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Food accessibility of different socioeconomic groups in sub-Saharan African cities: a mixed-method analysis in Kampala, Uganda

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Abstract

Cities in sub-Saharan Africa are characterised by rapid urban sprawl, which has implications for urban food accessibility. Urban sprawl results in inefficient structures of cities, and is often related to patterns of socioeconomic segregation. An important research gap in food accessibility studies is that these local socioeconomic imbalances are not considered in broad-scale studies. This research analyses how the dimensions of food access (physical, social and economic) relate to the food insecurity and dietary diversity of inhabitants of different socioeconomic groups in the rapidly growing Greater Kampala Metropolitan Area (Uganda). We use the Food Insecurity Experience Scale and Household Dietary Diversity Score to assess the overall state of food consumption. To measure physical accessibility, we geographically map the formal food system potential. A radar chart was used to visualise the vulnerability of different socioeconomic groups within the city food system. The results show that more established urban dwellers experience different access vulnerabilities than newly migrated residents, depending on their income. Lower income groups compensate their limited economic accessibility by participating in food sharing networks. Obtaining a better understanding of the dimensions of urban food accessibility can aid stakeholders in the urban food system in their policy making processes towards a more food secure and sustainable future.

Keywords Urban food insecurity • food accessibility • spatial analysis • household surveys • sub-Saharan Africa

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1 Introduction

1.1 Food security and accessibility in sub-Saharan African cities

While sub-Saharan Africa (SSA) is the most rapidly urbanising region in the world, it is also the region with the highest prevalence of severe food insecurity (Fig. 1). The Food and Agriculture Organization (FAO) defines food security as *"a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life"* (FAO et al., 2017:107). Physical, social and economic access to food therefore make up an important pillar of food security. Food accessibility is inherently spatial in its three dimensions: (i) physical access implies that a consumer has the time and means to travel to obtain food from a given location; (ii) social access refers to an inclusive food environment and support networks; (iii) economic access refers to the financial capacity to purchase foodstuffs at a certain location.

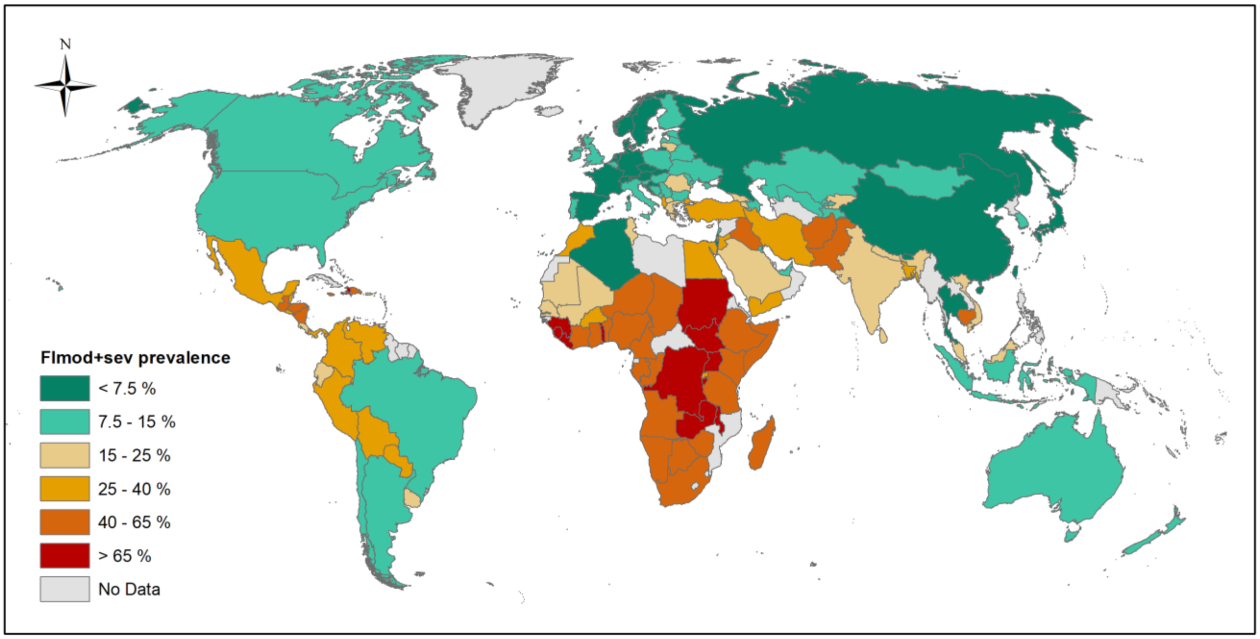

Fig. 1 Prevalence rates of moderate to severe food insecurity ($FI_{mod+sev}$) according to the FAO Food Insecurity Experience Scale (Data from Table A-1 in FAO, 2016:36).

