in the context of the rapid urbanization of the Global South [3,4]. Sprawling informal settlements are now a common feature of the urban form alongside the rise of megacities (cities with more than one million residents) in the developing world [5–13]. Typically associated with rural populations, hunger and malnutrition are now increasingly associated with urban populations [2,14–16]. As a result, "malnutrition is in turn a major contributor to both mortality and morbidity and is consequently also a vexing development problem, the locus of which is increasingly urban" [16] (p. 119).

Notwithstanding the positive development potential of widespread urbanization in Sub-Saharan Africa, the continent remains beset by persistent hunger and malnutrition [14–17]. Research indicates that the long-wave demographic impacts of malnutrition at gestational and early childhood stages are negative and non-reversible [18–20]. Moreover, those who survive into adulthood many face a lifetime of sub-optimal physical and mental development that undermines the second and third UN Sustainable Development Goals—to end hunger and to ensure healthy lives [18,21–24].

Hunger and malnutrition are part of the epidemiological transition that is also underway in the Global South. The epidemiological transition describes a shift in the determinants of morbidity and mortality from predominantly communicable diseases (e.g., tuberculosis, influenza, hepatitis) towards predominantly non-communicable diseases (e.g., heart disease, cancer, diabetes) [25]. While the epidemiological transition has been a helpful conceptualization of changing disease prevalence, the theory has evolved as empirical evidence has come to light. As an example, Harper and Armelagos [26] note that new infectious diseases have begun to emerge and spread because of antimicrobial resistance and globalization. The theory has also expanded to include socio-economic factors that have been identified as drivers of the epidemiological transition [27]. Wilkinson [28] highlighted the role of socio-economic inequality in mortality trends linked to the epidemiological transition. In response, Santosa et al. [29] recommended further research into the socio-economic determinants of health to inform needed revisions in the evolving concept. Dye et al. [30] identified a specific interaction between the prevalence of tuberculosis infection rates, and diabetes in a study of India and South Korea. This study noted the role of urbanization (the urban transition) as well as nutrition as key drivers of the epidemiological transition in these countries. Uauy and Kain [31] highlighted the growing need to focus on obesity prevention, in addition to malnutrition, in nutrient programming. This point was reiterated by Broyle et al. [32] who identified a growing pandemic of childhood obesity, driven in part by socio-economic factors like household income.

As would be expected under these transitions, global human nutrition itself is in a state of flux and is described by a third shift: the nutrition transition. As outlined by Drewnowski and Popkin [33], the nutrition transition refers to the shift from the consumption of carbohydrates and fibers to sugars and saturated fats. This transition has been linked to the epidemiological transition through the health outcomes of this dietary shift. Shetty [34] notes the growing challenge of obesity and non-communicable diseases resulting from the nutrition transition. Popkin [35,36] noted that the speed of the nutrition transition appears to differ between the Global North and South. This observation has been conceptualized as the "dual burden" of nutrition where developing countries are faced with a high prevalence of diseases stemming from both under-weight and over-weight populations [37]. In other words, rather than proceeding through the nutrition transition, many developing countries are faced with the burden of both widespread hunger and obesity (or a dual burden). The urban poor are particularly at risk in these countries, where food systems have evolved to accommodate cheap processed food high in sugar and saturated fat [38]. Popkin [39] notes that the nutrition transition in the developing world may also be linked to the urban transition, with urban diets and activity levels becoming increasingly distinct from rural diets and activity levels [40].

Together, these transitions highlight a shift in the vulnerability profile of poorer communities that mirrors the transition from rural to urban livelihoods. These transitions indicate a growing public health threat to future urban residents in the Global South. Children growing up in an environment of limited access to nutritious food are at an increased risk of developing chronic diseases into adulthood [41]. The co-occurrence of stunting and obesity among poor urban neighborhoods is indicative of a food system where highly processed food are more easily accessed while nutritional food is often out of reach to poor families [42]. This situation is highlighted particularly in the context of Southern African cities [43–45].

The rapid growth of these cities has also strained the food systems supporting the urban populations in the Global South, leaving pockets of food deserts in many Southern African cities. In a study of Cape Town, Battersby, and Peyton [46] note that the geographic distribution of supermarkets

across the city limits access for poor households. Those supermarkets that are in poor areas of the city often stock fewer healthy foods than are available among supermarkets in high-income areas. This practice may be interpreted as a form of retail redlining, where food retailers, often driven by profit margins, are unwilling to service certain vulnerable sectors of the population or provide inferior goods and services in those areas [47]. In response to this limited accessibility, poor households in the city often rely on informal food markets [48]. As a result, the urban food desert has been criticized as having too narrow a view of the urban food system in the Global South [49]. While traditionally defined by limited geographic availability of supermarkets [50], Crush and Battersby [51] note that the concept of food deserts in the African context often ignores the informal economy and the importance of food access rather than availability. Battersby [52] further highlights the importance of accounting for non-market food sources. This investigation posits that given that supermarkets are not the only indicator of the presence or absence of food availability, the idea of a food desert might be more usefully thought of as a food swamp—readily available, cheap, poor quality and nutritionally inadequate food [53,54]. The existence of this kind of food swamp (both in terms of food source availability and nutritional diversity) poses a significant threat to the long-term health of poor urban households in Southern Africa [43].

The health impacts of this food system on poor urban households are keenly felt among children. Popkin [35] notes that the regular intake of sugars and saturated fats during early childhood could have significant implications for the prevalence of non-communicable diseases later in life. Caesar et al. [55] further suggest that the food insecurity may be linked to communicable diseases (like HIV and TB) in Southern African cities through circuitous socio-economic poverty. Crush et al. [56] suggest that food insecurity and HIV may share a cyclical relationship via precarious and uncertain household income. Household members carrying these diseases often require greater nutritional diversity but are unable to afford it, further progressing the disease impacts.

It is within this broad developmental context that this paper assesses the odds of exposure to health risks for children, precipitated by limited access to adequate and nutritious food in rapidly urbanizing cities. This investigation has two research objectives: First, to determine the change in the odds of household food insecurity among poor urban households in Southern Africa based on whether those households contain children aged 5 years old and younger. This objective assesses the distribution of food insecurity to assess the positioning of these households in access-defined food deserts/swamps. Second, to describe the food security and poverty characteristics of poor urban households with children 5 years old and younger in Southern Africa. This objective identifies the vulnerability of these households according to their nutrition access and adaptive capacity. The analysis focuses on the African Urban Food Security Network (AFSUN) data drawn from household surveys in 11 cities and nine countries in Southern Africa. This investigation argues that nutrition-related health outcomes are less a consequence of food deserts as they are of highly constrained access to already available food in these cities by individuals and households, and that cheap, processed, and nutritionally poor foods dominate food affordability. This investigation provides novel insight into the experiences of urban food swamps among households with small children in Southern Africa by going beyond the spatial availability of food and directly assessing the food access patterns of these households to determine their nutrition-related vulnerabilities.

2. Materials and Methods

2.1. Approach and Limitations

To achieve this study's research objectives, this investigation relied on household survey data and nonparametric statistics. Household surveys are a common method for understanding the food consumption patterns of a large population where direct observation is often logistically unfeasible. That said, urban household surveys, particularly among poor households, are challenging given the rapidly changing nature of cities in the Global South. In response to this challenge, this study's

household survey was completed in partnership with local institutions and experts in each sampled city to ensure that the survey design and sampling was guided by the most up-to-date research, census data and maps. The use of nonparametric statistics in this investigation allowed for direct comparison of groups of household respondents categorized by variables of interest (e.g., food security, food consumption, household demographics). While neither open to causal interpretation or precise predictive modeling, these methods provide accurate and interpretable descriptions of the health vulnerabilities of poor households housing young children.

2.2. Research Objectives

Determine the change in the odds of household food insecurity among poor urban households in Southern Africa based on whether those households contain children aged 5 years old and younger.

Describe the food security and poverty characteristics of poor urban households with children 5 years old and younger in Southern Africa.

2.3. Sample

The sample for this investigation was drawn from a survey of 6453 poor households sampled using systematic and random sampling across 11 cities in 9 countries in Southern Africa. From that original survey sample, this investigation selected only those households containing children 5 years old and younger. This revised sample contained 2499 poor households distributed across the sampled cities. Both samples are demonstrated in Table 1.

Table 1. The Household Sample Distributed Across the Sampled Cities.

	Total Household Sample		**Households with Young Children**	
City	***n***	**%**	***n***	**%**
Blantyre	432	6.7	241	9.6
Cape Town	1060	16.4	388	15.5
Gaborone	400	6.2	58	2.3
Harare	462	7.2	232	9.3
Johannesburg	996	15.4	277	11.1
Lusaka	400	6.2	221	8.8
Manzini	500	7.7	192	7.7
Maputo	397	6.2	226	9
Maseru	802	12.4	275	11
Pietermaritzburg	556	8.6	254	10.2
Windhoek	448	6.9	135	5.4
Total	6453	100	2499	100

2.4. Variable Descriptions

This investigation measured household food consumption using the food item list in the Household Dietary Diversity Score (HDDS). The HDDS measures whether these food items were consumed by any member of the household in the last 24 h [57]. The food items included in the HDDS are: bread and other grains, potatoes and other foods made from roots or tubers, vegetables, fruits, red meats, eggs, fish or shellfish, beans or nuts, dairy, oils or other fats, sugars, and other foods such as condiments, coffee, or tea.

These food items were also used to measure the kinds of food items that household went without due to high food prices in the last six months. As a result, this food items list is used in this investigation to identify the foods that are commonly consumed and those food items that are vulnerable to in-access due to rising food prices. This investigation also measured the frequency with which households went without food due to rising food prices in the last six months. The investigation also measured the extent to which households had consistent or inconsistent access to water, medical care, and cooking fuel in the last year.

Finally, this study included the Household Food Insecurity Access Prevalence (HFIAP) that measured the frequency of household food access challenges in the month prior to the survey [58]. This scale is administered as a series of 9 sub-scale Likert questions measuring the frequency of social, physical, and economic experiences of limited food access by any member of the household. The score for this scale is derived using a weighted scoring algorithm that ranks household as: food secure, mildly food insecure, moderately food insecure, and severely food insecure. In addition, this investigation relied on the Months of Adequate Household Food Provisioning (MAHFP) scale to measure long-term household food access [59]. The scale measures the number of months in the last year during which a given household had access to adequate household food provisioning.

2.5. Analysis

In order to assess the change in the odds of household food security based on whether a household contains children aged 5 years and younger, this investigation will make use of odds ratios, Pearson's chi-square tests, and Fisher's exact tests. Odds ratios measure the change in odds of a household being categorized as food secure/insecure based on other characteristics (e.g., whether the household contains children aged 5 years old or younger). This investigation makes use of Pearson's chi-square tests and Fisher's exact tests to determine whether the distribution of households across any two variables is significantly non-random.

This investigation then provides descriptive statistics to indicate the experiences of food insecurity among poor urban households in the Southern African region that contain children aged 5 years old and younger. This analysis will highlight the potential impediments to attaining sufficient nutrition for these children and hypothesize the long-term ramifications of this experience for those children.

3. Results

3.1. Research Objective One

Across the board, households with children aged 5 years old and younger had greater representation among food insecure households when compared to households that did not contain children aged 5 years old and younger. That said, for each measure of food insecurity, most of the sampled poor urban households were categorized as food insecure on each measure (indicating the widespread prevalence of food insecurity among the sampled households) (Table 2). These findings demonstrate the widespread nature of food insecurity faced by the sampled poor households in cities across Southern Africa. These frequency distributions also indicate that the majority of the sampled households did not contain children aged 5 years old and younger.

Table 2. Descriptive statistics of household food security by households with children.

Variable	Value	No Children		Children < 5 Years		Total	
		n	%	*n*	%	*n*	%
Food Price Impact	No	825	67.8%	392	32.2%	1217	100%
	Yes	2845	58.7%	1998	41.3%	4843	100%
HFIAP *	Food Secure	707	70.6%	295	29.4%	1002	100%
	Food Insecure	3081	58.8%	2158	41.2%	5239	100%
MAHFP **	12 Months	1368	66.9%	677	33.1%	2045	100%
	<12 Months	2423	58.1%	1749	41.9%	4172	100%

* Household Food Insecurity Access Prevalence. ** Months of Adequate Household Food Provisioning.

The odds ratio calculations of household food insecurity and the age of children contained in households validate many of the observations made via descriptive statistics. First, all of the food insecurity variables indicated a statistically significant relationship with households categorized based

on the age of the children in the household. Second, households with children aged 5 years old and younger had greater odds of experiencing food insecurity according to each of the food insecurity measures included in this investigation when compared to households without children aged 5 years and younger (Table 3). While no other demographics were controlled in these findings, the results indicate a broad positioning of the sampled households with children in vulnerable conditions. Despite these findings, the odds ratios do not indicate a large increase in the odds of food insecurity based on the child membership in the sampled households. As a result, these findings are better interpreted as descriptive rather than predictive.

Table 3. Odds ratio calculations of household food security by households with children.

	95% C.I.					
Variable	**O.R.**	**Lower**	**Upper**	X^2	***p*-Value**	***N***
Food Price Impact **	1.478	1.294	1.689	33.315	<0.001	6060
HFIAP **	1.679	1.450	1.944	48.678	<0.001	6241
MAHFP **	1.459	1.306	1.629	44.837	<0.001	6217

** $p < 0.01$ on both the Pearson-Chi-Square Test and Fisher's Exact Test (2-Sided).

3.2. Research Objective Two

The sampled households with children 5 years old and younger demonstrated limited dietary diversity. The household survey data indicated that these households consumed just over 5 food groups, on average, in the last 24 h. Among the foods consumed in the previous 24 h, the most commonly consumed food types were bread, condiments, sugar, vegetables and oils (Table 4). 70% of the surveyed households with young children did not consume dairy in the previous 24 h. Meats and beans were only consumed by a minority of these households. The surveyed households with young children also favored refined sugars over fruit consumption.

Table 4. Food Items Consumed by Households with Children 5 Years Old and Younger. HDDS: Household Dietary Diversity Score.

HDDS Food Items Consumed in the Last 24 h	***n***	**%**
Bread, rice noodles or any other locally available grain	2408	96.9%
Other foods, such as condiments, coffee, tea	1745	70.5%
Sugar or honey	1741	70.1%
Vegetables	1711	69.0%
Foods made with oil, fat, or butter	1404	56.7%
Beef, pork, lamb, goat, rabbit, or other meat/organ meats	990	39.8%
Potatoes, yams, manioc, cassava or other foods made from roots or tubers	846	34.3%
Fruits	740	30.0%
Cheese, yoghurt, milk or other milk products	673	27.2%
Foods made from beans, peas, lentils, or nuts	571	23.1%
Fresh or dried fish or shellfish	495	20.0%
Eggs	465	18.8%

The sampled households also demonstrated a high degree of food insecurity. Only 12% of the sampled households were categorized as food secure on the HFIAP (Household Food Insecurity Access Prevalence), while almost 60% were categorized as severely food insecure. These statistics indicate that food access challenges were a common experience among the sampled households. These findings were confirmed by the frequency with which the households went without food due to food prices in the last 6 months. Only 16% of the sampled households did not go without food due to rising food price in the last 6 months (Table 5). Finally, over 70% of the sampled households with young

children experienced at least one month of insufficient food provisioning the previous year and 8% indicated that they did not have a single month of adequate food provisioning the previous year.

Table 5. Food Security and Food Price Impacts Among Households with Children 5 Years Old and Under.

HFIAP	***n***	**%**
Food secure	295	12.0%
Mildly food insecure access	166	6.8%
Moderately food insecure access	550	22.4%
Severely food insecure access	1442	58.8%
Food Price Impact	***n***	**%**
Never	392	16.4%
About once a month	573	24.0%
About once a week	398	16.7%
More than once a week but less than everyday of the week	649	27.2%
Every day	378	15.8%
Months of Adequate Household Food Provisioning	***n***	**%**
Zero Months in the Last Year	197	8.1%
One Month in the Last Year	16	0.7%
Two Months in the Last Year	49	2.0%
Three Months in the Last Year	26	1.1%
Four Months in the Last Year	46	1.9%
Five Months in the Last Year	57	2.3%
Six Months in the Last Year	74	3.1%
Seven Months in the Last Year	95	3.9%
Eight Months in the Last Year	164	6.8%
Nine Months in the Last Year	281	11.6%
Ten Months in the Last Year	390	16.1%
Eleven Months in the Last Year	354	14.6%
Twelve Months in the Last Year	677	27.9%

Some key nutritional food items were not accessed by households in the last 6 months due to food prices. The sampled households with young children identified meats, dairy, eggs, fish, and fruits as largely inaccessible in the previous 6 months due to rising food prices (Table 6). This table may provide an explanation for some of the dietary trends observed among these sampled households so far in this investigation. Sugars and condiments were identified by these households as more affordable than meats or fruits. That said, it is likely that other factors like preference or availability may be at play. While vegetables were ranked by these households as the most affordable, this food item was not the most commonly consumed by these households in the previous 24 h.

Those sampled households with children 5 years old and younger also demonstrated challenged access to key infrastructure resources. As an example, approximately 40% of the sampled households indicated inconsistent access to water and medical care in the last year. Of importance to household food security, about 60% of the sampled households also went without consistent access to cooking fuel in the last year. Limited access to cooking fuel limits the potential food items that a household can consume (Table 7). The limited access to these infrastructure services indicate the marginal coping capacity of these households to manage the onset of diseases. As a result, these findings demonstrate the limited adaptive capacity of these households in the face of long-wave nutrition-related health impacts.

Table 6. Unaffordable food types for households with children aged 5 years and younger.

Unaffordable Food Types	*n*	%
Beef, pork, lamb, goat, rabbit, or other meat/organ meats	1310	66.9%
Cheese, yoghurt, milk or other milk products	1237	63.2%
Bread, rice noodles or any other locally available grain	1214	62.0%
Foods made with oil, fat, or butter	1142	58.6%
Eggs	1112	57.5%
Fresh or dried fish or shellfish	1078	55.5%
Fruits	1037	53.6%
Sugar or honey	1000	51.8%
Potatoes, yams, manioc, cassava or other foods made from roots or tubers	982	50.7%
Other foods, such as condiments, coffee, tea	963	50.4%
Foods made from beans, peas, lentils, or nuts	938	48.5%
Vegetables	764	39.3%

Table 7. Poverty characteristics of households with children aged 5 years and younger.

Resource Access	Access Consistency	*n*	%
Clean Water	Consistent Access	1500	60.6%
	Inconsistent/No Access	977	39.4%
Medical Care	Consistent Access	1390	57.7%
	Inconsistent/No Access	1021	42.3%
Cooking Fuel	Consistent Access	975	40.2%
	Inconsistent/No Access	1449	59.8%

4. Discussion

The findings from this investigation indicate that, among the sampled urban households in Southern Africa, households with children aged 5 years old and younger had increased odds of experiencing food insecurity when compared to households that did not contain children in this age bracket. When those households with children aged 5 years old and younger are assessed further, they demonstrated limited dietary diversity, widespread food insecurity, and vulnerability to food price increases with limited access to key urban infrastructure services. As a result, this investigation found that the children living in these households are susceptible to the long-term health implications of limited dietary diversity and inconsistent food access. In addition, the findings from this study identified the limited capacity of these households to manage the nutrition-related health outcomes of their current consumption.

These findings describe the vulnerability context of poor households with young children living in an access-based food swamp [60,61]. While further research will be needed to identify the long-wave health-outcomes of the nutritional patterns observed here, this investigation identified that the current dietary diversity of children growing up in poor urban households across Southern Africa suggests that they are positioned for sub-optimal physical and cognitive development (in addition to long-term nutrient-related diseases) [62–64]. Future longitudinal research should also investigate how the vulnerability context observed here might relate to the onset of communicable diseases as well.

These findings highlight the precarious position of many poor households with young children in Southern African cities and indicate a looming public health threat [60,61]. As Popkin et al. [38] noted, the widespread intake of sugars and saturated fats during infancy has the potential to instigate the onset of non-communicable diseases later in life and speed the epidemiological challenges predicted by both the nutrition transition and the epidemiological transition. Furthermore, the limited capacity of these households to maintain food security increases their vulnerability to communicable diseases like HIV, TB and the new disease-scape of antimicrobial resistant pathogens [26,56]. Given the urban transition underway in Africa over the coming decades [8,9], these vulnerabilities are likely to become exacerbated by poorly planned and implemented urbanization [10,15].

5. Conclusions

This study is not alone in suggesting that children are not all receiving sufficient food to develop fully, from conception through to adulthood [60,61]. The issue is not simply one of food availability [16,62], characterized in this paper as urban food swamps; nor is it only the distribution of that food, characterized more broadly in the literature as urban food deserts [51]. At the heart of the urban nutrition discussion is a more complex interplay of economic, social, political, infrastructural and environmental factors that together underpin the vulnerability of children (and adults) to hunger and malnutrition [21].

To end hunger (SDG 2) and to ensure health and well-being for all people (SDG 3), the international development agenda has to focus on food and nutrition security in urban areas, where the majority of people already live—or in the case of Africa—will live within the coming decade. Yet, with high levels of food and nutrition poverty in cities of the Global South (and Sub-Saharan Africa in particular), and with the long-term, negative impacts of poor-quality diets and resultant malnutrition on children, the very basis of much needed human capital to achieve sustainable development is undermined. On this specific point, Ogundaria and Awokuseb [63] argue that health is an even more important determinant than education in human capital development in Sub-Saharan Africa and is a crucial component of economic growth.

The urgency of childhood malnutrition cannot be overstated within the broader sustainable development debate [64] and further research that considers the prevalence of urban malnutrition in the context of adequate aggregate food supply is important within the broader food and nutrition security policy arena. Finally, as argued in this paper, while access to food affects nutrition outcomes (as in the case of food deserts), the ubiquitous presence of cheap, industrially manufactured food products (referred to as food swamps in this paper) has serious negative health implications for all people, but especially for children. Both research and policy must focus on food quality and not just availability and access to food.

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Mapping Obesogenic Food Environments in South Africa and Ghana: Correlations and Contradictions

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Abstract: In sub-Saharan Africa, urbanisation and food systems change contribute to rapid dietary transitions promoting obesity. It is unclear to what extent these changes are mediated by neighbourhood food environments or other factors. This paper correlates neighbourhood food provision with household consumption and poverty in Khayelitsha, South Africa and Ahodwo, Ghana. Georeferenced survey data of food consumption and provision were classified by obesity risk and protection. Outlets were mapped, and density and distribution correlated with risk classes. In Khayelitsha, 71% of households exceeded dietary obesity risk thresholds while 16% consumed protective diets. Obesogenic profiles were less (26%) and protective more prevalent (23%) in Ahodwo despite greater income poverty in Khayelitsha. Here, income-deprived households consumed significantly ($p < 0.005$) less obesogenic and protective diets. Small informal food outlets dominated numerically but supermarkets were key household food sources in Khayelitsha. Although density of food provision in Ahodwo was higher (76/km^2), Khayelitsha outlets (61/km^2) provided greater access to obesogenic (57% Khayelitsha; 39% Ahodwo) and protective (43% Khayelitsha; 16% Ahodwo) foods. Consumption and provision profiles correlate more strongly in Ahodwo than Khayelitsha (rKhayelitsha = 0.624; rAhodwo = 0.862). Higher obesogenic food consumption in Khayelitsha suggests that risky food environments and poverty together promote obesogenic diets.

Keywords: obesity; food environments; urban; mapping; nutrition; South Africa; Ghana; governance; supermarkets; ultra-processed

1. Introduction

Urbanisation, poverty, globalisation, industrialisation, climate change and the emergence of a concentrated corporate food regime [1–3] are converging and mutually reinforcing global transitions [4]. Cities in the Global South and their large populations are at the epicentre of these transitions. These have significant implications for sustainability in terms of the health of populations, in terms of the ecosystem disruptions caused by food system activities and in terms of the economic exclusion of large segments of populations from food system activity. Although the United Nations sustainable development goals (UN SDGs 2 and 12) make reference to food security and poverty, they do not recognise the urbanisation of food insecurity nor the dietary transition [5]. This entails increasing consumption of ultra-processed, energy-dense and micronutrient-poor foods, compounded by sedentary lifestyles with reduced physical activity. Consequently, rates of obesity and non-communicable diseases (NCDs) are rising rapidly [6–8]. This shift is particularly severe in low- and middle-income countries (LMICs) and is characterised in some by an increasing "double burden" of simultaneous obesity and persistent childhood stunting [9–11]. Obesity is a major public health concern as it promotes the development of NCDs such as diabetes, hypertension, circulatory disorders and some cancers [12].

This transition has been particularly rapid in Sub-Saharan Africa [13,14], with nutritional change, obesity and NCDs in South Africa and Ghana especially advanced [15,16]. Thus, in 2016, 43% of Ghanaian adults were overweight or obese. Urban (48%) populations were more obese than rural (25%) and rates were higher among women (50%) than men (28%). Forty-three per cent of all adults in the Ashanti region were obese [17]. Similarly, in South Africa, 68.5% of women in urban areas were overweight or obese in 2015. The highest prevalence of female obesity (73%) was recorded in the Western Cape province. The corresponding statistics for men are 34.2% (SA urban) and 43.7% (men, Western Cape) [18]. In Ghana, in 2011, 23% of children were stunted nationally, and approximately 21.7% of children in the Ashanti region [19,20]. The 2014 Ghana Demographic and Health Survey reported that nationally 18.8% of children under five were stunted, while 16.1% in the Ashanti region. In South Africa, 26.5% of children under five were stunted in 2013 [21], and, in 2016, 27.4% of children under five in South Africa and 22.9% in the Western Cape were stunted [18]. Stunting in South Africa persists [22], with obesity often affecting other individuals in the same household [23].

High prevalence of obesity and stunting are linked to multiple dimensions of poverty and deprivation, including water, fuel, medicine, food and income [24]. De-agrarianisation is leading to increased urbanisation of poverty and food insecurity in Southern African [25–27] and West African cities [16,28]. Food insecurity contributes to nutrition transitions in low- and middle-income countries (LMICs), as food insecure households reduce dietary diversity and substitute cheaper foods such as starchy staples, sugar and oils. The level of national food insecurity in Ghana appears on the rise, especially in northern Ghana [29–31]. State estimates of food insecurity in Ghana suggest that about 5% of the population are food insecure with another two million people vulnerable [30]. There seem to be few analyses of urban food insecurity for Ghanaian cities. Evidence from major cities such as Accra suggests that large percentages of the urban poor in Ghana experience food insecurity [32–34]. Accra households spend an average of 54% of income on food, meaning that they are vulnerable to food price fluctuations [34]. Kumasi has experienced significant poverty linked to challenges in governance and service provision, particularly the provision of water, sanitation, and markets critical for food provision [35]. Food insecure city dwellers in Ghana cope by reducing the amount of food consumed, consuming fewer portions, or substituting nutritionally inferior foods such as gari for rice [20] or cutting back on supplementary foods such as rice to enable consumption of primary staples such as maize or yam [36].

In middle-income but high inequality South Africa, food insecurity affects 54.3% of the population, with 28.3% at risk of hunger and 26.0% experiencing hunger. This is especially severe in urban informal

areas (shantytowns), where 68.5% experience hunger or are at risk of hunger. In the Western Cape, 42% of households are food insecure [21]. Particularly high levels of urban food insecurity affect poor city-dwellers [37,38]. Levels of food insecurity in the low-income "black" African township of Khayelitsha are especially high, with 89% moderately or severely food insecure in a 2008 survey [39].

Both urban food insecurity and the nutrition transition are attributed to transformations of global food systems [40], understood as the web of processes, actors and infrastructure by which food is produced, processed, distributed and sold [41,42]. These transformations entail trade liberalisation, concentration in agrofood value chains, the dominance of corporate agribusiness, the rise of Big Food—large food manufacturing corporations which frequently operate at regional or global scales [43]. This has been accompanied by the expansion of supermarket retail and corporate fast food chains. Market liberalisation has facilitated food imports, enabling foreign direct investment into the expansion of formal retail and service outlets and supply chains, consolidation of value chains, and exposing domestic industry to increasing global competition. These dynamics accelerate the nutrition transition by making ultra-processed foods and animal protein products more available and affordable [9,44–46].

1.1. Obesogenic Food

Several recent epidemiological studies and meta-analyses correlate dietary composition with obesity and NCD risk in the United States. These studies indicate that the consumption of ultraprocessed crisps, fried potatoes, sugar-sweetened beverages, processed meat, unprocessed red meats, sweets and desserts, butter or margarine, and refined grains (in descending order) are associated with increased risk of obesity and associated NCDs [47–50].

Consensus appears to be emerging on several key points. Firstly, there is increased emphasis on synergistic effects of nutrients, foods and patterns of food combinations, and reduced emphasis on individual nutrients of concern [51,52]. Secondly, total fat consumption itself is less problematic than long thought [51–54]. Instead, it is the type of fats which is critical: saturated fats derived from red meat and industrial trans-fats seem particularly risky, especially in combination with refined carbohydrates [49,50,52,54]. Deep-frying foods, especially starchy foods, tends to increase the trans-fat content of such foods making these particularly problematic in terms of obesity and cardiovascular health [51,52]. Neutral association was found for most dairy foods, except consumption of butter. Instead, thirdly, consumption of refined starches with a high glycaemic index (GI) and low fibre content, appear to be key factors promoting obesity and related NCDs [48,55,56]. Fourthly, and conversely, consumption of certain foods appears to reduce the risk of obesity and associated NCDs. These foods include whole grains, nuts, seeds, and fish high in polyunsaturated fats, as well as yoghurt, vegetables and fruit [51]. A fifth convergence entails the recognition that ultra-processed foods, cheaply mass-produced using multiple industrially-refined ingredients and additives, are consistently obesogenic and risky. These foods are being made increasingly available, accessible and desirable by Big Food corporations extending their reach into Africa [43,57]. The NOVA framework classifies food according to four types depending on the nature, purpose and extent of processing. Type one foods are whole and minimally-processed foods; Type two are ingredients such as oil, butter or sugar derived from whole foods; Type three are combinations of Types one and two, frequently used to preserve food; and Type four, ultra-processed foods, are typically industrial mass-products composed of multiple refined ingredients including sugar, cheap starches and oils, salt and various other additives which increase shelf life or alter the flavour, texture or colour of food. Examples include processed cheese, processed meats, confectionery, instant noodles, most breakfast cereals, and sugar-sweetened beverages. Consumption of ultra-processed food decreases intake of fibre, protein and various health-promoting micro-nutrients, while typically increasing the intake of free sugar, sodium and problematic fats. Detailed studies using this framework have been conducted in several countries. These

studies have revealed a direct association between consumption of ultra-processed products and weight gain and increased risk for various NCDs [58–62]. The transformation of systems of food production towards industrial mass-production of ultra-processed food has been mirrored by other structural changes including the transformation of food retail.

1.2. Changing Food Retail Environments

Changes in retail, especially linked to the expansion of supermarkets in Africa, have transformed food environments. These changes have included centralised and consolidated procurement and distribution systems of increasingly regional scale, more direct contractual relationships with large-scale producers and suppliers who are able to meet demanding formal-sector standards. These upstream trends are matched by a downstream diffusion and penetration of "supermarkets for the poor" into areas previously dominated by traditional and informal markets [46,63].

Ultra-processed foods are becoming increasingly dominant in the global food system [64]. In Ghana, not only has there been a rise in supermarkets but ultra-processed foods have also penetrated the traditional food retail outlets and are widely available. Although about 6% of processed foods in Ghana are imported from South Africa, they derive predominantly from continents other than Africa [65]. In South Africa, the food retail transition has unfolded extensively—shopping malls and supermarkets are rapidly expanding into erstwhile underserviced, impoverished neighbourhoods, as documented for Cape Town [66–69]. This expansion and the entry of more vertically-integrated networks of informal shops which employ more competitive business practices appears to be transforming the local informal economy [70]. This represents a hybrid system with a highly consolidated formal core and an informal periphery closely linked to the formal economy and to transnational networks of people, goods and finance [5,67,68].

However, these transformations in economic regimes and food systems take place at a scale which is far removed from the everyday lived experience of the many poor who are affected. Paradigmatic food systems models emphasise the global and national scale [41,42,71], or discuss household food security outcomes while neglecting intermediate scales of analysis [4]. Consequently, there is a theoretical disjuncture between macro-scale transitions and shifts in household purchasing and consumption patterns. Structural determinism emphasising systemic transitions fails to show how food system change translates into micro-level dietary changes and neglects how the the poor respond to structural change and how these responses in turn might influence systemic transitions. Finally, while trade and investment policy could influence food environments at a national scale by limiting the import and raising costs of problematic foods, global and regional processes are beyond the reach and remit of local governance. This raises the question how local governance processes can engage with these macro-level drivers of food systems transitions.

1.3. Food Environments in South Africa and Ghana

The concept of food environments introduces an intermediate scale of analysis which may bridge this gap [72–74]. Conceptually, food environments enable, constrain and shape people's food purchase and consumption patterns in several ways related to food availability, accessibility and affordability, and desirability. The notion of food environments still suggests an environmental determinism wherein external environmental factors decisively shape people's purchasing and consumption behaviour. However, this should not lead to neglect of the specific role played by poverty and its various implications. For this reason, we also draw attention to systemic disadvantage faced by poor people. The poor inhabit food geographies differently from wealthier populations, and analysis needs to be sensitive to that and to how large-scale poverty itself shapes the nature of markets. In this sense, the nature of the retail environment

and the strategic decisions of food retailers themselves are shaped by the constraints on aggregate demand in poor food geographies.

A multi-scale perspective on food environments suggests distinctions between personal and external food environments composed of various factors emanating from different scales, e.g., local, national, regional, and global [73]. For this paper, we do not consider the personal scale, but two intermediate scales instead: the household and neighbourhood (i.e., within walking distance of a household) food environment, and the degree to which broader structural drivers such as poverty and food systems transitions influence these. This perspective reveals how systemic transformations change the nature of the local environments which shape the availability and accessibility of food. Conversely, household food purchasing and consumption patterns aggregate to reinforce structural shifts, suggesting multiple cross-scale feedback loops. The food environment concept also has implications for food governance because it frames food consumption drivers at a territorial scale that is amenable to local policy, planning and design interventions [75,76] while also making explicit linkages to higher levels of scale such as regional and global flows of goods and finance.

Food environments in Ghana and South Africa are characterised by a mix of formal and informal food outlets. Informality entails various economic activities which operate without formal registration for tax, licensing, or providing employee benefits such as retirement or paid leave [77]. The informal sector is a key source of food for the poor [39,78,79] but this role is not adequately considered in policy debates [80] and is still poorly researched [81]. Supermarkets and the informal food economy provide different and complementary retail sources of food [66,68,82]. Informal food trade presents advantages to the urban poor: affordable unit sizes, convenient locations, long opening hours, credit, daily re-stocking of fresh produce, which is often cheaper than at supermarkets, and meat cuts that cater to cultural preferences. However, there are disadvantages, too, such as higher unit costs for non-perishables, a limited range of goods of perceived lower quality and shorter shelf life due to the lack of a cold chain, and perceived food safety risks particularly in meat retail. The informal economy thus offers food sources which respond to key needs of poor consumers. This is particularly relevant in cities where unemployment and poverty are often concentrated in fragmented and remote peri-urban informal settlements [83,84].

Food environments in Ghana have traditionally been characterised by large markets and ubiquitous informal roadside stalls and shops. Although research on urban food environments in Ghana is limited, it appears that they are undergoing considerable changes, with increasing prevalence of supermarkets commonly frequented by wealthier city-dwellers, while open-air markets and hawkers are more usually patronised by the poor [85,86]. Fruit and vegetables are scarce in some areas [33], while there is an abundance of cooked foods and convenience stores selling processed and ultra-processed foods that require little or no cooking before consumption. In Accra, informally-sourced food comprised mainly polished rice, vegetable oil, frozen chicken and frozen fish. Increased density of convenience stores appears associated with increases in BMI [87], but food safety issues seem of primary policy concern in Ghanaian and South African cities. Research has therefore emphasised the risks of microbial contamination [34,88,89] and pesticide residues [81,90] in the informal economy.

In South Africa, consumption of street foods correlates with low dietary diversity. Despite widespread consumption of fruit from street trade, there is also a high consumption of ultra-processed foods such as sugar-sweetened beverages and savoury snacks [91]. In poorer areas of Cape Town, food environments promote unhealthy choices [92]. In addition to a challenging food environment, a lack of public safety discourages physical activity, converging with psychosocial stress to promote NCDs, particularly in settlements such as Khayelitsha [93,94].

1.4. Framing Food Environments as Objects of Governance

Key elements of African food systems are clustered in cities, including retail, distribution and processing, presenting opportunities for improved governance [95]. Given the importance of food environments, it is clear that they warrant more effective governance. Governance typically involves various combinations of hierarchical state power, indirect governance through markets, and "adaptive governance" through transversal multi-stakeholder networks and alliances [94,96]. A growing food systems governance narrative emphasises adaptive governance eliciting multi-stakeholder participation [97–100]. There is a growing movement in cities of the Global North towards the democratisation of food systems governance at the urban scale through mechanisms such as departments of food, food policy councils, local food charters, and extensive processes of public participation [4]. Proponents also advocate the incorporation of food issues within urban planning, design and management, for example through food sensitive planning guides or incorporation within local ordinances [101]. However, this requires the development of suitable indices, measurement technologies, and data collection to set benchmarks, design interventions and assess change [102,103]. For governance purposes, complex data need to be simplified and aggregated to render them accessible and amenable to interpretation and intervention by non-academics such as officials, activists and designers. Charts and maps [104] are among the media used to promote discursive and policy aims in ideologically loaded and contested environments [104–106]. These media can draw on novel sources of data by leveraging technical innovations that facilitate the rapid and simple collection of geo-referenced data. These approaches permit the spatial representation of food-related datasets, thus making them more relevant for spatial planning and urban design, which are key local governance competences. However, such media can be obscure and exclusionary. This paper therefore builds on previous approaches [82,107] to develop ways to make the hybrid and diverse food environments of African cities visible, accessible and legible.

1.5. Research Question

This paper explores correlations and linkages between neighbourhood food environments and household food environments, with particular emphasis on the risk they pose for obesity. At the household scale, we are concerned with household purchasing and consumption patterns as elements of household food environments, rather than as a reflection of individual consumption. We are thus interested to know household consumption levels of obesogenic foods and diverse healthier foods, and the aggregate patterns of consumption. At the neighbourhood level, we are interested to describe the density of food outlets, their variety, and the types of food available. The underlying interest is to understand to what extent food outlets in the local food geography facilitate the consumption of obesogenic foods or of healthier food options. The second line of inquiry considers the policy, planning and governance implications of these findings.

2. Materials and Methods

The study gathered quantitative data linking household consumption patterns and local food geographies. Two analytical approaches are combined in this paper. Firstly, descriptive statistics are employed to reflect key features of household and neighbourhood food environments in the research sites. This includes the number and density of food outlets and the relative availability of obesogenic foods in diverse food outlets. Secondly, geo-referenced indices of provision and consumption of obesogenic food are mapped to reveal potential spatial correlations between food consumption and food environments. Ethics clearance was obtained in South Africa from the University of the Western Cape research ethics council (BM17/8/20) and in Ghana from the Centre for Scientific and Industrial Research (CSI: RPN 011/CSIR-IRB/2017).

2.1. Sites, Instruments and Analysis

Two urban research areas in Ghana and South Africa, namely Khayelitsha (Cape Town) and Ahodwo (Kumasi), were chosen. Khayelitsha was chosen as an urban South African site due to previous research experience in the neighbourhood, its large population of urban poor, and its peripheral geographic location. It is located on the far outskirts of the Cape Town metropolis, a major port city with 3.4 million inhabitants. Ahodwo is a central suburb of Kumasi, a metropolis of approximately two million people located in the central Ashanti region of Ghana. Kumasi was chosen as an urban area due to the high level of development and socio-economic status of residents. The spatial dislocation of Khayelitsha as a remote peri-urban dormitory settlement, a legacy of apartheid-era spatial planning, reinforces poverty as it traps the urban poor in areas far from job opportunities [83,84,108]. By comparison, Ahodwo is located fairly centrally in the Southeast of Kumasi metropolis, which reflects a ubiquitous and vibrant street economy.

Digital survey instruments utilising the ODK smartphone survey app were developed in a consultative process involving the entire interdisciplinary research team. The instrument incorporated standardised survey instruments such as the Lived Poverty Index [24] as well as the adapted PURE food frequency questionnaire incorporating the NOVA classification framework. Surveys were additionally reviewed and validated by enumerators as part of an iterative training process including several workshops to ensure clarity and consistency of comprehension. A link to the survey instruments is in the appendix. The instrument was pilot-tested with a small sub-sample of respondents to further assess comprehension and time required. The survey recorded: (i) key aspects of household socioeconomic status and foodways including consumption, sourcing, and preferences; and (ii) the types of outlet, the variety of food sold, key aspects of business practice such as operating times, upstream sources, and modes of provisioning. Georeferences were recorded for each survey response. The research teams in Ahodwo selected a six-area sample frame demarcated by a roundabout and two exit roads which border the township (Figure 1). Two survey areas were selected in Khayelitsha using a transect principle (Figure 2). The one area is Site B, the other is Enkanini-Makhaza. The transects focused on a central zone defined by the railway stations, adjacent minibus taxi ranks and nearby shopping mall complexes. Data were gathered between September and November 2017. Enumerators walked along the roads identified in the sample frame and selected residential properties in the Khayelitsha sampling frame on a 1 in 7 ratio, and in Ahodwo on a 1 in 5 ratio. Enumerators interviewed the household member most knowledgeable about food purchasing and consumption. Enumerators sought to interview all food outlets within the sample frame. Because the sampling rate in Khayelitsha was higher and properties smaller, the sample frame area in Khayelitsha was also smaller (1.32 km^2 as compared with 5.62 km^2).