Food security is a key priority of the Sustainable Development Goals (SDGs). However, according to Crush and Riley (2017), the SDGs put an uneven emphasis on food production and rural areas, neglecting cities where food access (instead of production) is of crucial importance for the food security of vulnerable urban dwellers (Crush and Riley 2017). In SSA, the vulnerability of food access strategies adapted by urban dwellers strongly depends on their socioeconomic status (Mackay 2019). When food systems are studied at the urban scale, these socioeconomic differences within the city are often overlooked. For example, Karg et al. (2016) have conducted an in-depth analysis of the geographies of the food systems in the cities of Tamale (Ghana) and Ouagadougou (Burkina Faso), yet they assume a socioeconomically uniform urban population for their analysis. Another approach is to focus research efforts on certain disadvantaged areas within an urban agglomeration (Caley 2016; Gallaher et al. 2013; Swanepoel et al. 2017), however, without contrasting these to better-off neighbourhoods. Hence, there is a lack of city-wide data concerning food insecurity and accessibility across the socioeconomic spectrum, although this could be valuable for decision makers (Battersby and Watson 2019) and follow-up research. As a priority SDG, food security relies as much on food access as it does on food production. There is therefore an urgency to solve the food access problem in cities if we are to meet the SDGs.

1.2 The impact of urbanisation on the geographies of food accessibility

SSA cities are expected to triple in population by 2050 (UN-DESA 2015), and are showing spatial patterns of urban sprawl (Vermeiren et al. 2016). As these sprawling cities extend outwards instead of becoming more densely built-up, they tend to enfold patches of vegetation, with urban agricultural practices being prevalent (Vermeiren et al. 2013). Another key characteristic of the rapid urbanisation in SSA is socioeconomic segregation (Vermeiren et al. 2016). Socioeconomic groups residentially cluster amongst similar people, guided by living expenses, support networks and dynamics of social exclusion (Smets and Salman 2008). The availability and quality of services and infrastructure correlate to the socioeconomic status of a segregated area, which causes poorer neighbourhoods to be deprived of livelihood opportunities as well as being underserviced in terms of (healthy) food provision (UN-DESA 2015). Because of rapid urbanisation, the cost of food insecurity will increasingly be shifted towards vulnerable socioeconomic groups within cities.

Therefore, the SSA region is experiencing high levels of food insecurity on one hand, paired with quickly changing urban configurations on the other hand. While usually analysed separately, urban expansion and the associated dynamics can significantly impact the geographies of food insecurity within cities (Mackay 2019). There is a clear impact on food provision: urban sprawl can reduce the production of food in and around cities as new urban built-up areas often emerge on former croplands (Van Vliet et al. 2020). This tactic adapted by residents calls for sustainable planning approaches (Vermeiren et al. 2013). Nevertheless, the complex issue of food insecurity in African cities will not be solved by focussing solely on agricultural production.

Urban expansions affect the geographies of food insecurity through physical, social and economic access to food. Physically - or geographically - one must be able to reach the food with their available means of transport. While definitions of food deserts in developed regions focus predominantly on travel distance to food sources (Hamidi 2020; Shaw 2016), African food deserts are defined by Crush and Battersby (2016:13) 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.*" Horizontal cities with a low availability and quality of infrastructure experience higher levels of food insecurity (Frayne and McCordic 2015). For consumers who are (partly) self-provisioning, i.e. obtaining food from non-market food sources, access to farmland can directly increase physical food accessibility (Mackay 2019). An inefficient city layout due to urban sprawl could therefore contribute to long travel times to food sources (Hamidi 2020).