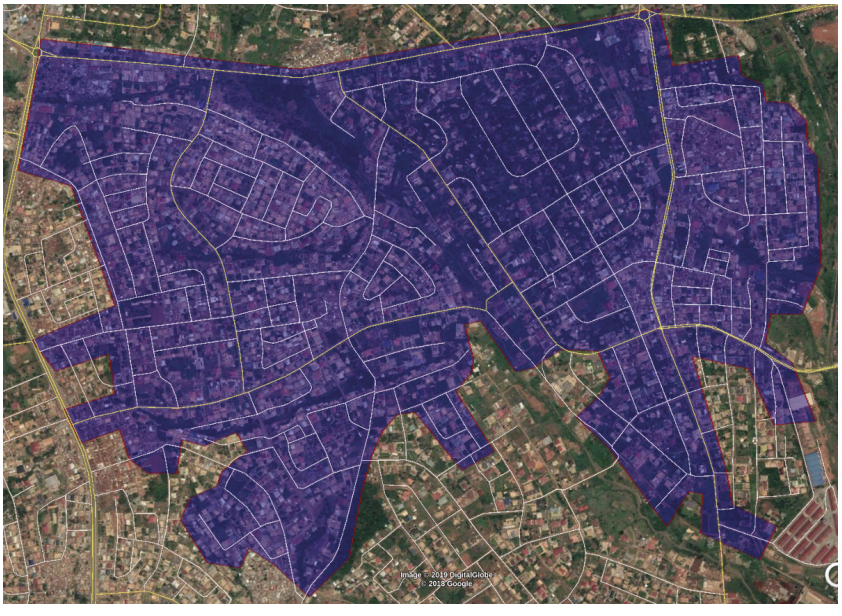

Figure 1. Ahodwo Sample Frame, 5.62 km^2.

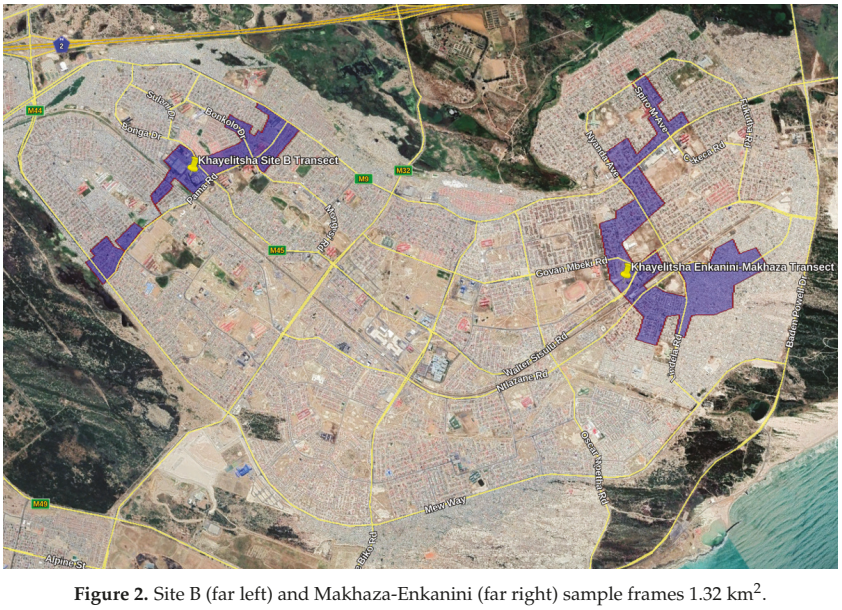

Figure 2. Site B (far left) and Makhaza-Enkanini (far right) sample frames 1.32 km^2.

2.2. Analysis

Data were anonymised and cleaned by checking for inconsistencies, identifying outliers, and correcting obvious errors contradicting known observations (especially for fast food outlets). In some cases, georeferences could not be collected due to technical errors or because enumerators considered the use of smartphones unsafe. In these cases, georeferences were randomly allocated based on the approximate location of the sample.

Customised analysis frameworks for both household and neighbourhood scales were developed on google sheets. Standard spreadsheet functions were used to recode data to generate composite indices of obesogenic and protective food provision and consumption. These were analysed using descriptive statistics such as counts and frequency distributions. Crosstabulations were done to compare dietary risk class distribution between Ahodwo and Khayelitsha samples, internally between income-deprived and non-deprived households in each area sample, and between outlet risk distribution in both sites. Significance of distribution patterns were tested using Pearson's chi-square test. Finally, the correlation (r) between provision and consumption risk classes was tested for both sites.

2.3. Food Outlet Typology

Food retail and service providers were categorised according to a typology based on whether the outlet was located in public or private space, their trading history or temporal persistence and the degree to which permanent or fixed structures have been built. This typology draws on previous work done by AFSUN [37,82]. The food provider typology included the food retail and service categories shown in Table 1.

Table 1. Food outlet typology.

Outlet Type	Outlet Detail
Formal retailer	Wholesaler/Distributor; Supermarket; General dealer
Small or informal shop	Small shop/Convenience store/Spaza (dedicated shop with a sign); House-shop (informal shop attached to or part of a home; no sign; not dedicated to food retail only); Container shop
Stall or mobile trader	Fixed municipal stall (with shelter and display); Permanent stall (fixed shelter, table and display shelves which stays in place after trading hours); Temporary stall (boxes with board; removable stall and shelter; trailer with wheels); Mobile trader (trolley, wheelbarrow; carry-tray, basket or buckets); Bakkie (pick-up truck) trader or trike.
Formal food service	Formal restaurant; Corporate fast food shop; Independent take-away/fast-food.
Informal food service	Informal restaurant; Informal take-away or grill.

It is important to note that there are significant differences between South African and Ghanaian supermarkets. In South Africa, this usually means a large floor space (200 m^2 or more), multiple aisles, trolleys, large-scale refrigeration, multiple (5 or more) electronic tills with card payment facilities, barcode scanning systems used for electronic inventory management, and typically also corporate ownership or formal franchise operations with standardised corporate image and branding. By contrast, in Ghana, supermarkets are often smaller operations with floor space of 100 msq or greater. Where the supermarket is owned by a multinational company such as Shoprite, its characteristics are similar to that described for South Africa. Supermarkets may have some features such as trolleys, multiple aisles, barcode scanning systems, etc., but on smaller scales. Additionally, cash is the typically accepted mode of payment in most Ghanaian supermarkets.

2.4. Obesogenic Food Consumption and Provision Indices

To operationalise the concept of obesogenic food environments, a nutritional classification framework was developed for the household and neighbourhood scales of analysis. This interpretive framework was informed primarily by relevant literature and deliberation among the authors. Although it requires further validation [109–111], in the absence of suitable alternatives, it represents a transparent and evidence-based framework which renders a high degree of complexity visible and legible. Food groups were allocated to two classes of obesity risk—risky and protective—based on their composition and their classification in terms of the NOVA system. The household questionnaire recorded the frequency of consumption of various foods but not the quantity. Consequently, this framework considers both frequency and diversity, but cannot predict dietary adequacy without further validation. Table 2 reflects the different foods considered part of the obesogenic risk index. Only foods where the evidence for impacts on obesity was clear and compelling were considered. Other foods, where the evidence is more ambiguous (e.g., maize meal, red meat, and chicken), were not counted towards the obesity risk index. Both white and brown bread in both sites were classified as ultra-processed food due to the typically high-volume, industrial Chorleywood production process involved [112], which results in just slightly more fibre in the brown bread, although otherwise almost identical with white bread. Nuts and seeds were not included as review of brand information showed that these typically had high salt and added oil content, which arguably offset possible nutritional benefits. A frequency cut-off was set to establish whether a given food is consumed frequently enough to contribute to obesity risk or prevention. Two or more occasions of consumption per week was selected as reflecting frequent consumption for risky foods, five per week for protective foods, as these need to be consumed at a high frequency in order to provide protective benefit. The obesogenic cutoff is set low in order to ensure the index is sensitive to the aggregate effects of occasional consumption of different obesogenic foods. A second cutoff was set to test for the number of foods exceeding the first (frequency) cutoff. As there is a larger number of food types in the risky category than in the protective category, this class has a higher cutoff (4) for number of foods. For example, if a household reported consuming processed meat three times a week, industrial bread five times a week, cookies twice, and sugar-sweetened beverages every day, they would have reached the cutoff for intake of obesogenic foods. If they also ate fruit only once or twice a week, cooked vegetables and legumes five times a week, and no other protective foods, the diet would not reach the minimum cutoff to be classed protective. A binary index was computed based on the number of foods that exceeded frequency cutoffs in either of these categories. This was used to compute a two-category "risk index" and a "protective index". Above the cutoff, that category was scored with 1, where it was below the limit, the category score is 0 (Table 2).

Table 2. Food consumption risk classes.

Household Consumption Risk Class	Risky	Protective
Description	Ultra-processed, processed and fried foods and ingredients	Minimally-processed, plant-based foods
Cutoff frequency	2–4 times a week or more	5 times a week or more
Cutoff number of foods	4	3
Food types	Processed Meat; Instant Noodles; Salty snacks; Sugary drinks; Ready-to-eat foods; Fast food; Fried potatoes/hot chips; Processed Dairy; Breakfast cereals; Sweets; Confectionery; Sugar; Vetkoek/Dumpling; Commercial Bread—White; Commercial Bread—brown	Vegetables—fresh; Vegetables—cooked; Vegetables (fried/stir fry); Fruit; Legumes; Bread—wholewheat; Fish

The same logic was followed to develop a synoptic indicator of the degree to which food outlets provide access to foods promoting obesity. A list of food types traded was assessed in terms of the obesity risk these foods pose. A threshold of two foods traded was set for each category. An outlet was scored high-risk if the outlet stocked two or more risky food types, low-risk if it stocked only one or less. Similarly, an outlet was scored based on the provision of foods known to mitigate obesity risk (Table 3). Low risk foods include mainly NOVA Class one (whole) staples such as maize meal, rice, potatoes, meat, eggs or Class two (refined ingredients such as oil). Where details of shop stock were not available due to refusal to participate in the survey, a score was interpolated based on average scoring of similar outlets and description of type of outlet (e.g., unsurveyed "fruit and veg stalls" were scored as "low risk and protective" as this was the dominant scoring for similar stalls).

Combinations of these two binary indices were used to calculate an aggregate risk index based on four mutually-exclusive categories of obesity risk and vulnerability of household and neighbourhood food environments (Table 4 below).

Table 3. Food provision risk classes.

Class	Risky	Protective
Description	Ultraprocessed and obesogenic foods high in salt, sugar and saturated fats	Minimally processed, nutrient-dense foods
Threshold	2	2
Foods	Instant Noodles; Confectionery and Sweet Snacks; Sweets; Sugar-sweetened beverages; Salty Snacks; Dairy, Ultraprocessed; Meat, Ultraprocessed; Commercial bread; Breakfast Cereals; Flour-based meal with roasted or baked additions, (e.g., burger, pizza, dagwood, gatsby, kota); Dessert; Confectionery (Cookies, scones, muffins); Sugar; Deep fried starchy food (deep-fried dumpling, potato chips)	Fruit; Vegetables; Legumes; Legumes, cooked; Vegetables, cooked or fried; vegetables and relish; Fish, cooked or grilled; Fish

Table 4. Food environment risk and vulnerability matrix.

Household	PI 1	PI 0
RI 1	**high risk, protective** (households frequently consume risky foods but also protective foods)	**high risk, vulnerable** (households frequently consume risky foods, but lacking adequate protective food consumption)
RI 0	**low risk, protective** (households consume risky foods infrequently, and frequently consume protective foods)	**low risk, vulnerable** (households infrequently consume risky foods but also consume inadequate protective foods)
Neighbourhood		
RI 1	**High risk and protective** (outlet stocks a wide variety of high risk and protective foods)	High risk (outlet stocks a variety of high risk foods but few protective)
RI 0	**Low risk and protective** (outlet stocks a variety of low-risk and protective foods)	**Low risk** (outlet stocks mainly low-risk staple foods and few protective or high-risk foods)

In the household example just mentioned, the household would be considered high-risk and vulnerable. Outlets marked as low-risk would stock few ultra-processed food types, but mostly the low-risk, minimally-processed foods mentioned above. Outlets stocking a variety of foods known to protect against obesity were classed as protective. Thus, supermarkets would generally be scored as "high risk and protective" as they provide access to both types of foods, while fruit and vegetable stalls

would generally be scored as "low risk and protective" because they do not stock a variety of obesogenic foods but offer various protective foods. The statistical distribution of households and food outlets belonging to these different risk classes was calculated at both the household and neighbourhood level. At the neighbourhood level, this distribution was calculated with reference to the number of food outlets per square kilometre. Household and neighbourhood food environment categories were mapped.

3. Results

In Khayelitsha, 327 households participated in the survey and 309 households in Ahodwo. Response rates were 91% and 97%, respectively. In total, 407 outlets were surveyed in Ahodwo and 83 in Khayelitsha. However, the outlet response rate in Khayelitsha was low (53%), possibly due to mistrust related to recent xenophobic persecution of foreign-owned informal outlets in South Africa [113] and absence of shop-owners. By contrast, 100% of Ahodwo retailers agreed to participate in the study. Descriptive statistics and maps reflecting survey findings are presented in the following two sections. The first section presents the distribution of the aggregate household risk index and profiles the key obesogenic and protective foods consumed. The second section first presents the diversity of food outlets in the local food environment, then maps the aggregate food provision index, juxtaposing this with aggregate food consumption.

3.1. Household Food Environment

The findings reflected in Figure 3 show that 71% of Khayelitsha respondents reported household diets that met or exceeded the cutoffs for obesogenic foods, while only 16% reported consuming diets meeting or exceeding cutoffs for protective food. In Ahodwo, the pattern is different, with approximately one quarter of households surveyed (26%) consuming diets high in obesogenic foods, and only 23% consuming high amounts and varieties of protective food. Here, two thirds of respondent households consumed low-risk diets composed largely of minimally-processed staples but lacking in protective food intakes. In both samples, there is a notable dearth of protective food consumption. The difference in the risk class distribution between the two sites is statistically highly significant ($p < 0.000$).

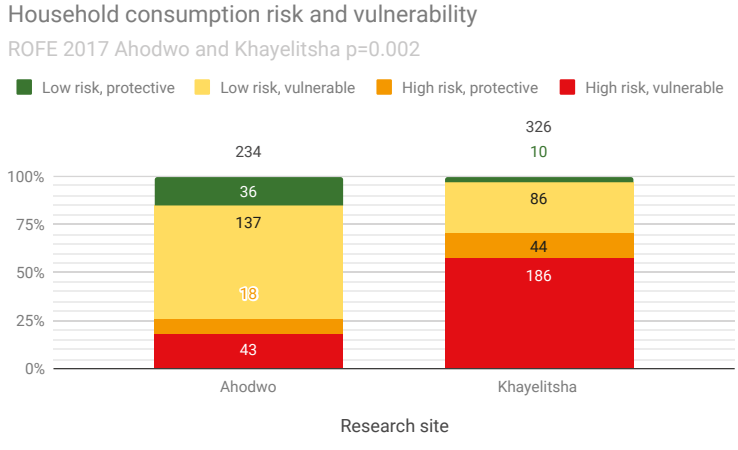

Figure 3. Household consumption risk and vulnerability classes—numbers on the bars reflect class and aggregate totals.

Figure 4 shows which of the high-risk foods most commonly exceeded the thresholds. In Khayelitsha, commercial bread, sugary drinks, processed meat and sugar were the most prevalent obesogenic foods. In Ahodwo, commercial bread was followed by sugar, sugar-sweetened beverages, and confectionery as the top four high-risk foods exceeding threshold.

In Khayelitsha, the top three protective foods consumed were fruit, fresh and cooked vegetables (Figure 5). More than a third of households met the threshold for "protective" fruit consumption, just more than a third for cooked vegetables but just more than one in ten met the threshold for fresh vegetables. In Ahodwo, fish and fruit (38% each) were the most common obesity-mitigating food consumed at or above threshold, followed closely by cooked vegetables (28%). Only about one in five households (23%) exceeded the frequency threshold for fresh vegetables.

In Khayelitsha, supermarkets and formal retail outlets clearly dominate as sources for most foods except fruit, bread and sugary drinks (Figure 6). Informal and small shops dominate as sources of bread and sugary drinks, but play a minor role in the provision of protective food options. Informal stalls play an important role in the provision of fresh fruit and vegetables.

In Ahodwo, small shops play a greater role in providing access to the key foods than in Khayelitsha (Figure 7). Formal retailers are also a key source of sugary drinks, confectionery and sugar. Fruit, vegetables, legumes and fish are provided primarily by stalls and by "other", which mostly refers to open markets, table top (stationary) food vendors as well as mobile food vendors.

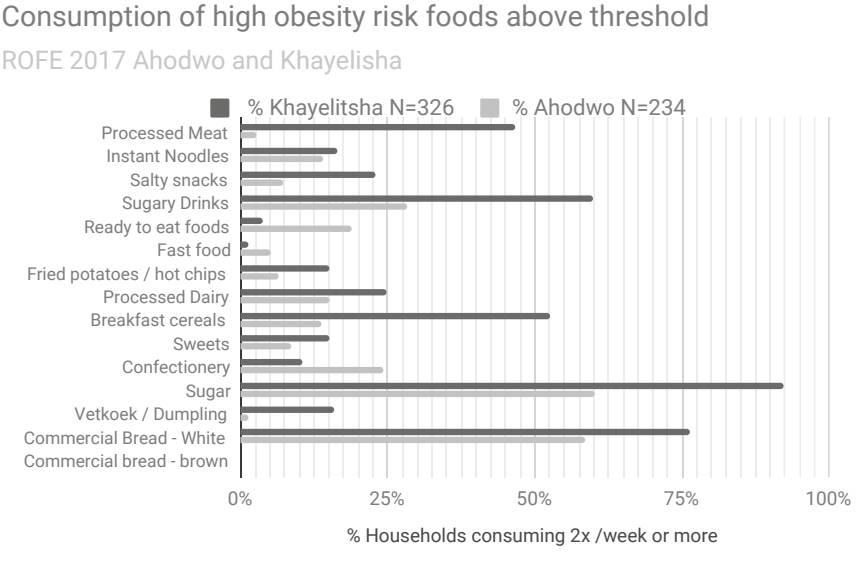

Figure 4. High-risk household food consumption above threshold.

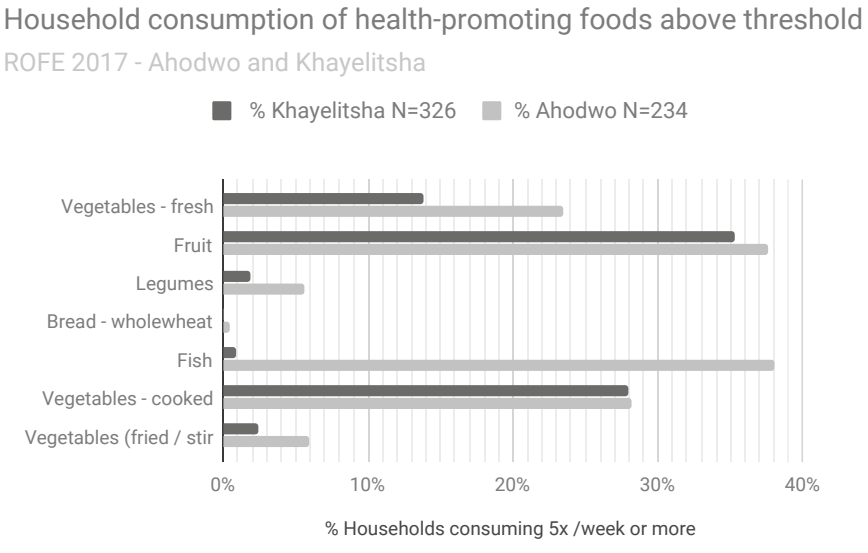

Figure 5. Household consumption of protective foods above threshold.

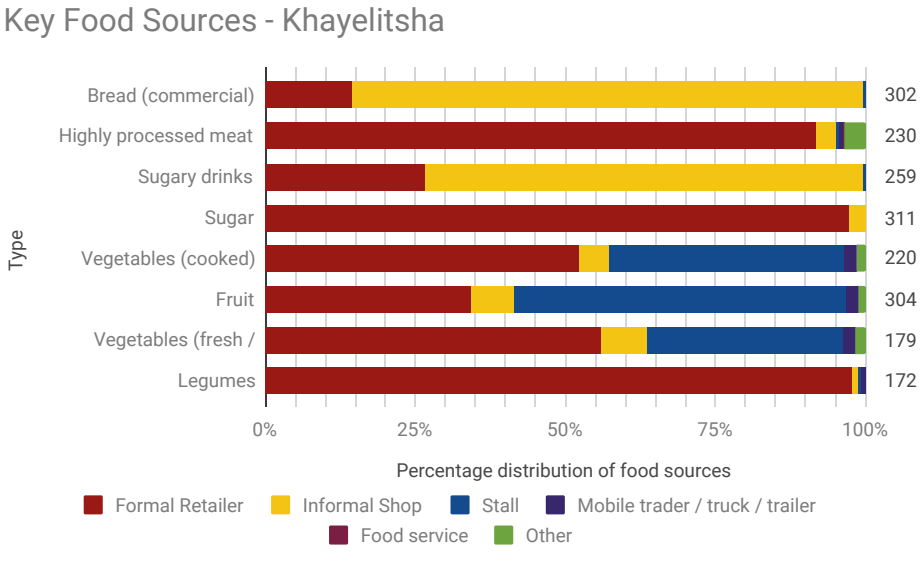

Figure 6. Household sources of key foods in Khayelitsha—numbers on the right reflect total counts of households consuming each food.

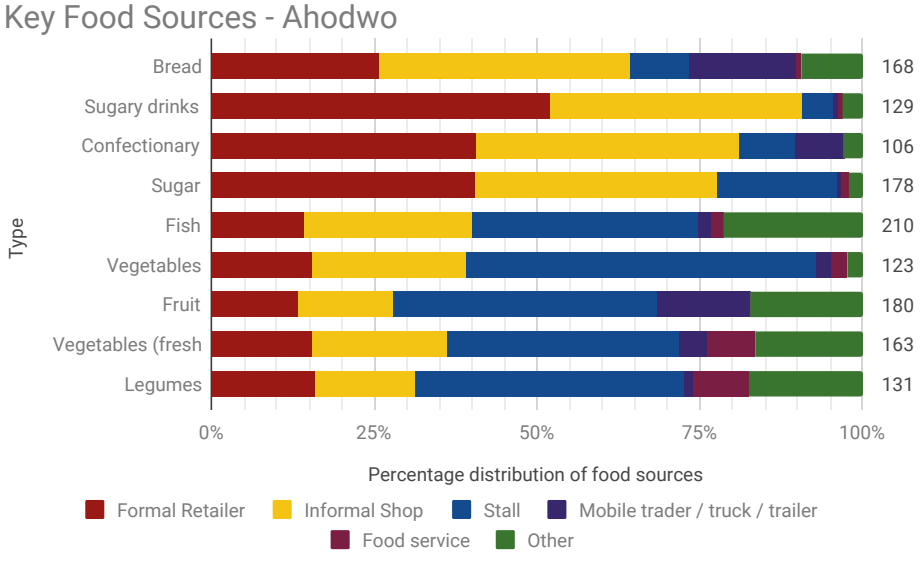

Figure 7. Household sources of key foods in Ahodwo—numbers on the right reflect total counts of households consuming each food.

3.2. Neighbourhood Food Environment

The Ahodwo sample frame contained a far larger number of both food retail and food service outlets than the Khayelitsha sample frame due to the larger geographical area (Table 5). However, food retail outlets are represented at similar densities of approximately 39/km^2 in Khayelitsha and 41/km^2 in Ahodwo. Food service outlets are represented slightly more densely in Ahodwo, with 32/km^2 as opposed to 23/km^2 in Khayelitsha. The proportions of the different outlet classes are similar in both sites. Ahodwo has more outlets per square kilometre, but in Khayelitsha the proportions of outlets providing access to obesogenic as well as those providing protective food are larger (Figure 8). The difference in distribution between the two sites is statistically significant at $p = 0.0001$. This indicates that Khayelitsha residents have fewer outlets to choose from, and that, of those, more than half (57%) are risky, as opposed to one in three in Ahodwo (39%). However, Ahodwo residents appear to have poorer aggregate access to protective foods (16% vs. 43%).

Table 5. Number and composition of food outlets.

Outlet Type	Ahodwo	Khayelitsha	% Ahodwo	% Khayelitsha
Formal Retailer	27	6	7%	7%
Informal Shop	109	27	27%	33%
Stall or mobile trader	89	19	22% &23%	
Formal food service	58	12	15%	14%
Informal food service	116	19	29%	23%

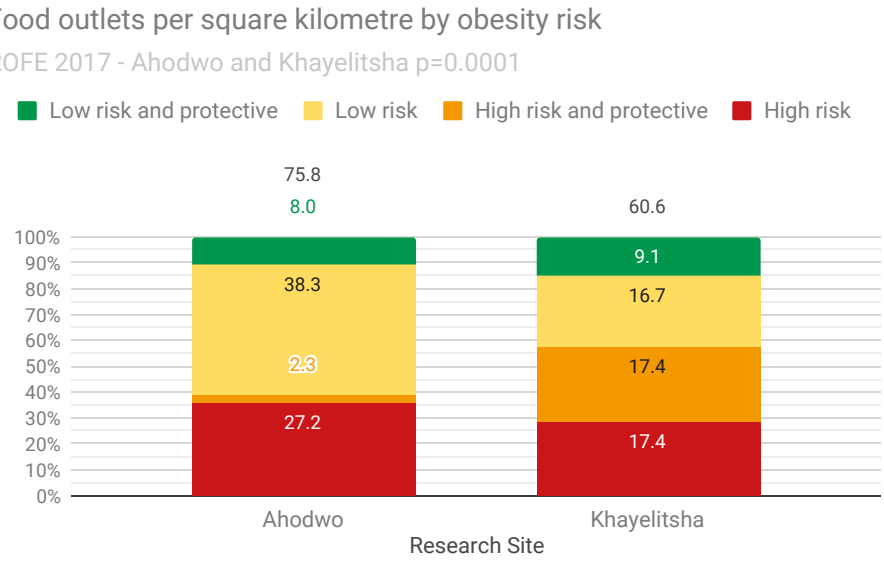

Figure 8. Food outlets per square kilometre by risk and protection class—numbers reflect class and aggregate totals.

The distribution of household and neighbourhood food environment classes show a strong (r = 0.862) positive correlation in Ahodwo, while the correlation in Khayelitsha is less strong (r = 0.624), suggesting confounding variables. Poverty was identified as the most likely confounding variable. Income levels for both populations were low, with 49% in Khayelitsha earning below R3000/month (187 Euro), and 37% earning less than 964GHc/month (166 Euro) in Ahodwo. However, the 2016 upper-bound poverty line (UBPL) in Ghana was 1314 GHS [114], thus 47% of respondent households can be considered income-poor. In Khayelitsha, 70% of households reported aggregate incomes below the South African 2018 UBPL of R1183/person [115]. Moreover, the PACSA annual food price report of 2017 indicates that the cost of a basic basket of food to feed a household of seven persons comes to R1912.98, thus roughly half that to feed the average Khayelitsha household. Consequently, about half of the population in the Khayelitsha sample would have to spend more than a third of household income just to satisfy basic food needs [116].

Noting the prevalence of poverty in the research sites, additional analysis was done cross-tabulating risk classes with the experience of income poverty documented by the Lived Poverty Index component of the survey [24]. Lack of access to cash incomes was a key issue (46% in Khayelitsha and 20% in Ahodwo). Chi-test analysis yielded statistically significant ($p = 0.005$) differences in dietary risk distribution between households in Khayelitsha experiencing income deprivation and those who did not. Eighteen per cent fewer poor households exceeded obesogenic food consumption cutoffs than those who had not reported income deprivation. Cutoffs for protective food consumption were met by slightly fewer (6%) income-deprived households than by non-deprived, likely because consumption levels were already low. This indicates that households experiencing income deprivation reduce consumption of obesogenic and, to a lesser extent, protective foods in favour of dietary staples. The Ahodwo sample showed a slight increase in consumption of protective foods among poor households (7%) and a slight decrease in consumption of

obesogenic. However, the association was not statistically significant ($p = 0.54$), suggesting that income poverty may have a more ambiguous impact on household food provisioning in Ahodwo.

3.3. Mapping Obesogenic Food Provision and Consumption

The following section presents maps reflecting food provision and consumption patterns. The food provision maps reflect the distribution of outlets belonging to the different risk classes. These are each juxtaposed with maps reflecting the distribution of household food environments in terms of the aggregate risk index.

3.3.1. Food Provision and Consumption—Ahodwo

The overview of food provision outlets in Ahodwo reveals a large number of outlets, concentrated along major roads and densely clustered around key intersections (Figure 9).

The Aggregate Consumption Index Map for Ahodwo (Figure 10) reveals no definite spatial clustering or pattern except for an apparent concentration of low risk, high protection diets around Kufuor I and Kufuor II streets and near the outlet clusters in the Northeast and Northwest corners of the sample frame (circled in red). The map reflects widespread prevalence of low-protection diets, with a fairly even distribution of low risk and high risk diets.

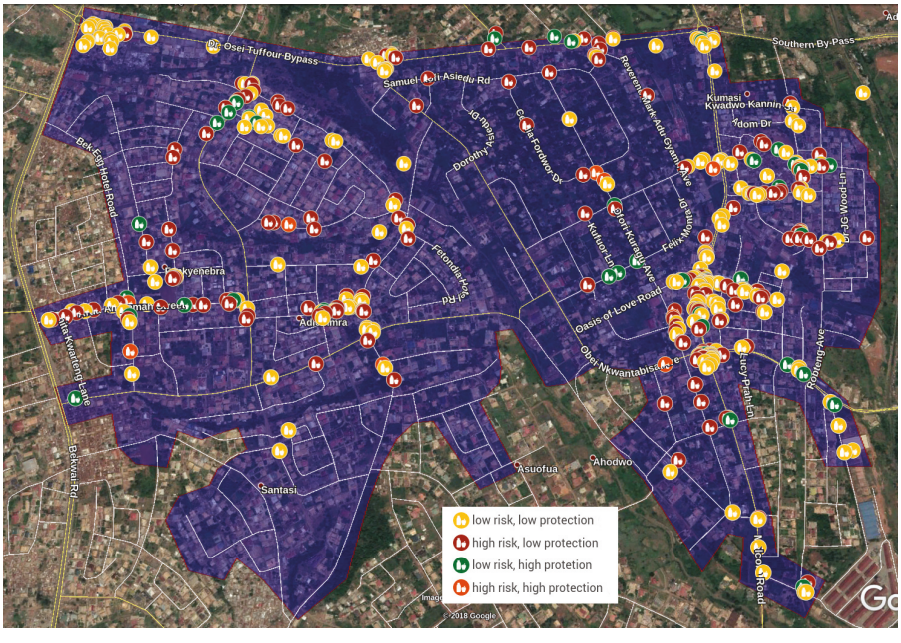

Figure 9. Ahodwo—food provision.

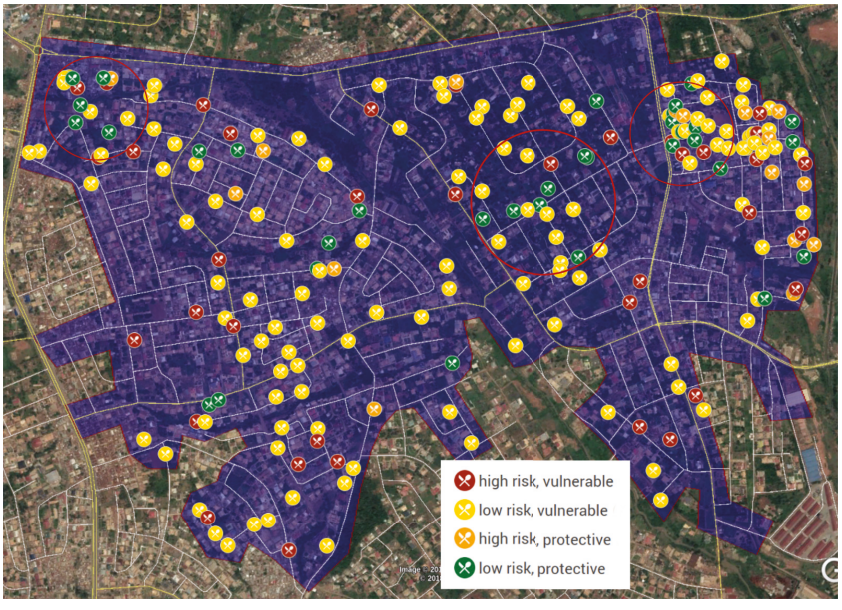

Figure 10. Ahodwo—aggregate food consumption.

3.3.2. Food Provision and Consumption—Khayelitsha

The food provision outlet map of Khayelitsha Site B (Figure 11) reveals a fairly low density of outlets, most clustered around the Nonkqubela shopping mall.

Figure 11. Khayelitsha Site B—Food provision.

The Makhaza area (Figure 12) shows dense clustering around the Makhaza shopping mall area, and a concentration of informal outlets along Ntlazane road in the informal settlement of Enkanini.

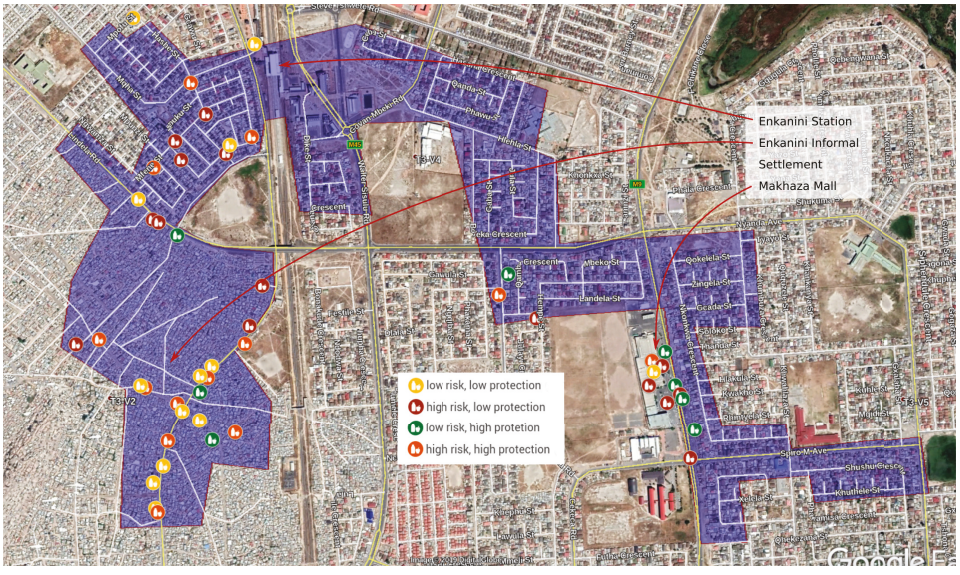

Figure 12. Makhaza-Enkanini—food provision.

In neither of these transects is there a clear spatial clustering of different food consumption risk categories (Figures 13 and 14).

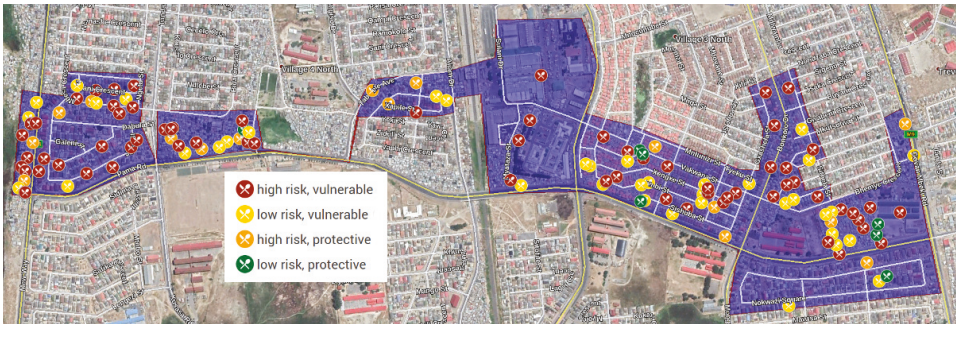

Figure 13. Map 7: Khayelitsha Site B—aggregate food consumption.

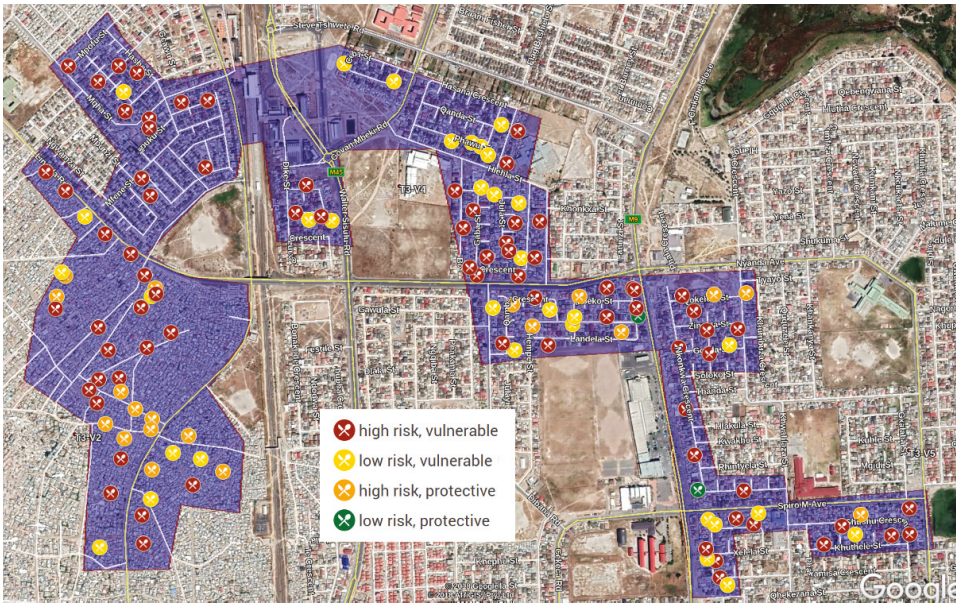

Figure 14. Map 8: Makhaza-Enkanini—aggregate food consumption.

3.4. Summary

In summary, household consumption patterns revealed that a large proportion of the Khayelitsha household food environments were high risk (i.e., frequent consumption of ultra-processed and obesogenic foods—71%), but with low consumption of protective foods (only 16% meeting the threshold). The most commonly-consumed obesogenic foods in Khayelitsha were industrially produced bread, processed meat, sugar-sweetened beverages, and sugar (typically in hot beverages and added to porridge). These foods can be interpreted as a response to the poverty experienced, as they are typically cheap [9,117,118], and do not require much preparation. The most commonly consumed protective foods were cooked vegetables.

Ahodwo household food environments differed slightly: Only 26% of the respondents reported risky diets, and only 23% met cutoffs for protective food consumption. While commercial bread and sugar-sweetened beverages were also frequently consumed, consumption of processed meat was less prevalent and confectionery was instead eaten more widely. Sugar was also among the obesogenic foods consumed regularly in Ahodwo. Protective foods commonly eaten included fish, cooked vegetables, as well as a slightly higher intake of fresh fruit and vegetables than in Khayelitsha (Figure 5). Consumption of low-risk, vulnerable diets is clearly higher, indicating a larger segment of the population relies on staple foods sourced from convenience stores and open-air vendors, while lacking other foods rich in micronutrients including fruits, vegetables and legumes.

Respondents' reports of their usual food sources show that in Khayelitsha, supermarkets play a key role in providing access to obesogenic foods. Roadside stalls, although often selling sweets on the side, are important sources of fresh produce in Khayelitsha. This confirms earlier AFSUN findings [37,78]. However, supermarkets are less important as a source of sugar-sweetened beverages. Instead, large proportions of the population access obesogenic foods such as commercial bread and sugar-sweetened beverages from small shops. People frequently access protective foods through roadside stalls and through local markets.

The spatial patterning of the two research sites appears slightly different. In the more spatially extensive Ahodwo site, there was a higher number of food outlets which seem evenly dispersed except for dense clusters at busy intersections and markets. This may reflect the market culture of Kumasi, where outlets agglomerate in particular areas. By contrast, the transects surveyed in Khayelitsha suggest that in Site B food outlets are spatially clustered near the new malls and supermarkets, often close to public transport nodes and interchanges. In the Enkanini-Makhaza transect, there also appears to be a clustering of outlets along main access roads in the informal Enkanini settlement, providing convenient food access to residents far from the Makhaza mall. In Khayelitsha, the Site B and Makhaza malls are hotspots of obesogenic food provision, but also attract fruit and vegetable traders who provide access to healthier options. Mapping of aggregate food consumption risk indicated no obvious spatial clustering of risky household food intake in any of the research sites, nor any clear spatial relationship to food outlet location.

Outlets offering a variety of healthier food in Ahodwo were few and far between, and are clustered along Afua Ampomah street and Asante Frempong Avenue on the far eastern and western edge of the study area. However, many of these outlets also stock obesogenic food, and there is no obviously discernible pattern to the distribution of households consuming high levels of protective foods. In Khayelitsha, outlets providing access to healthier foods clustered around Site B mall, Ntlazane road and Makhaza mall. Supermarkets provide access to a range of healthier options, although of course they stock many obesogenic and ultra-processed foods, too.

4. Discussion

4.1. Limitations

Although the findings reveal information that speaks to previous research and has various implications for research and policy, the study has several limitations which constrain permissible inferences. The first is that approximately half of the food outlets mapped in Khayelitsha refused to participate in the survey (see below). In these cases, georeferences were recorded along with the store typology and a basic description (e.g., vegetable stall) to infer their level of nutritional risk. Secondly, the household survey did not document outshopping, i.e., that consumers travel to retail outlets outside of their local neighbourhoods to access food due to better prices, particular quality, or convenience along commuting routes. Thirdly, some informal outlets operate at times during which enumerators could not be in the field. Finally, the findings cannot be extrapolated as representative of broader consumption patterns in the immediate environments of the survey sample areas. Household scale of analysis means that internal dietary differences related to age, gender and power remain uncaptured in this particular analysis. Indicators of vulnerable household food environments are based on reported household food consumption, not individual food consumption, which will be published elsewhere.

4.2. Key Insights

The findings confirm the conclusions reached by several previous studies, namely that: (i) there is a co-existence of a diverse range of formal and informal food outlets [66,68,82,85,86]; (ii) obesogenic foods are widely prevalent and available [65,87]; (iii) supermarket expansion in particular is making ultra-processed and other obesogenic foods more accessible, although also offering access to a range of healthy options [25,38,46,85,87,117]; and (iv) there are high levels of consumption of obesogenic foods. This appears correlated with a local food geography which presents a large proportion of outlets with high prevalence of obesogenic foods.

Comparison also reveals important differences between the two sites. Both sites are urban and of comparable density, yet degrees of obesogenic risk in household and local food environments are

clearly different. **Firstly**, the overall number of outlets per square kilometre is slightly higher in Ahodwo than in Khayelitsha, offering consumers a greater range of conveniently-located options, particularly of prepared foods. **Secondly**, the proportion of outlets stocking a range of obesogenic foods appears higher in Khayelitsha. **Thirdly**, from a spatial perspective, food outlets in Khayelitsha are far more densely clustered around the supermarkets and transport nodes, which likely influenced the location of the supermarkets. By comparison, in Ahodwo, although there is also some clustering around key intersections and open-air markets, there is a far broader distribution of food outlets spatially, making foods more easily accessible. However, the correlation between distributions of consumption and provision is far stronger in Ahodwo. Despite far greater relative availability of protective foods in Khayelitsha than Ahodwo, the household food environments suggested lower levels of protective food consumption in Khayelitsha (23% Ahodwo; 16% Khayelitsha). This finding suggests that the local availability of protective foods alone plays only a partial role in promoting their consumption, and that other factors, such as cost, availability of refrigeration, and cost of cooking fuel [25,80,82,119–122], may constrain consumption of protective foods. In particular, poverty appears to play a strong role in influencing household food consumption in Khayelitsha. These findings have implications for the study of food environments, for our understanding of the nutrition transition and its drivers, and ultimately, for planning, policy and governance.

4.3. Implications for Food Environment Research Methods

The study results demonstrate that the widely accessible capabilities of smartphones, geo-location technologies, and online enumeration and data management technologies offer new opportunities to gather and evaluate data on informal food environments. However, the study also revealed limitations in the usefulness of such technology in areas of high poverty and inequality, where they present a safety risk to enumerators. By surveying two scales of food environment analysis (household and neighbourhood) and comparing emerging patterns, we were nevertheless able to identify key obesogenic and protective foods constituting household food environments. Moreover, statistical analysis based on the geographical density of outlet classes and the distribution of household risk classes revealed suggestive correlations and disjunctures. However, these quantitative and spatial perspectives should be complemented with qualitative and participatory approaches to document the experience of food environments by consumers and to interpret the findings of this survey.

4.4. Implications for the Dietary Transition and Non-Communicable Disease

The findings confirm that the dietary transition in LMICs [9] and Africa [13] is progressing apace, although further along in South Africa [14,15,26,91] than in West Africa [16]. Household food environments in Khayelitsha appear more severely obesogenic than in Ahodwo, mainly due to the higher consumption of risky foods and slightly lower consumption of protective foods. This appears to accord with the higher levels of obesity in the Western Cape than in Ashanti Region. The transition is often explained with reference to urbanisation and greater disposable incomes. Indeed, global sales of ultra-processed food correlate with higher levels of urbanisation and higher income countries. Nevertheless, sales growth of ultra-processed food over the last decades have been higher in low- and middle-income countries, compared with high-income ones [59]. The present study confirmed high levels of purchase and consumption of ultra-processed foods in urban settings in South Africa and Ghana. However, the higher prevalence of obesogenic food consumption in Khayelitsha in comparison with Ahodwo, where poverty is less extreme, calls the generic correlation of obesogenic food consumption with increased incomes into question. Nevertheless, within the Khayelitsha sample, households experiencing income deprivation consumed far less obesogenic foods. Therefore, while the availability of obesogenic foods in the Khayelitsha neighbourhood food environment appears to promote greater obesogenic household food

consumption despite deeper levels of poverty than in Ahodwo, within the Khayelitsha population, higher incomes do appear to be correlated with greater obesogenic food consumption. The contradictions noted above suggest that other factors play a key role in explaining the disjunctures noted above, including levels of poverty, the structure of the food economy, as well as the spatial patterning of urban settlements.

These data suggest that a cautious and nuanced discussion of the role of supermarkets and their interaction with the informal economy in Khayelitsha and Ahodwo is necessary. While they provide access to obesogenic foods and may out-compete some small shops, supermarkets also provide access to legumes, fruit and vegetables which are healthier foods and attract footfall, which in turn draws fruit and vegetable traders. Transnational supermarket and mall expansion into the Ahodwo area has begun, evidenced by the nearby construction of a modern shopping mall including a Shoprite supermarket. This confirms that the South African supermarket retail model is being exported to other countries in the continent [57,123]. This may cause a contraction in the informal economy which could affect livelihoods and increase the availability of ultra-processed and obesogenic foods while making healthier options less attractive and less conveniently available. However, the informal food economy has proved resilient and adaptive, developing a complementary relationship with formal outlets [66,68,124]. Small shops in Khayelitsha may have adapted by specialising in the provision of regularly-consumed obesogenic foods such as commercial bread, SSBs, and confectionery, as well as grocery hampers composed of staples (not considered high-risk in this study as they are dietary staples). In Ahodwo, however, small shops also are a key source of healthier options.

4.5. Implications for Food Environments Theory

These findings are relevant to a more fundamental inquiry concerning the balance of forces between local food environments and endogenous household drivers (poverty and other forms of disadvantage), themselves conditioned by larger systemic and structural dynamics. The lack of clear geographical clustering of different household risk classes in relation to the location of food outlets suggests that, at the neighbourhood level, the aggregate density and composition of outlet types is more relevant than their location. The above-mentioned contradictions raise the question whether the greater consumption of protective food in Ahodwo is a result of the lack of big corporate penetration—or simply a reflection that this urban landscape, with less poverty than Khayelitsha, is one in which local demands can be met despite lower aggregate availability?

It thus appears that in Khayelitsha, household incomes are a stronger determinant of obesogenic food consumption patterns than local food availability—while most households are poor, the poorest tend to reduce consumption of ultra-processed foods and protective foods—their obesity risk derives from a reduction of protective foods and increased reliance on energy-dense staples. Poverty in Khayelitsha is reinforced spatially by the dislocation of Khayelitsha as a remote peri-urban dormitory settlement, a legacy of apartheid-era spatial planning, which traps the urban poor in areas far from job opportunities [82,83,114]. By comparison, Ahodwo is located fairly centrally in the Southeast of Kumasi metropolis, with a ubiquitous and vibrant street economy, presumably presenting more opportunities for equitable participation. This suggests that it is not urbanisation per se which is the issue, but that the spatial forms of urban spaces and the economic opportunities they offer which are perhaps more important.

4.6. Implications for Planning, Governance and Policy

Spatial analysis has enabled the identification of hotspots of obesogenic food provision, particularly around malls in Khayelitsha and busy intersections in Ahodwo, providing urban governance actors with potential points of geographic focus and leverage. This means that urban planners should consider the impacts of shopping malls and their immediate food environments on local livelihoods that property

developers and commercial landlords be required to take into account the needs and opportunities presented by informal traders—especially fruit and vegetable stalls. Local government officials should not only adopt less obstructionist attitudes to street trade, but also consider how its role in providing access to fresh, whole foods can be supported in terms of land-use regulations, infrastructure and services. Interventions which make fresh, protective foods more cheaply and abundantly available to street traders may indirectly counter the tendency of the poorest households to economise by reducing their consumption of these foods. Infrastructure, regulation and social capital development supporting local aggregation and distribution and sale of fresh produce through cold chains, as well as the development of distributed micro-processing facilities may enhance the availability and lower costs of fresh and minimally-produced food.

The findings concerning small and informal shops suggest that particular attention should be paid to the regulation of upstream suppliers of obesogenic and ultra-processed foods as the small size, widespread distribution and large numbers of the retail outlets would make any form of direct regulation costly and logistically challenging. Although engagement with local trading associations may present opportunities to create awareness and develop adaptive multi-stakeholder governance approaches [97–99], the fractious nature of informal trade makes it challenging to find effective points of governance engagement and co-ordination [125]. Unless fresh, whole foods can be supplied more cheaply, it is therefore likely that traders will continue to respond to the demands of the urban poor for by providing cheap and convenient, but obesogenic foods. In Ahodwo, the development of large fresh-produce wholesale markets may support the provision of more affordable fresh produce through small shops and stalls.

The strong role which household poverty appears to play in constraining the consumption of protective foods suggests that regulatory intervention in local food environments alone may be of limited benefit unless accompanied by economic policy ensuring greater and more equitable economic participation, comprehensive social safety nets, and lower prices for fresh, healthy foods. At the local scale, the improvement and subsidisation of public transport could facilitate greater mobility essential to accessing economic opportunities.

5. Conclusions

The methodologies developed offer planners, activists and officials ways to visualise, engage with and interpret local food environments more concretely. The study reveals important insights into these particular food environments. The findings show that household food environments promoting obesity, more prevalent in Khayelitsha than in Ahodwo, appear correlated with neighbourhood food environments, which make obesogenic foods accessible and available, despite greater poverty in Khayelitsha. They also suggest that poverty is a powerful determinant not only of household consumption and purchasing but also of local food environments, thus suggesting a systemic feedback loop contrary to the direction of causality commonly implied in food environments theory. Making these "foodscapes" visible and legible may enable state and civil society agents to frame them as more concrete objects of local governance discourse. This is essential to galvanise the "will to transform" them [126,127]. In light of the above interpretation of the findings, however, governance of food environments may offer only limited leverage to address obesity in the face of systemic poverty and inequality. It cannot substitute for more fundamental engagement with socio-economic and spatial drivers of obesity which transcends a narrow focus on food.

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The Impact of Proximity to Wet Markets and Supermarkets on Household Dietary Diversity in Nanjing City, China

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Abstract: This study investigated the influence of the proximity to wet markets and supermarkets on urban household dietary diversity in Nanjing. Based on the data collected through a citywide survey in 2015 and the map data of wet markets and supermarkets, the Poisson regression model was deployed to examine the correlations between geographical proximity to supermarkets and wet markets and household dietary diversity. The result shows that the coefficients for the distance to the nearest wet market are not statistically significant. Although the coefficients for the distance to nearest supermarket are statistically significant, they were too minor to reach a practical importance. We argue, however, that the insignificant correlations reflect exactly the high physical accessibility to food outlets and the extensive spatially dense food supply network constituted by wet markets, supermarkets and small food stores in Nanjing, due in part to the food infrastructure development planning in Nanjing that has ensured relatively equal and convenient access to wet markets or supermarkets for all households. Our findings are verified by the survey data that more than 90% of households purchased fresh food items within their neighborhoods or in walking distance. In addition to the densely distributed food outlets, various other factors contributed to the non-significant influence of the distance to the nearest wet market and supermarket, in particular, the numerous small food stores within or close to residential communities, the prevalence of three-generation extended household structure and the high household income.

Keywords: proximity to food outlets; dietary diversity; food access; food security; food environment; food geographies

1. Introduction

The relationship between household dietary diversity and access to food markets was investigated in several studies. Some suggest that an increase in distance to food markets may decrease dietary diversity and increase food insecurity [1–3]. Restricted access to supermarkets, in particular, can reduce healthy food consumption [4]. In contrast, other studies maintain that there is no causal linkage between access to food markets and dietary diversity. A study in Michigan, USA, for example, found that physical distance to food outlets providing healthy food did not significantly influence fruit and vegetable consumption [5]. Another study suggests that it is the price of food in supermarkets, rather

than the physical distance to market, that most influences the consumption of fruits and vegetables [6]. This implies that the direct cost of food is a much more important factor than indirect factors such as physical distance and travel cost.

Another group of researchers suggest that the potential impact of distance on dietary diversity is mediated by other factors. Even when supermarkets are physically present in low-income urban areas, for example, this does not necessarily improve dietary diversity since they tend to carry a less healthy and diverse range of foods [7]. A study in the US found that an increase in the distance to a supermarket decreases the odds of fruit and vegetable consumption in metropolitan areas but has no impact in non-metropolitan areas [4]. An analysis of data from 21 different African countries found that distance to the nearest road (and therefore transaction costs for food purchase) had a significantly negative impact on fruit and vegetable consumption, but no significant effect on animal source food consumption [8]. The impact of improved locational access to food markets also tends to vary with household income with low-income households benefitting more than wealthier groups [9]. Thus, while distance to food outlets does seem to be an important variable in household food consumption, a consensus has yet to be reached on its influence on household food security [10].

There is a widespread assumption that the one-stop shopping associated with supermarkets is more convenient than multi-stop shopping and therefore more attractive to consumers. However, in practice, food shopping practices are complex and there are interactions and integration between different market outlets [11]. Despite the proliferation of large supermarkets and hypermarkets, the multi-stop shopping model still prevails in much of Asia [12]. Chinese consumers value the freshness of food and prefer to buy small amounts of fresh vegetables on a daily basis rather than storing vegetables for a longer period [13]. The main advantages of wet markets over supermarkets is the freshness and affordability of food, regardless of supermarket penetration [13,14]. Food purchasing is also shaped by the practice of shopping for different foods at different outlets (i.e., cross-platform shopping); for instance, buying perishable food in traditional wet markets and processed food in supermarkets. Multi-stop shopping at different forms of retail outlet means that dietary diversity and household food security cannot be seen as the outcome of distance to a single food purchasing location.

Previous studies have focused on the impact of proximity to supermarkets on food security and have neglected the influence of proximity to wet markets. Moreover, most studies of food security in China have focused on national or regional-level food supply with few studies paying attention to household-level food security in urban areas. Quantitative analysis of the relationship between physical access to food outlets and household dietary diversity of China is absent. To bridge this gap, this study examines the relationship between proximity to wet markets and supermarkets and urban household dietary diversity.

2. Wet Markets and Supermarkets in Nanjing

Despite the proliferation of supermarket chains since the 1990s, wet markets remain the most prevalent food outlet in urban China. They specialize principally in fresh vegetables, fruit, livestock products, aquatic products (such as live fish and shrimp), poultry products, and staple foods (such as rice and other grains and flours). The Chinese government launched a program in the early 2000s, known as *nong gai chao* in Chinese, to convert wet markets into supermarkets in many large cities [15,16]. However, this project failed in many cities including in Nanjing [13] and wet markets remain dominant in fresh food retailing [13,17]. In the city of Dalian, in northeast China, wet markets are the main fresh food source for almost half (49%) of urban households [18]. In Shanghai, they are the source of fresh meat and vegetables for 76% and 59% of households, respectively [19]. Wet markets carry a variety of fresh foods at low cost, providing a price advantage over supermarkets [13].

The study area is Nanjing, the capital city of Jiangsu province located in East China. It has a population of 8.33 million by the end of 2017 [20]. In Nanjing, wet markets have conventionally been the dominant outlet for fresh, unprocessed food. There were 351 wet markets in Nanjing in 2015, equating to about one wet market per 19,100 people on average (excluding rural households) or one

per 23,464 people (including rural households). The overall density of wet markets is one per 2.1 km^2. In contrast, there are 63 chain supermarkets in Nanjing, operated by eight companies. The major chains include two Chinese chains, Suguo (38 supermarkets) and BHG (8), and two foreign-owned chains, Carrefour (5) and Wal-Mart (5). Figure 1 shows the location of wet markets and supermarkets across Nanjing's 11 districts.

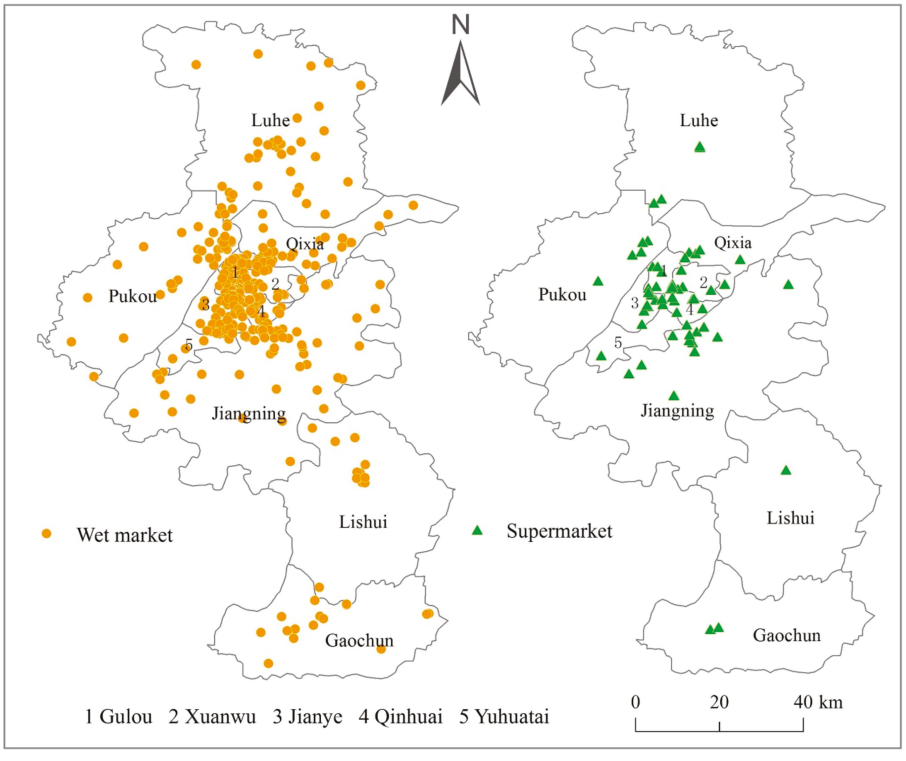

Figure 1. Location of Wet Markets and Supermarkets in Nanjing City. Source: Data from BaiduMap (map.baidu.com).

Nanjing's upgraded wet markets are somewhat different from traditional Chinese wet markets. Traditionally, wet markets were housed in temporary sheds or in the open air. Most wet markets in Nanjing are now housed in permanent buildings and stalls selling meat are usually equipped with refrigeration facilities [13]. Nanjing has had no open air wet market or wet markets in temporary sheds since the end of 2014 [21]. The space of a wet market is usually divided into small stalls which are rented and operated by private individual food vendors.

Wet markets in Nanjing fall under a two-tier management system. The first tier is the Nanjing Municipal Government which owns the city's wet markets and regulates their distribution [22]. The municipal government has supervised the establishment of wet markets to ensure a spatially even distribution by enacting several specific regulations. We elaborate on this policy context in Section 5.1. The second management tier means that wet markets are operated and managed either by state-owned or private companies or offices (hereafter, the management body). The management body is selected by the district-level governments and is responsible for the safety and sanitation of the wet market, stall lease management, facility maintenance and food safety monitoring [22]. The vendors renting the

stalls in wet markets buy food from wholesale markets, distribution centers or other sources and pay a stall rent and fee to the management body.

Supermarkets are another important food source for households in Nanjing. Table 1 shows the distribution of wet markets and supermarkets in each of the 11 districts. It demonstrates that, with only 63 supermarkets selling vegetables and fruit, the number of supermarkets is much smaller than the number of wet markets in every district. Unlike wet markets, there is no statutory requirement for supermarket development by the size of population of an area. The variation of population per wet market across the districts is much smaller than that of supermarket.

Table 1. Wet Markets, Supermarkets and Population in Nanjing.

District	Population	No. of Wet Markets	No. of Super-Markets	Population Per Wet Market	Population Per Supermarket
Xuanwu	652,400	21	6	31,067	108,733
Qinghuai	1,022,400	27	7	37,867	146,057
Jianye	454,500	25	8	18,180	56,813
Gulou	1,275,600	54	6	23,622	212,600
Pukou	749,400	37	6	20,254	124,900
Qixia	679,800	38	7	17,889	97,114
Yuhuatai	426,900	27	3	15,811	142,300
Jiangning	1,191,400	56	14	21,275	85,100
Liuhe	934,400	37	4	25,254	233,600
Lishui	424,400	13	1	32,646	424,400
Gaochun	424,700	16	1	26,544	424,700
Total	8,235,900	278	42	29,626	196,093

Source: Population data from [23].

3. Methodology

3.1. Household Dietary Diversity

The household data used in this paper are extracted from the urban household baseline food security survey in Nanjing conducted in July 2015, and funded by the Hungry City Partnership. The total sample size was 1210 households, randomly selected from 972 urban communities in all 11 districts of Nanjing. The survey was conducted by undergraduate and graduate student enumerators from Nanjing University using digital surveys on android tablets. The data were then uploaded and synthesized on the online Ona database. Household dietary diversity was measured by the Household Dietary Diversity Score (HDDS) [24]. HDDS is a widely used indicator developed by the Food and Nutrition Technical Assistance (FANTA) project [25]. Various studies have proved its relevance and significance in measuring per capita energy consumption. We recognize the critiques on the indicator's accuracy to measure the quality of food access [26], yet it is still a valid indicator to reflect the diversity of household food intake. Food items consumed in the 24 h prior to the survey were grouped into the following 12 food groups: (a) cereals; (b) roots and tubers; (c) vegetables; (d) fruit; (e) meat, poultry and offal; (f) eggs; (g) fish and seafood; (h) pulses, legumes and nuts; (i) milk and milk products; (j) oil and fats; (k) sugar and honey; and (l) other foods. The HDDS is calculated from the number of food groups eaten from and ranges in value from 0 to 12, where the higher the score the greater the diversity in the household diet.

Tables 2 and 3 show the statistical summary of the HDDS in Nanjing and household food consumption by food groups. The dietary diversity of Nanjing households is relatively high with a mean HDDS of 7.83. Some 60% of households scored between 7 and 12 (i.e., eating foodstuffs from between 7 and 12 of the food groups). Over 80% had a score of 6 or more and only 17% had a score of 5 or less. By way of comparison, the mean HDDS of other cities in the Hungry Cities Partnership project was significantly lower (Table 3).

There were notable differences in the frequency of consumption of different food groups (Table 4). Cereals (including wheat, rice and other grains) ranked first with about 98% of households consuming cereals. The vegetable and fruit groups ranked second and third, respectively, with percentages of about 97% and 80%. The roots and tubers group ranked lowest with a proportion of about 34%, slightly lower than fish and seafood at 37%.

Table 2. Frequency Distribution of HDDS in Nanjing.

	No. of Households	%	Cumulative %
1	7	0.6	0.6
2	10	0.8	1.4
3	43	3.6	5.0
4	61	5.0	10.0
5	85	7.0	17.1
6	117	9.7	26.7
7	148	12.3	39.0
8	213	17.6	56.6
9	219	18.1	74.8
10	164	13.6	88.3
11	110	9.1	97.4
12	31	2.6	100.0
Total	1208	100.0	

Table 3. Comparison of HDDS Scores in HCP Cities.

	Household Dietary Diversity Score		
	Mean	% $\leq$ 5	*n*
Nanjing	7.83	17.1	1208
Cape Town	6.75	29.3	2504
Nairobi	6.04	40.9	1414
Mexico City	5.85	49.8	1210
Bangalore	5.37	59.1	1878
Kingston	4.51	70.6	698
Maputo	4.14	76.2	2071
Windhoek	3.21	89.1	855

Table 4. Frequency Distribution of Consumption of Food Groups.

Food Item	No. of Households	% of Households
Cereals	1179	97.6
Vegetables	1171	96.9
Fruits	964	79.8
Meat, poultry, offal	952	78.8
Eggs	949	78.6
Oil and fats	937	77.6
Milk and milk products	791	65.5
Pulses, legumes, nuts	539	44.6
Sugar or honey	477	39.5
Fish and seafood	450	37.3
Root and tubers	406	33.6
Other foods	645	53.4

Wet markets and supermarkets are the two most frequently used food sources in Nanjing [27]. Almost 93% and 87% of households buy food from wet markets and supermarkets, respectively (Table 5). However, there is a notable difference between the purchasing frequencies at wet markets and supermarkets. About 70% of households use wet markets at least five days a week, while the number for supermarkets is only about 17%.

Table 5. Frequency of Patronage of Wet Markets and Supermarkets.

Frequency (at Least)	Supermarkets		Wet Markets	
	No. of Households	%	No. of Households	%
Five days a week	176	16.7	843	75.2
Once a week	673	63.9	248	22.1
Once a month	187	17.8	26	2.3
Once in six months	16	1.5	3	0.3
Once a year	1	0.1	1	0.1
Total	1053	100.0	1121	100.00

3.2. Network Distance to Food Markets

Household locations were collected by the enumerators using android tablets with built-in GPS, with a positioning accuracy of 15 m. The location data of wet markets and supermarkets were calculated from the BaiduMap (map.baidu.com)—the most widely used online map service in China. Other outlets, such as small stores and mobile vendors, were not included in the analysis because of the logistical difficulty of plotting their GPS locations. Because the GPS in tablets is based on the WGS84 coordinate system but the BaiduMap uses the BD09 coordinate system where obfuscation were added based the WGS84 coordinate system [28], the GPS coordinates of the households' location were converted into BD09 coordinates before analysis.

The network distance from households to wet markets and supermarkets was calculated using Route Matrix API v2.0 Beta of BaiduMap which is an API (Application Programming Interface) providing the service for map distance calculation, developed by BaiduMap [29], where the travel distance between origins and destinations are calculated by summing the distance between multiple points based on road network [30]. The Route Matrix API v2.0 Beta provides three transport modes for network distance calculation: walking, by car and by bicycle. This study chose the pedestrian mode because walking and bicycling are the two principal transport modes for food shopping and, of these, walking is the most important. The survey found that about 90% of households bought their primary food within walking distance of their homes more than five times a week. The percentage of respondents who bought fresh vegetable, fruit and pork within walking distance were 93% (N = 988), 92% (N = 974) and 92% (N = 957), respectively. Another survey conducted in Nanjing in 2012 found that 61%, 20% and 17% of elderly Nanjing residents went shopping by walking, bicycle (including electric bicycle), and public transportation, respectively [31]. The figures for young adults were 40%, 37%, and 11% for young adults. We then calculated the walking distance from each household residence to the nearest wet market and the nearest supermarket.

3.3. Dependent and Independent Variables

Table 6 presents the definitions, expected signs, and summary statistics of variables used in this paper. The HDDS was used as the dependent variable. The primary factors seen as potentially influencing household dietary diversity were as follows:

(1) *Proximity:* The distance to the nearest wet market and supermarket were used to reflect the proximity of a household to food stores. They are represented by independent variables *DTWM* and *DTSM*. The variable *DTNM* was generated by taking the minimum value of the variables *DTWM* and *DTSM* for each household, i.e., the distance to the nearest supermarket or wet market. Assuming that there is a negative correlation between physical proximity to food stores and household dietary diversity [1,4], the coefficients for the variables *DTWM*, *DTSM* and *DTNM* are hypothesized as negative.

(2) *Household head:* The demographic characteristics of household heads have been considered possible determinants of household dietary diversity in previous studies [32–34]. The second set of independent variables—*HHA*, *HHE*, *HHM* and *HHG*—therefore represent the age, education level, marital status and gender of the household head, with positive coefficients (Table 6).

(3) *Household size*: A third set of variables relates to household size or *HHS*. The value of *HHS* is the number of household members. A set of dummy variables was used for household size, i.e., *HHS2*, *HHS3*, *HHS4*, *HHS5*, *HHS6*, *HHS7*, *HHS8* and *HHS9*. As larger households tend to consume more diverse food items [35], they are expected to have a higher HDDS. The *HHS* and the eight dummy variables are hypothesized to have positive coefficients.

(4) *Household structure:* Households were categorized into five types in the survey: female-centered, male-centered, nuclear, extended and other. The female-centered household has a female head with no male spouse/partner in the household but may include relatives, children, and friends. Male-centered households have no female spouse/partner. Nuclear households have a husband and wife (male/female partner) with or without children. Extended households refer to those with a male husband/partner and female wife/partner plus children and relatives. In China, the extended household usually includes grandparents, which influences family-based food consumption and could increase food diversity [1]. In the Nanjing survey, nuclear households were most common (57% of households), followed by extended households (29%), female-centered (7%) and male-centered (6%). The variable *SEXC* represents female-centered or male-centered households, and *EXTD* represents extended households. The variable *EXTD* is hypothesized to have positive coefficients.

(5) *Household income*. Data on household monthly income were collected in the household survey and for the purposes of this analysis into income terciles. *HHIM* and *HHIH* represent the middle and high income terciles. As household income is positively correlated with dietary diversity in other studies [1,34], the variables *HHIM* and *HHIH* were projected to have positive coefficients.

(6) *Housing type.* Type of housing is generally considered to be correlated with household food security [36,37]. The variable *HOUSE* was used to reflect the housing type of each household. In the case of Nanjing, the flat or apartment is the dominant housing type, accounting for 82% of all the surveyed households. The traditional dwelling is the second most common housing type, accounting for 13%. House and other types account for 3% and 2%, respectively. The variable *HOUSE* is assumed to have positive coefficients, which is a dummy variable whose value is 1 for those households living in a house or townhouse.

(7) *Urban agriculture*. Some households living on the urban periphery engage in urban agriculture, and about 18% household grow some of their own food. The variable *CROPPING* was used to reflect those households growing food. The variable was hypothesized to have positive coefficients.

3.4. Regression Model

A Poisson model was used in this study to investigate the influence of physical access to food stores on household dietary diversity. The value of the dependent variable *HDDS* varies from 1 to 12, which is a count variable. The value of *HDDS* is assumed to have a Poisson distribution with expectation μ, for independent variables X_i, the Poisson regression model for expected counts can be specified as an exponential function [38]. For the dependent variable *HDDS*, the Poisson regression model is as follows:

$$\mu_i = E(HDDS_i|X_i) = \exp(\beta_0 + \beta_i X_i)$$

where *HDDS* is the HDDS of household i, X_i refers to the vector of independent variables, and β_0 and β_i are the constant and the coefficient vector for independent variables, respectively. The alternative log–linear model can be written as:

$$\ln(\mu_i) = \exp(\beta_0 + \beta_i X_i)$$

Table 6. Dependent and Independent Variables.

Variable	Definition	Expected Sign	Mean	Std. Dev.	Skewness	Kurtosis
HDDS	Dependent variable, Household Dietary Diversity Score with value ranging from 0 to 12		7.83	2.31	−0.50	−0.26
DTWM	Distance to the nearest wet market (100 m)	−	15.16	16.31	2.28	5.51
DTSM	Distance to the nearest supermarket (100 m)	−	40.53	42.16	2.08	4.49
DTNM	Distance to the nearest wet market or supermarket (100 m)	−	13.09	12.86	2.22	6.13
HHE	Household head highest level of education, *HHE* = 1 for no formal schooling, *HHE* = 0 for otherwise	−	0.05	0.21	4.28	16.35
HHM	Household head marital status, *HHM* = 1 for unmarried, 0 for otherwise	−	0.02	0.15	6.48	40.01
HHG	Household head gender, *HHS* = 1 for male, 0 for otherwise	−	0.74	0.44	−1.11	−0.77
HHA	Household head age (year)	−	53.57	15.72	0.01	−0.71
HHS	Household size (person)	+	3.13	1.37	0.57	−0.18
HHS2	Dummy variable for household size, *HHS2* = 1 for 2 persons, 0 for otherwise	+	0.31	0.46	0.80	−1.36
HHS3	Dummy variable for household size, *HHS3* = 1 for 3 persons, 0 for otherwise	+	0.27	0.44	1.02	−0.96
HHS4	Dummy variable for household size, *HHS4* = 1 for 4 persons, 0 for otherwise	+	0.12	0.32	2.35	3.51
HHS5	Dummy variable for household size, *HHS5* = 1 for 5 persons, 0 for otherwise	+	0.18	0.39	1.61	0.59
HHS6	Dummy variable for household size, *HHS6* = 1 for 6 persons, 0 for otherwise	+	0.03	0.17	5.46	27.87
HHS7	Dummy variable for household size, *HHS7* = 1 for 7 persons, 0 for otherwise	+	0.00	0.05	13.72	186.66
HHS8	Dummy variable for household size, *HHS8* = 1 for 8 persons, 0 for otherwise	+	0.00	0.06	12.69	159.28
HHS9	Dummy variable for household size, *HHS9* = 9 for no less than 9 persons, 0 for otherwise	+	0.00	0.03	16.85	282.49
EXTD	Dummy variable for extended family, *EXTD* = 1 for extended family, 0 for otherwise	+	0.27	0.45	1.01	−0.98
SEXC	Dummy variable for male-centred or female-centred family, *SEXC* = 1 for male-centred or female-centred family, 0 for otherwise	−	0.12	0.33	2.27	3.17
HHIM	Dummy variable for net household income Tercile, *HHIM* = 1 for middle income (4501–8200 Yuan monthly), 0 for otherwise	+	0.31	0.46	0.81	−1.34
HHIH	Dummy variable for net household income Tercile, *HHIH* = 1 for high income (more than 8200 Yuan monthly), 0 for otherwise	+	0.33	0.47	0.72	−1.49
HOUSE	Dummy variable for dwelling type, *HOUSE* = 1 for house or town house, 0 for otherwise	+	0.01	0.11	8.53	70.94
CROPPING	Dummy variable for growing food, *CROPPING* = 1 for household growing its own food, 0 for otherwise	+	0.18	0.38	1.70	0.88

Both the variable *HHS* and the dummy variable set including *HHS2–HHS9* are used to reflect the size of a household, in terms of continuous and discrete numbers, respectively. Because of the one-child policy enforced in China between 1979 and 2015, nuclear households generally have a small household size. Thus, it is not reasonable for the model to include both the variable *HHS* and the dummy variable for household size. Households with more than 4 or 5 persons are also usually extended households. The independent variable *HHS* representing household size therefore reflects almost the same information as the dummy variable *EXTD* when the value of variable *HHS* is more than 4 or 5 persons, which makes it inappropriate to include both the variable *HHS* and the dummy variable *EXTD* in the analysis. Therefore, this study considered three different models including different sets of independent variables reflecting household size (variable *HHS* or dummy variables *HHS2–HHS9*) and household type (dummy variable *EXTD*) (see Model I, Model II and Model III in Table 7).

Table 7. Estimated Results of Poisson Model for Household Dietary Diversity.

Variable	Model I	Model II	Model III	Model IV	Model V	Model VI
DTWM	−0.0003	−0.0002	−0.0003			
DTSM	−0.0006 **	−0.0006 **	−0.0006 **			
DTNM				−0.0006	−0.0004	−0.0005
HHE	−0.1936 *	−0.1754 *	−0.1974 *	−0.2004 *	−0.1827 *	−0.2042 *
HHM	−0.2117 **	−0.1446	−0.2161 **	−0.2119 **	−0.1477	−0.2209 **
HHG	−0.0485	−0.0593	−0.0493	−0.0525	−0.0628 ***	−0.0512
HHA	0.0010	0.0011	0.0007	0.0011	0.0012	0.0009
HHS	0.0307 *			0.0306 *		
HHS2		0.1554 **			0.1526**	
HHS3		0.1846 *			0.1788 *	
HHS4		0.1867 *			0.1838 *	
HHS5		0.2683 *			0.2649 *	
HHS6		0.2106 **			0.2074 **	
HHS7		−0.5423			−0.5463	
HHS8		0.1987			0.1934	
HHS9		0.0240			0.0115	
EXTD			0.0825 *			0.0845 *
SEXC			−0.0406			−0.0325
HHIM	0.1235 *	0.1082 *	0.1226 *	0.1300 *	0.1154 *	0.1302 *
HHIH	0.0999 *	0.0895 *	0.1062*	0.1113 *	0.1019 *	0.1184 *
HOUSE	0.1867 ***	0.1870 ***	0.1856 ***	0.1927 **	0.1934 **	0.1911 **
CROPPING	0.0313	0.0240	0.0295	0.0138	0.0061	0.0121
Constant	1.9275 *	1.8514 *	2.0169 *	1.8971 *	1.8237 *	1.9831 *
N	858	858	860	858	858	860
LR chi^2	75.9900 *	87.6000*	76.8700 *	71.4600	82.8800	72.3800
Pseudo R^2	0.0194	0.0224	0.0196	0.0182	0.0211	0.0184
Log likelihood	−1921.5824	−1915.7798	−1925.2048	−1923.8491	−1918.1398	−1927.4492
AIC	3867.1650	3869.5600	3876.4100	3869.6980	3872.2800	3878.8980
BIC	3924.2200	3959.8970	3938.2500	3921.9990	3957.8630	3935.9820

Note: * denotes significant at 1%-level, ** significant at 5%-level, and *** significant at 10%-level.

To investigate the relationship between dietary diversity and proximity to the nearest supermarket or wet market, the variable *DTSM* and *DTWM* in Model I, Model II and Model III were replaced by the variable *DTNM*. As a result, Model IV, Model V and Model VI were generated and calculated, i.e., Model IV was built from the Model I by replacing the variable *DTSM* and *DTWM* with variable *DTNM*, and the same holds for Model V and Model VI. For the estimated results for Model IV, Model V and Model VI, see Table 7.

4. Models of Dietary Diversity

The models with different sets of independent variables are presented in Table 7. The correlation coefficient between the variable *DTWM* and *DTSM* is 0.2038 (significant at 1% level, N = 1180), the collinearity diagnostics results indicated that the issue of multicollinearity can be ignored. To mitigate

or avoid the possible problems due to a relatively large number of dummy variables being used, three groups of models with different number of dummy variables were estimated, and the three groups included Model I and Model IV, Model III and Model VI, and Model II and Model V, respectively. Model III includes those variables reflecting household structure and excluding those reflecting household size. Models I and II include those variables reflecting household size and excludes those reflecting household structure. Model I uses the variable *HHS* to measure household size rather than the set of dummy variables *HHS2–HHS9*, while Model II used the set of dummy variable *HHS2–HHS9* rather than the variable *HHS*. The three models perform satisfactorily in terms of goodness of fit. All six models are significant at the 1%-level. The signs for all the explanatory variables are consistent with expectations.

Table 6 presents the value of AIC and BIC. Smaller AIC and BIC indicate better models [38]. Model I has the smallest values of both AIC and BIC, suggesting that it is statistically superior to the other five models. As there are no major differences in AIC and BIC in the six models, the estimated results of the other five models are also worthy of being analyzed as they include different variables from Model I.

The results of this analysis indicate that physical access to wet markets is not a predictor of household dietary diversity in Nanjing. The signs of the estimated coefficients for the variable *DTWM* are consistent with expectation, but the estimated coefficients are statistically insignificant, which suggests that the distance to the nearest wet market is not a determinant of HDDS. However, the suppression effect caused by a "third variable" ($X2$, suppressor) could render the relationship between independent variable ($X1$) and dependent variable (Y) insignificant [39], smaller, or of opposite sign [40,41]. Households that are farthest from wet markets could have decreased odds of buying food from wet markets but increased probability of buying food from small food stores, so that purchase of food from small food stores could be a suppressor (the "third variable" $X2$). Thus, a new variable *SFSA* was generated, which refers to whether households buy food in small food stores. Following the testing procedure developed by Wen and Ye [42], the possible mediation and suppression effects of the variable *SFSA* were tested. The results indicate that there are no mediation or suppression effects for the variables *DTWM* and *SFSA*. This confirms that distance to wet markets is not a predictor or determinant of urban household dietary diversity in Nanjing.

The estimation results also suggest that physical access to supermarkets has a limited influence on household dietary diversity. The estimated coefficients of the variable *DTSM* of Models I, II and III are all statistically significant at 5% level and the signs of the estimated coefficients are consistent with expectations. However, all the coefficients of the variable *DTSM* in Models I, II and III are quite small (Table 7). The factor by which the expected count changes can be calculated as $\text{Exp}(\beta)$ for a unit change in the explanatory variable, keeping other independent variables constant [43]. According to the estimated coefficients in Models I, II and III, for a unit increase of 100 m in the variable *DTSM* (distance to the nearest supermarket), the expected value of a household's HDDS decreases by a factor of 0.9994 or 0.1 percent, which is a very small magnitude of change. Even for an increase of 10 units (1000 m) in the variable *DTSM*, the expected value of a household's HDDS decreases by a factor of only 0.9934, or less than 1%. The test results also indicate that there is no mediation and suppression effect for the variable *DTSM* and variable *SFSA*. Therefore, the influence of the proximity to a supermarket on HDDS is also nearly negligible, regardless of the statistical significance of the estimated coefficients.

The estimation coefficients for the variable *DTNM* also indicate that proximity to the nearest wet market or supermarket is not a predictor of household dietary diversity. The signs of the estimated coefficients for the variable *DTNM* are consistent with expectations, but the estimated coefficients for the variable *DTNM* of Model IV, Model V and Model VI are statistically insignificant. The test of the mediation and suppression effects indicates that there are no effects for the variable *DTNM* and variable *SFSA* which suggests that physical access to wet markets or supermarkets is not a determinant of household dietary diversity. Thus, information regarding the estimated coefficients of the variable *DTWM*, *DTSM* and *DTNM* indicates that proximity to wet markets and supermarkets is not a predictor

or determinant of urban household dietary diversity. In other words, the difference in the distance to wet markets or supermarkets makes no difference to urban household dietary diversity in Nanjing.

5. Implications for Dietary Diversity

5.1. Wet Market Planning Policies

The insignificant statistical correlation between the distance to the nearest market and household dietary diversity in Nanjing does not necessarily mean that proximity to food outlets is not important for residents' access to diverse food items. It is therefore important to understand the underlying reasons for the insignificant correlation. The most important reason is that the food infrastructure development planning in Nanjing has led to relatively equal and convenient access to wet markets or supermarkets for all households. This relates to the "mayor responsible for vegetable basket" system launched by the Chinese central government in 1988.

The system makes mayors responsible for promoting the production of and securing the supply of non-grain food [44]. The mandatory system has ensured an extensive food supply network in Nanjing, and is the foundation for the high level of physical accessibility to food. Accessibility was further enhanced by the Development Plan for Vegetable Basket Project (2008–2012) issued by the Nanjing Municipal Government in 2008, which specifies that the construction of wet markets should be strengthened [45].

Food infrastructure, and particularly the development of wet markets, has been a requirement for the development of new residential communities in Nanjing since the early 2000s. In 2003, the Nanjing Municipal Government issued regulations on wet market planning and construction, which specified that each newly-developed residential community with a construction area over 50,000 square meters should construct a new wet market with an area no less than 1000 square meters [46,47]. In 2004, the Commodity Network Plan of Nanjing City planned to have a wet market with a service radius of 500–1000 m for every 30,000 residents [48]. In 2011, the Nanjing Municipal Government updated these standards and required a wet market with an area of no less than 2000 square meters and a service radius of 500 m for every 25,000 residents; and a wet market with an area no less than 1500 square meters for each town with a population larger than 20,000 [49]. According to the Plan of Commercial Network in Nanjing (2015–2030) for Public Consultation, more than 200 new wet markets will be established in Nanjing by 2030 [50]. Besides these food infrastructure planning policies, the Nanjing Municipal Government has implemented the policy of "fresh produce zones" in supermarkets. In 2011, Nanjing Municipal Government issued a policy document which required that no less than 20% of existing supermarkets' area and 30% for newly-opened supermarkets should be used for fresh produce retail [49].

The implementation of these policies regarding food market development and planning means that there is relatively easy access to wet markets and supermarkets in Nanjing. About 26%, 56%, 74% and 80% of the interviewed households had a network distance to the nearest wet market or supermarket of less than 0.5 km, 1.0 km, 1.5 km and 2.0 km, respectively (Table 8). Assuming a median walking speed for an adult of 4.5 km/h or 1.25 m/s [51], and a 15-min walk as the commonly accepted walking time in food studies [36,52], then anything up to about 1.1 km is an acceptable walking distance.

About 58% of the surveyed households' walking distance to the nearest wet market or supermarket was less than 1.1 km (Table 8). The average distance to the nearest wet market or supermarket was 1.2 km for those households that reported buying vegetables, fruits and meat from wet markets or supermarkets. Cycling is also a popular transportation mode in Nanjing. An average speed by bicycle of 6.05 km/h [53] would mean about 1.5 km for a 15-min or 2.0 km for a 20-min ride by bicycle. About 74% and 80% of the surveyed households had a cycling distance to the nearest wet market or supermarket of less than 1.5 km and 2.0 km, respectively.

Table 8. Distance from Households to the Nearest Wet Markets or Supermarkets.

Distance Range (m)	% of Households	Distance (m, ≤)	Cumulative Percent (% of Household)
0–500	25.9	500	25.9
501–1000	29.8	1000	55.8
1001–1500	15.5	1500	71.3
1500–2000	8.6	2000	79.8
2001–2500	5.2	2500	85.0
2501–3000	6.1	3000	91.1
>3000	8.9	≤7303	100.0

5.2. Offsetting Effect of Small Food Stores

Another factor that contributes to the high level of physical access to food in Nanjing could be the many small food stores, including small shops and *xiao mai bu* (family run small stores, which are often a window on the wall facing the main street, selling processed food, condiments, cigarettes and other small commercial goods), located within or near residential communities. The survey in 2015 shows that 35% of surveyed households buy food from small food stores and that 26% do so at least five days a week or once a week. Unfortunately, the massive number of small food stores in Nanjing make it nearly impossible to comprehensively geocode them. However, we should not ignore the important role of small food stores in household food accessibility.

There probably has been an offsetting effect of small food stores in ensuring food diversity for households who live relatively far away from wet markets and supermarkets. A study in New Orleans found that other types of stores did offset the relative lack of supermarkets for snack foods but not fresh produce [54]. The offsetting effect could also be true in Nanjing. As small food stores are close to residential communities, they could contribute to household dietary diversity in relatively underserved areas. This is a reasonable conclusion given that individual small food stores provide more than seven of the types of food included in the HDDS indicator. Additionally, the common clustering of small food stores further enhances the diversity of their supply. Unlike small stores in the US where food is more expensive compared to supermarkets and large grocery stores [36], supermarkets in China have no price advantage over wet markets [13]. The primary reason is that the labor cost and food waste of supermarkets is higher than that of wet markets, and, in most cases, wholesale markets are the main supplier for both supermarkets and wet markets, although some supermarkets have their own source of fresh produce or suppliers [13]. As the small shops can also obtain vegetables directly from peri-urban small-scale producers at lower costs than that from wholesale markets, wet markets have no price advantage over small-scale stores [13].

5.3. Local Food Purchasing Behavior

The high level of physical accessibility to food outlets in Nanjing is mirrored in the high proportion of households buying food in their neighborhood or within walking distance. According to the Hungry Cities Food Purchases Matrix used in the survey [55], more than 90% of households said they normally buy most fresh food items within their neighborhoods or within walking distance (Table 9). Specifically, 92–93% of households buy their fresh vegetables, fruit and pork in their neighborhoods or within walking distance. A slightly lower percentage buy fresh animal products in their neighborhoods or within walking distance: 89% for eggs, 88% for fresh shellfish, 86% for fresh lamb and 73% for milk. Table 9 shows that more than 90% of surveyed households bought their main food items in their neighborhoods or within walking distance. In contrast, only 58% of households were within easy walking distance (up to 1.1 km) of their nearest wet market or supermarket. The difference between 90% and 58% is 32%, which is offset by the presence of small food stores. This is further evidence that small-scale food stores contribute to access to food within neighborhoods, in addition to their offsetting effects where households are relatively far away from wet markets and supermarkets.

Table 9. Location of Food Outlets Where Fresh Food Items Normally Purchased.

Item	% Beyond Neighborhood	% within Neighborhood
Fresh/cooked vegetables	7.0	93.0
Fresh pork	7.9	92.1
Fresh fruit	8.2	91.8
Fresh chicken	8.7	91.3
Offal	8.8	91.2
Fresh fish	9.2	90.8
Fresh beef	10.0	90.0
Eggs	11.5	88.5
Fresh shellfish	11.7	88.3
Fresh lamb	14.1	85.9
Milk	26.8	73.2

Note: "Within" refers to within walking distance, "beyond" refers to beyond walking distance.

5.4. Household Demographic Factors and Dietary Diversity

This study also examined the impacts of other factors (including household size, structure and income) on dietary diversity. The estimation results indicate that, unlike distances to food outlets, household size, structure, and income all significantly influence household dietary diversity (Table 7). Those coefficients of variables in Model I and V are statistically significant and consistent with expectations, including the variables *HHS*, *HHS2–HHS6*, *EXTD*, *HHIM* and *HHIH*. The coefficients for the variable *HHS* in Models I and V were 0.0307 and 0.0306, respectively. For an increase in household size by one, a household's mean HDDS increases by a factor of 1.03% or by 3.10%. This is also a small change considering that the mean HDDS is 7.83. The coefficients for variables *HHS2*, *HHS3*, *HHS4*, *HHS5* and *HHS6* are statistically significant in Models I and V. There are similar coefficient values for variables *HHS2*, *HHS3*, *HHS4*, *HHS5* and *HHS6* in Models I and V. The coefficients for variable *HHS7*, *HHS8* and *HHS9* are not statistically significant in both models. This indicates that those households with 2–6 members have a higher HDDS than one-person households. Compared with the reference category of households with one person, multi-person households have an expected HDDS value increase of 17% (2 persons), 20% (3), 21% (4), 31% (5) and 23% (6) (based on the estimated coefficients in Model I). The variable *HHS5* has the highest coefficient among variables *HHS2–HHS6*. Due to the one-child policy, a five-person household usually means a household with one child, parents and grandparents (which is also categorized as an extended household). The coefficients for the variable *EXTD* were 0.0825 and 0.0845 in Model III and Model VI, respectively. Being an extended household increases the value of HDDS by about 9% (8.6% and 8.8% for Model III and Model VI, respectively). This indicates that household size and household structure have a moderate impact on household dietary diversity.

Extended households are relatively common in Nanjing, making up just over one quarter of all the surveyed households (households were sampled in the daytime when it was more likely that retired people were home, but employed people were not). The relatively high percentage of extended households diminishes the sensitivity of household dietary diversity to physical access to wet markets and supermarkets. Another study has indicated that household structure plays an important role in Chinese family-based food consumption [35]. Dual-career families (where both husband and wife work) are common in China. This means that it is the grandparents in extended households who buy the food and do most of the cooking and other domestic work [35]. In addition to extended households with three generations living in one dwelling, it is also common for grandparents to live in different dwellings within a short distance from the household of their adult children and grandchild and are commonly involved in the food purchasing and preparation for their children's household [35]. As retired grandparents in extended households have more flexibility in terms of time and food purchase location, they are less sensitive to the shopping distance than young family members who devote most of their time to work. As a result, support from grandparents could make

the HDDS of extended households and some nuclear households less sensitive to the distance to wet markets and supermarkets than households without the support of grandparents.

The estimation results also suggest that some characteristics of household heads are predictors of household dietary diversity. The coefficients for the variable *HHE* and *HHM* are significantly negative. Being a household with an unmarried household head decreases the expected HDDS by 18%, compared with other households. Being a household with a household head without formal schooling decreases the expected HDDS by 19%, compared to a household with a household head with formal schooling (calculated based on the estimated Model I). However, the coefficients for the variable *HHA* (household head age) are not statistically significant, and neither are the coefficients for the variable *HHG* (household head gender) except in Model V. This is consistent with previous studies about household dietary diversity in China [1].

5.5. Household Income and Dietary Diversity

The significant positive coefficients for the variables reflecting household income and housing type (*HHIM*, *HHIH* and *HOUSE*) indicate that income is an important determinant of urban household dietary diversity. An increase in household income contributes to an increase in dietary diversity. Middle- and high-income households have a higher HDDS than low-income households. Being a middle-income household increases the expected HDDS by about 13% compared to a low-income household (mean of 13.1%, 11.4%, 13%, 13.9%, 12.2% and 13.9% for Model I, Model II, Model III, Model IV, Model V and Model VI, respectively). Being a high-income household increases the value of HDDS by about 11%.

In Nanjing, three-quarters of households live in apartments, with only a small proportion (2.4%) of wealthier households living in houses. The significant positive coefficients of the variable *HOUSE* suggest that households living in houses have higher dietary diversity. This is reflected in the 21% increase of HDDS of households living in houses, compared to low-income households. Other studies indicate that an increase in household income increases a household's economic access to food [56].

Increased income could contribute to dietary diversity by improving a household's transport facilities and food-preserving facilities. Electric bicycles, for example, are a faster and more expensive vehicle than traditional bicycles (priced about 10 times higher). The speed limit of an electric bicycle is 20 km/h, which means that the travel distance of ten minutes by electric bicycle is about 3 km. Our spatial analysis found that more than 90% of households had a network distance to the nearest wet market or supermarket of less than 3 km. The high-level of food accessibility is further enhanced by the increasing popularity of private cars in Nanjing. On average, there were 59.7 electric bicycles and 40.4 private cars per 100 urban households in 2015 [23]. In 2012, 10% of young adults and 1% of the elderly in Nanjing shopped for food by car [31]. The prevalence of refrigerators may also contribute to dietary diversity. In 2016, there were 102.4 and 109.5 refrigerators per 100 urban and rural households, respectively [23].

5.6. Urban Agriculture and Dietary Diversity

Although the estimated coefficients for the variable *CROPPING* are positive and the signs are consistent with expectation, the coefficients are statistically insignificant. This indicates that whether households grow their own food or not does not significantly influence dietary diversity. This is simply because urban farming in Nanjing has very limited access to land and thus is unable to produce a significant quantity of food. Moreover, even in the peri-urban or rural areas, the variety of produce is constrained by the size of farms and seasonality, which does not contribute to household dietary diversity.

6. Conclusions

This paper shows that, in contrast to studies in other contexts where proximity to food stores is one of the determinants of household dietary diversity [1,57], the distance from the household home

to the nearest wet market or supermarket has no significant impact on household dietary diversity in Nanjing. The coefficients for the distance to the nearest wet market are not statistically significant. The coefficients for distance to the nearest supermarket are of statistical significance but no economic significance or practical significance, as the very small coefficients indicate that distance to the nearest supermarket has no noticeable impact on household dietary diversity. However, these results do not necessarily indicate that the distance to food outlets is not important for household dietary diversity in other contexts. Indeed, the high level of food accessibility, thanks to the spatially dense food supply network in Nanjing, diminishes the correlation between distance and dietary diversity. Small food stores, together with wet markets and supermarkets, have created a favorable food environment in terms of physical access to food, which in turn leads to a non-significant relationship between the proximity to wet markets or supermarkets and household dietary diversity. The spatial distribution of wet markets, supermarkets and small-scale food stores constitute a favorable food environment in term of geographic access to food, which results in a relatively equal geographical access to food outlets. Such access decouples any linkage between the proximity to wet markets or supermarkets and household dietary diversity.

The study also found that various factors contribute to the non-significant influence of distance to the nearest wet market and supermarket. These include relatively high accessibility to food outlets, the prevalence of three-generation extended household structure, and household income. Extended households with three generations are less sensitive to the distance to wet markets and supermarkets because the grandparents who conduct most food purchasing and cooking in the households are more flexible in terms of time and food purchase location. In addition, higher household income and better transport and the popularity of refrigerators all contribute to the insignificance of the proximity to wet markets or supermarkets in determining urban household dietary diversity.

The implications of this study for food system planning in terms of urban land use governance are twofold. First, it is important to achieve high access to food by allowing and encouraging mixed land use for food outlets within or close to residential communities. Most wet markets and supermarkets in Nanjing are located close to residential communities, and small food stores are even located within residential communities. The policies that encourage mixed land use for food outlets have greatly enhanced residents' physical accessibility to food outlets. This is not only the situation in Nanjing but also common in other Chinese cities. Second, it is important to include wet markets in urban infrastructure planning systems, and making the construction of wet markets a requirement for the development plan of new residential areas can be an effective tool to improve and secure physical access to food outlets.

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Urban Food Sources and the Challenges of Food Availability According to the Brazilian Dietary Guidelines Recommendations

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Abstract: The study investigated availability and food sources in urban areas using elements of the NOVA food classification system, adopted by the Brazilian Dietary Guidelines, in a Brazilian municipality. In addition, the study also aimed to identify inequalities in the geographical distribution of food retailers that commercialize healthy and/or unhealthy foods. This cross-sectional study was performed in the municipality of Jundiai in the State of São Paulo, Brazil. Data from within-store audit and geographic data were used to characterizing the nutrition community environment. The mean was calculated for food items available in each of the four NOVA groups for each audited food retailer. The mean of food items available in each of the four NOVA groups for each audited food retail were calculated. The density and proportion of different types of food retailers were georeferenced. The supermarkets, medium market stores, and grocery stores presented the highest availability of unprocessed foods as well as ultra-processed foods. Establishments that sold primarily unprocessed foods and included a fruits and vegetables section at the entrance of the store had a greater availability of healthy foods, but their density in the territory was low compared to establishments that prioritized the sale of ultra-processed foods and sold ultra-processed foods in the checkout area. Especially in middle- and low-income areas, the concentration of food retailers with priority sale of ultra-processed products is reaches 22 times higher than the sale of unprocessed or minimally processed foods. The study supported the identification of regions where it was necessary to improve access to equipment that marketed unprocessed foods as a priority.

Keywords: food sources; food security; food deserts; urban food system; NOVA food classification system

1. Introduction

Evidence indicates that food environment influences food accessibility [1–3], diet quality [4–6], and even the occurrence of obesity [7–11]. Factors in the community food environment linked to healthy food consumption include the presence of food stores and access to them, the types of food retailers in the territory [4,12,13], availability (quality of food stores) [14], accessibility (hours of operation), affordability of healthy foods [15,16], product placement, and food advertising [17–19].

The growing literature on the associations between food environment and obesity has been constantly explored in the context of "food deserts", a term which has been used, more specifically, to refer to areas with low access to adequate food at affordable prices, which can contribute to social disparities in the diet and have a negative impact on the health of the population [2]. The relation with obesity has been greatly investigated, since food deserts are environments that, paradoxically,

may encourage excessive caloric consumption [2]. Another important concept that has emerged in food-environment studies is the "food swamp", which involves relative amounts of different types of foods (e.g., an assessment of energy-dense foods swamping out healthier options) and/or retail establishments [20].

In the food environment, most specifically in the community nutrition environment, it is possible to identify several types of food retailers such as supermarkets, wholesalers, grocery stores, convenience stores, confectioners, coffee shops, bars, restaurants, bakeries, among others [21]. These food retailers play a key role in the food choices and health of individuals, since they can offer healthy food varieties as well as ultra-processed foods [4,8,12,19]. The lack of food retailers near households and workplaces and the availability of unhealthy foods in these places can hinder access to a balanced diet [5,22–24]. A previous study conducted in the city of Jundiai, São Paulo, using secondary data showed higher concentrations of small markets in relation to supermarkets in lower-income neighborhoods. In addition, food retailers that sold fresh and unprocessed foods, such as farmers' markets and butchers, were more present in the central areas of the city [25].

Both the access to various food retail services and the types of food they sell can become significant environmental barriers for vulnerable populations to achieving food security [1]. The high prevalence of obesity among low-income populations has been related to the restricted access of these populations to healthy foods, as well as to the increasing density of fast-food and convenience stores in the food environment where they live [1,8,10,11].

The greater supply of unprocessed foods (i.e., fruits, vegetables, cereals, fresh meat, eggs, milk) in food retail environments such as supermarkets and farmers' markets has a significant influence on food consumption, especially among low-income people [4,6]. In Brazil, a study conducted by Duran et al. [4] showed that living in the vicinity of supermarkets, grocery stores, and farmers' markets that commercialize fresh and unprocessed foods led to their consumption. On the other hand, the same study showed that living near food retailers that had a greater variety of sugary drinks and ultra-processed foods also increased the prevalence of their consumption.

Knowing the role played by the food environment, especially the community food environment, in the access to a healthier diet, and the fact that areas known as food deserts put food security at risk, thereby contributing to the increased obesity in the surrounding populations, the main goal of this study was to investigate availability and food sources in urban areas using the elements of the NOVA food classification system, adopted by the Brazilian Dietary Guidelines (BDG), in a Brazilian municipality. In addition, the study also aimed to identify inequalities in the geographical distribution of food retailers that commercialize healthy and/or unhealthy foods.

2. Materials and Methods

This cross-sectional study was performed in the municipality of Jundiai in the State of São Paulo, Brazil. According to the Brazilian Institute of Geography and Statistics (IBGE), the municipality has approximately 414,810 inhabitants (in 2018) with a Human Development Index (HDI) of 0.82, total area of 431,207 km [2], 686 census tracts (urban and rural), and its territory is divided into 74 neighborhoods according to the municipality's master plan. The average per capita income of the municipality in the rural area is R$643 and in the urban area is R$925. The city of Jundiai has 95.7% of its population residing in urban areas. This study is part of the research project "Interventions in the food retail environment: Overcoming the information obstacle for the promotion of adequate and healthy food habits in a municipality of the State of São Paulo", approved by the Ethics Committee of the Faculty of Public Health—protocol number 69045917.5.0000.5421.

To investigate the consumer nutrition environment and the community nutrition environment, an audit was carried out in the urban area of the municipality. Data collection began in December 2017 and ended in April 2018, totaling 573 of the 683 census tracts in the municipality, ensuring variability in audited aspects. A total of 650 food retailers were audited. In this process, a tool called "NOVA-based Audit of the Food Environment (AUDIT-NOVA)" was applied. Researchers were

trained according to the protocol developed specifically for this research, containing information on approach, form fill, product specifications, and detailed explanations for each item to be audited in the food retail trade. This reliability and validation instrument measures aspects concerning food retailer types, availability, prices, food advertising, and number of food brands. The indicators present in the AUDIT-NOVA were based on the food classification proposed by Monteiro et al. [26] and called "NOVA", which classifies food into four groups according to the extent and purpose of its processing: 1. Unprocessed or minimally processed foods (i.e., fresh fruits and vegetables, meat, cereals, beans, fish, eggs, milk), 2. Processed culinary ingredients (i.e., salt, sugar, oil, butter, olive oil, animal fat), 3. Processed foods (i.e., canned vegetables and fruits, canned fish, dried meat, cheese, French bread), and 4. Ultra-processed foods (i.e., soft drinks, sweetened beverages, snacks, cookies, chocolates, sweets, instant noodles, breakfast cereals, milk drinks, and others).

All the establishments where the population could purchase food were audited. The identified commercial establishments were grouped into 13 major categories of retail establishments, as proposed by Costa et al. [13]: 1. Butchers and fish markets, 2. Central markets of fruits and vegetables, 3. Municipal markets of fruits and vegetables, 4. Private markets of fruits and vegetables, 5. Grocery stores, 6. Medium market stores (e.g., Carrefour Express, Dia Express), 7. Supermarkets/hypermarkets/wholesalers, 8. Bakeries, 9. Candy stores, 10. Convenience stores, 11.'Non-alcoholic beverage stores, 12. Pharmacies, food supplement stores, and 13. Others (pasta houses, cheese bread houses, houseware stores, cheese shops).

The AUDIT-NOVA contains a total of 66 foods and, in this study, these foods were categorized into four groups: 1. Unprocessed or minimally processed foods (orange, banana, papaya, apple, watermelon, tomato, onion, lettuce, carrot, zucchini, chayote, parsley and green onion, potato, cassava, corncob, eggs, prime beef, other beef, chicken, chicken breast, fish, cow's milk, beans, black beans, white rice, wheat flour, cassava flour, pasta, raw peanuts, water 500 mL, water 5 L), 2. Processed culinary ingredients (butter, soybean oil, olive oil, salt, refined sugar, granulated sugar), 3. Processed foods (dried meat, cheese, canned corn, tomato extract, canned sardines), and 4. Ultra-processed foods (dairy drink, noodles, seasoning, white bread, cornflakes, pizza, ice cream, soda can, soda 2 L, light or diet soda, juices with added sugar, powdered beverage, corn snacks, chocolate cookies, candies, hot dog, sausage, bacon). The mean was calculated for food items available in each of the four NOVA groups for each audited food retailer, allowing the researchers to estimate the mean availability of unprocessed or minimally processed foods, processed culinary ingredients, processed foods, and ultra-processed foods.

The instrument also measures aspects of food availability according to NOVA, using indicators such as: availability of ultra-processed foods on checkout (yes or no); availability of fruits and vegetables at the entrance (yes or no); and whether the establishment commercializes mainly unprocessed or minimally processed foods (yes or no), processed culinary ingredients (yes or no), processed foods (yes or no), and ultra-processed foods (yes or no). Both "commercializes mainly unprocessed or minimally processed foods" and "commercializes mainly ultra-processed foods" were used in order to classify the establishments into healthy or unhealthy, respectively. Furthermore, availability of fruits and vegetables at the entrance (yes or no) and availability of ultra-processed foods on checkout (yes or no) were used as indicators of healthy and unhealthy food retailers, respectively.

This study combined the food environment audit data (carried out in commercial establishments) and the geographical measures. It was possible to identify the geographical coordinates of 643 of the 650 commercial establishments audited, with a loss of 1.08% of the sample. The geographical coordinates of longitude and latitude for each retail establishment were obtained using the Google Earth® computerized system. A geographic information system, ArcGIS 10.0 (Esri, CA, USA), and a digital cartographic base of the census tracts were used to geocode and determine the spatial location of stores. To calculate the density of healthy and unhealthy food retailer indicators among the inhabitants, it was considered that the resident population was living in households in the census tracts, available at the Demographic Census of IBGE (2010) [2]. In addition, the proportion of food retail trades with priority availability of ultra-processed foods was calculated based on the availability of unprocessed or

minimally processed foods. Both the density of healthy and unhealthy food retailer and proportions were mapped together with the mean per capita income of each census tract. This mapping made it possible to verify social inequalities in the distribution of food retail trades around the municipality. To draw thematic maps, the technique of choroplethic representation was used.

To analyze the difference in mean food availability among the 13 types of retailers, Pearson's chi-square statistical tests were performed, due to the qualitative nature of the variable. To evaluate differences in the mean availability of unprocessed or minimally processed foods, culinary ingredients, processed foods, and ultra-processed foods according to the four indicators of healthy and unhealthy food retailers, mean comparison tests were used, because of the quantitative nature of the variable. Values of $p < 0.05$ were considered statistically significant. The analyses were performed using the Stata 14 statistical program (Timberlake Analytics Software, TX, USA).

3. Results

In the process of auditing the food environment, it was possible to identify and geocode 643 food retail establishments used by the population to purchase food and then prepare it at home. The total amount of audited retailers was distributed as follows: 25.2% ($n = 164$) grocery stores, 18.0% ($n = 116$) pharmacies, food supplement stores, 14.3% ($n = 92$) bakeries, 11.0% ($n = 71$) candy stores, 7.6% ($n = 49$) convenience stores, 5.9% ($n = 38$) butchers and fish markets, 3.9% ($n = 25$) non-alcoholic beverage stores, 3.6% ($n = 23$) private markets of fruits and vegetables, 3.2% ($n = 21$) other food retailers, 2.9% ($n = 18$) supermarkets/hypermarkets/wholesalers, 2.0% ($n = 13$) central markets of fruits and vegetables, 1.8% ($n = 12$) medium market stores (i.e., Carrefour Express, Dia Express) and 0.3% ($n = 2$) municipal markets of fruits and vegetables.

Table 1 shows the mean availability distribution of unprocessed foods, ingredients, processed foods, and ultra-processed foods according to retail types. Compared to other establishments, a higher availability of unprocessed foods was found in the supermarkets/hypermarkets/wholesalers, medium market stores (e.g., Carrefour Express, Dia Express), grocery stores, private markets of fruits and vegetables, central markets of fruits and vegetables, butchers and fish markets and municipal markets of fruits and vegetables ($p < 0.05$). As for the availability of culinary ingredients and processed foods, it was higher in medium market stores (e.g., Carrefour Express, Dia Express) and supermarkets/hypermarkets/wholesalers ($p < 0.05$). Finally, the availability of ultra-processed foods was higher in medium market stores (e.g., Carrefour Express, Dia Express), supermarkets/hypermarkets/wholesalers, grocery stores, bakeries, and convenience stores ($p < 0.05$).

The 643 commercial establishments were also grouped into four major categories according to the characteristics of the commercialized foods and indicators of healthy and unhealthy retailers in food environment. Unprocessed foods available in larger quantities than other food groups (Yes = 99 (15.4%)), ultra-processed foods available in larger quantities than other food groups (Yes = 560 (87.1%)), fresh fruits and vegetables located at the entrance of the store (Yes = 107 (16.6%)), and ultra-processed foods available in checkout areas (Yes = 568 (88.3%)). The number of retailers that prioritize the sale of ultra-processed foods is 5.6 times the number of retailers that primarily sell unprocessed foods.

Table 2 shows the distribution of the availability of unprocessed foods, ingredients, processed foods, and ultra-processed foods according to these four groups. It is possible to observe that the mean availability of unprocessed foods is higher in establishments that have unprocessed foods available in larger quantities than other food groups ($p < 0.05$), in the ones with a Fresh fruits and vegetables section near the entrance of the store ($p < 0.001$), but also in commercial establishments that have ultra-processed foods available in checkout areas. The highest mean availability of culinary ingredients and processed foods was found in establishments with a section of Fresh fruits and vegetables located near the entrance of the store ($p < 0.001$). Ultra-processed foods were available in all four groups; however, the highest availability of these foods was observed in establishments with a Fresh fruits and vegetables section ($p < 0.001$) and in establishments with the presence of ultra-processed foods available in checkout areas ($p < 0.001$).

Table 1. Availability (mean and confidence interval) of unprocessed foods, culinary ingredients, processed foods, and ultra-processed foods according to types of food retailers. Jundiai-BRAZIL. 2017–2018.

Audited Food Retailers	Availability of Unprocessed or Minimally Processed Foods		Availability of Culinary Ingredients		Availability of Processed Foods		Availability of Ultra-Processed Foods	
	Mean (CI)	*p* *	Mean (CI)	*p* *	Mean (CI)	*p* *	Mean (CI)	*p* *
Butchers and fish markets	8.2 (6.3–10.1)	0.000	1.5 (1.0–2.0)	0.000	2.5 (1.9–3.0)	0.000	6.4 (5.0–7.8)	0.000
Central markets of fruits and vegetables	14.7 (11.9–17.5)		0.8 (0.0–1.5)		0.8 (–0.0–1.6)		1.8 (–0.5–4.1)	
Municipal markets of fruits and vegetables	5.5 (4.5–6.5)		0		0		0	
Private markets of fruits and vegetables	18.7 (15.4–22.0)		2.3 (1.5–3.1)		2.3 (1.3–3.3)		7.3 (4.6–10.0)	
Grocery stores	19.2 (17.8–20.6)		3.8 (3.6–4.0)		4.9 (4.6–5.2)		13.3 (12.7–14.0)	
Medium market stores (e.g., Carrefour Express, Dia Express)	27.7 (22.4–33.0)		5.4 (4.4–6.4)		6.2 (5.1–7.4)		16.8 (14.9–18.8)	
Supermarkets/hypermarkets/wholesalers	28.9 (24.5–33.3)		5.2 (4.3–6.0)		5.7 (4.8–6.7)		16.8 (15.4–18.1)	
Bakeries	4.7 (3.9–5.5)		2.2 (0.1–0.4)		3.1 (2.9–3.4)		9.6 (9.0–10.2)	
Candy stores	0.9 (0.7–1.2)		0.2 (0.1–0.4)		0.1 (0.0–0.3)		3.9 (3.0–4.7)	
Convenience stores	2.0 (1.6–2.4)		1.1 (0.7–1.4)		1.1 (0.7–1.4)		8.6 (7.8–9.4)	
Non-alcoholic beverage stores	1.7 (1.3–2.1)		0.3 (0.0–0.6)		0.1 (0.0–0.3)		3.6 (2.7–4.6)	
Pharmacies, food supplement stores	0.6 (0.5–0.7)		0.0 (0.0–0.2)		0		1.9 (1.6–2.3)	
Others	2.0 (1.3–2.7)		0.6 (0.1–1.0)		0.7 (0.2–1.1)		6.2 (5.0–7.5)	

* Pearson's chi-square, CI: confidence interval. Mean: mean of food items available.

Table 2. Availability (mean and confidence interval) of unprocessed foods, culinary ingredients, processed foods, and ultra-processed foods according to healthy and unhealthy food retail. Jundiai-BRAZIL. 2017–2018.

Healthy and Unhealthy Food Retail	Availability of Unprocessed or Minimally Processed Foods		Availability of Culinary Ingredients		Availability of Processed Foods		Availability of Ultra-Processed Foods	
	Mean (CI)	*p* *	Mean (CI)	*p* *	Mean (CI)	*p* *	Mean (CI)	*p* *
Unprocessed foods or minimally processed foods available in larger quantities than other food groups								
Yes	11.0 (9.2–12.7)	0.02	1.5 (1.1–1.8)	0.03	1.9 (1.4–2.3)	0.04	5.1 (4.2–6.2)	0.0000
No	8.5 (7.5–9.4)		1.9 (1.8–2.1)		2.4 (2.2–2.6)		8.5 (8.0–9.0)	
Ultra-processed foods available in larger quantities than other food groups								
Yes	9.1 (8.2–9.7)	0.18	2.0 (1.8–2.2)	0.0000	2.5 (2.3–2.7)	0.0000	8.7 (8.2–9.1)	0.0000
No	7.4 (5.8–9.0)		0.8 (0.5–1.2)		1.2 (0.9–1.6)		3.4 (2.5–4.4)	
Fresh fruits and vegetables located near the entrance of the store								
Yes	20.3 (8.0–9.7)	0.0000	3.2 (2.8–3.6)	0.0000	4.0 (3.6–4.5)	0.000	11.2 (10.1–12.4)	0.0000
No	6.6 (5.8–7.4)		1.6 (1.4–1.8)		2.0 (1.8–2.2)		7.3 (6.9–7.8)	
Ultra-processed foods available in checkout areas								
Yes	9.4 (8.5–10.3)	0.0002	2.1 (1.9–2.2)	0.0000	2.6 (2.3–2.8)	0.0000	8.8 (8.3–9.3)	0.0000
No	4.6 (3.3–5.9)		0.4 (0.2–0.6)		0.6 (0.3–0.8)		1.9 (1.2–2.6)	

* *t* tests (mean comparison tests), CI: confidence interval. Mean: mean of food items available.

Figure 1 shows the density of the four groups of commercial establishments classified according to the healthy and unhealthy food environment indicator in the municipality. In relation to unhealthy food environment indicators, which are ultra-processed foods available in larger quantities than other food groups and ultra-processed foods available in checkout areas, it was found that most areas have concentrations ranging from 3 to more than 40 establishments per 1000 inhabitants, that is, they are spread throughout the territory, especially among areas with middle and low per capita income. When analyzing the indicators of a healthy food environment such as unprocessed foods available in larger quantities than other food groups and fresh fruits and vegetables located near the entrance of the store, a smaller density of these establishments was observed in the municipality, showing mostly areas with a density lower than 3/1000 inhabitants. In areas of middle and low per capita income, it was possible to verify some areas with zero density of food retail trades that had unprocessed or minimally processed foods available in larger quantities than other food groups.

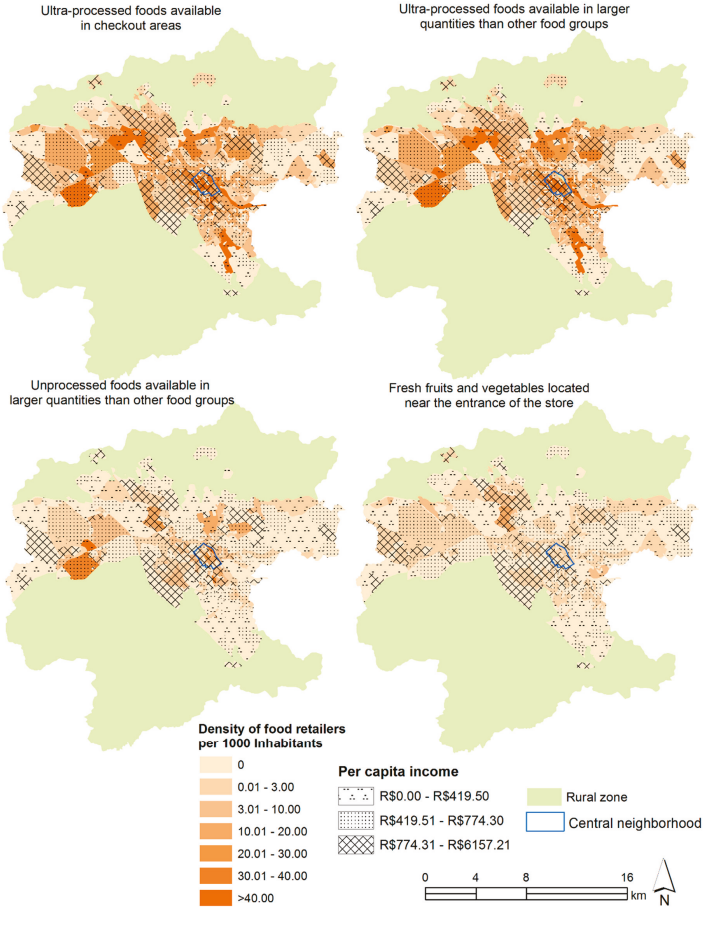

Figure 1. Density of healthy and unhealthy food retailers and per capita income in the municipality of Jundiai-BRAZIL. 2017–2018.

Figure 2 shows the proportion of food retail trades with priority availability of ultra-processed foods in relation to unprocessed and minimally processed foods. The highest proportions of food retail with priority availability of ultra-processed foods in relation to unprocessed or minimally processed

foods are in low- and middle-income regions. In these areas, the concentration of food retailers with priority sale of ultra-processed products reaches 22 times higher than the sale of unprocessed or minimally processed products.

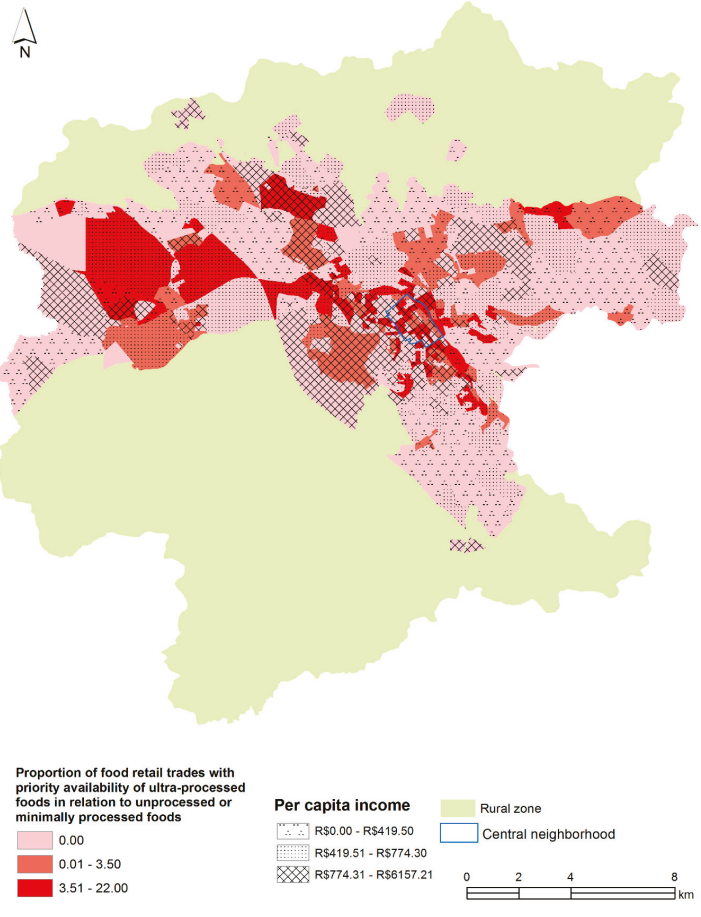

Figure 2. Proportion of food retail trades with priority availability of ultra-processed foods in relation to unprocessed or minimally processed foods and per capita income in the municipality of Jundiai-BRAZIL. 2017–2018.

4. Discussion

This study used cross-sectional data from an audit conducted in retail stores in the urban areas of a Brazilian municipality as well as geographic data in order to analyze food availability and spatial distribution of indicators of healthy and unhealthy food retailers in the municipality. Retail stores of the supermarkets/hypermarkets/wholesalers type, medium market stores (e.g., Carrefour Express, Dia Express), and grocery stores presented the highest availability of unprocessed foods as well as ultra-processed foods. When analyzing the distribution of healthy and unhealthy food environment indicators in the municipality according to socioeconomic indicators, establishments that sold primarily unprocessed foods and included a fruits and vegetables section near the entrance of the store had a greater availability of unprocessed foods, but their density in the territory was low, especially among

middle- and low-income areas, when compared to establishments that prioritized the availability of ultra-processed foods.

The high proportion of food retail trades with priority availability of ultra-processed foods in relation to unprocessed and minimally processed foods, especially in middle- and low-income areas in the municipality, revealed areas of food deserts and food swamps [2] since access to healthy food was difficult. These areas may compromise the food security of the local population [23]. In addition, there is a potential in these areas for the population to consume larger quantities of ultra-processed foods and for a higher prevalence of obesity [2,5,11]. In Mexico, a study showed that excessive access and exposure to unhealthy foods and drinks, or "food swamps," may be of greater concern than food deserts in developing an obesity-prevention policy [22].

The retailers most frequently found in the municipality were grocery stores, pharmacies, food supplement stores, and bakeries which together added up 57% of the audited retail trades. In this study, grocery stores displayed, at the same time, a high availability of unprocessed foods and a high availability of ultra-processed foods. In medium-sized municipalities such as Jundiai, bakeries are like mini-markets where locals often get some food products in addition to traditional baked goods. However, in general, these places sell mostly ultra-processed products, as seen in this study. The habit of buying food in places where there is a greater commercialization of ultra-processed foods favors their consumption and has a negative impact on nutrition [4]. A study using national and local data across the United States suggests that residents having low income, belonging to a minority, or living in rural neighborhoods are most often affected by poor access to supermarkets and healthy foods [3]. In this context, our study corroborates with these findings because it found a lower density of food retailers that sold healthy foods especially in low income neighborhoods.

In this study, a low proportion of trades was observed that sold primarily unprocessed or minimally processed foods in relation to ultra-processed foods, especially in middle- and low-income neighborhoods. The availability of healthy foods in a neighborhood has been associated with a higher consumption mainly of fruits and vegetables, which are unprocessed foods [6,27]. In Brazil, a study by Duran et al. [4] showed that the greater availability of fruits and vegetables in a neighborhood is associated with the regular consumption of these foods and, at the same time, living in places with few supermarkets and fresh-product markets reduces the consumption of these foods, mainly among the poorest inhabitants. In medium-sized municipalities like Jundiai, grocery stores are closer to individuals and facilitate the access to food, especially among people living in more peripheral neighborhoods [28,29]. Costa et al. [13] highlighted the role of small food retailers because of their wide variety of foodstuffs and geographical proximity to consumers, promoting a higher frequency of food purchases. However, these small supermarkets still need to improve the quality of the products they offer and the appearance of the stores, factors that can both potentially impact the food purchase decisions of low-income residents in particular [29].

The Brazilian Dietary Guidelines state the following golden rule: "always prefer unprocessed or minimally processed foods and freshly made dishes and meals to ultra-processed foods" [30]. In this case, in order for the population to respect this golden rule, food retailers must supply healthy foods. When verifying municipality areas having middle- and low-income populations with a high proportion of establishments that sold primarily ultra-processed food and at the same time with a low density of food retailers with availability of unprocessed food, we also verified the presence of the "supply" obstacle. According to the Brazilian Dietary Guidelines, the population should do the following to overcome this obstacle: "Shop mindfully. Avoid places that sell or serve mainly or only ultra-processed products. In supermarkets take and use a shopping list. Support farmers' markets, municipal markets, specialist retailers, and other places that sell varieties of natural and minimally processed foods, and prefer food produced by ecological methods" [30]. According to the findings of this study, the population in Jundiai-SP could have difficulties in overcoming the obstacle supply, especially middle- and low-income populations.

When we analyzed the commercial establishments according to two indicators, namely, a large presence of unprocessed food and the presence of a fruits and vegetables section near the entrance of the store, we noticed that they were establishments with the highest mean values of unprocessed food availability in relation to those without these indicators. However, the density of establishments which prioritized unprocessed food sales and had a fruits and vegetables section near the entrance of the store were low compared to establishments that prioritized the sale of ultra-processed foods and sold ultra-processed foods in the checkout area. The inequality in the distribution of food retailers in the municipality could lead to the difficulty of access to healthier foods by the population. In another study carried out in the same municipality by our research group, but using secondary data, a lower density of retail trades was observed that sold fresh and unprocessed foods especially in peripheral neighborhoods [25]. In both studies, we identified that the population living in this municipality could face obstacles to achieving a healthy diet and following the recommendations of the Brazilian Dietary Guidelines [30].

Analyzing the geographic information, it is possible to say that some areas of the municipality are considered food swamps, or areas that have adequate access to healthy foods but are flooded with opportunities to consume calorie-dense foods and drinks [20]. The high density of establishments with the presence of ultra-processed foods in the checkout areas is worrying, because these types of foods, which are high in fat and sugar and poor in nutrients, and when they are present in these areas, stimulate impulse purchases and favor the increase of obesity, especially among children due to the products being close to their sight and height [31–33]. Food swamps are also choice environments laden with tempting stimuli and are therefore "hot" decision environments likely to prompt choices for immediate gratification [34].

Ultimately, this study showed the availability of unprocessed foods, culinary ingredients, processed foods, and ultra-processed foods in the audited food retailers in the municipality, showing that some socially vulnerable areas were more prone to enable the purchase of unhealthier products and that the city was flooded with opportunities to buy ultra-processed foods. The Brazilian Dietary Guidelines recommend that the population eat culinary preparations that are based on unprocessed or minimally processed foods and culinary ingredients [28]. In this context, the places in the municipality studied that can better support this practice are supermarkets/hypermarkets/wholesalers, medium market stores (e.g., Carrefour Express, Dia Express), grocery stores, private markets of fruits and vegetables, central markets of fruits and vegetables, butchers and fish markets, and municipal markets of fruits and vegetables, in addition to places where unprocessed foods are available in large quantities and where there are fresh fruits and vegetables located near the entrance of the store.

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