Socially, an individual or group can access food through mechanisms such as (informal) food sharing, social support or credit programmes (Tevera and Simelane 2014). There is a range of informal activities that households undertake to access food: *"borrowing, gifting, or bartering food (...); receiving food through charity, food aid, or begging; remittances from rural–urban migration; collecting food from urban livestock or urban forests"* (Warshawsky, 2016:295). Social networks are especially relevant for obtaining food. For example, residents in Nairobi showed higher levels of food sharing and food exchange if they had good relationships with their neighbours (Gallaher et al. 2013). Households living in an inclusive food sharing environment were consequently shown to be more food secure. In addition, the food civil society organisations are gaining prominence in SSA cities as they provide food in areas where governments and markets fail to do so (Warshawsky 2016). On the other hand, mechanisms of social exclusion (Páez et al. 2010) may lead a consumer to avoid sourcing food from specific locations. Thus, in rapidly growing cities, social access to food can be critical for new rural-urban migrants to uphold their levels of dietary diversity and food security.

Economically, food access is affected by dynamics of poverty, price volatility, market structures and disruption (Crush 2014). Most food insecure households are affected by this dimension of food access, as it is inherently linked to physical and social access. Financial accessibility can be determined by income and food expenditure. Both income and food prices can strongly vary in time and space (Crush and Battersby 2016). Although incomes are relatively higher in urban areas, food prices tend to be higher as well, which may lower the economic accessibility for new rural-urban migrants (Cohen and Garrett 2010). Hence, through decreased accessibility, sprawl has a significant impact on the livelihoods of vulnerable (peri-) urban dwellers. These drivers need better understanding and appropriate consideration in policy interventions to address inequalities associated with urban food access.

To study the geographies of urban food insecurity, it is therefore crucial to untangle the dimensions of food accessibility. Socioeconomic dynamics in cities can impact social, physical and economic access to food and, in turn, contribute to consumer vulnerability (Leite et al. 2020). Aiming towards eradicating food insecurity that results from inaccessibility of affordable and healthy food, the body of knowledge on urban food systems increasingly strives for food justice (Heynen et al. 2012). Understanding urban food insecurity in a food justice framework can contribute to strategy development for a better management of urban food systems as cities quickly grow in terms of population and size (Karg et al. 2016).

1.3 Objectives and research questions

Consequently, to find answers to the issues of food insecurity in rapidly urbanising SSA cities, we must consider physical, social and economic accessibility to food (FAO et al. 2017). Holistic food systems approaches mostly implement broad-scale analyses, concealing socioeconomic differences between households (Battersby and Crush 2014). Therefore, we aim to research urban food insecurity and accessibility in a socioeconomic framework, taking the fast-growing city of Kampala (Uganda) as a case study. More specifically, the goal of this study is to obtain a better understanding of the impact of physical, social and economic food accessibility on the food insecurity of urban dwellers by answering the following research questions:

- What are the patterns of food security and dietary diversity of different socioeconomic groups in Kampala?
- How do the different dimensions of food accessibility contribute to the vulnerability of socioeconomic groups?

Our hypothesis is that, depending on income, new rural-urban migrants experience more difficulties regarding food accessibility than more established urban dwellers, making these newcomers more vulnerable to food insecurity. This article takes a geographical perspective to study how access to food impacts consumers' levels of food security and dietary diversity. Through the lens of socioeconomic group dynamics, we explore the impact of spatially related factors such as proximity to formal food sources to explain patterns of food insecurity. We aim to aid policy makers by informing them of the vulnerabilities of food accessibility of different socioeconomic groups.

2 Study area: the Greater Kampala Metropolitan Area

Aiming at analysing the geographies of urban food accessibility at the city scale, the Greater Kampala Metropolitan Area (GKMA) in Uganda was chosen as a case study (Fig. 2). Kampala is experiencing a very rapid urbanisation process with a population increase of over 5% per year (Vermeiren et al. 2012). The city is characterised by urban sprawl resulting in an inefficient city layout with radial access roads and socio-economically segregated settlement patterns (Vermeiren et al. 2016). The GKMA as depicted in Fig. 2 is inhabited by over 3 million people (UBOS 2016a), most of whom live in the inner city. Driven by high fertility rates on the one hand (UN-DESA 2017) and rapid rural-urban migration on the other hand, Kampala's population is likely to continue to increase in the future (Vermeiren et al. 2012). While evidence suggests rapid urbanisation goes along with an increase in supermarkets, Kampala's food system still heavily relies on smaller retailers, street and market vendors (Wanyama et al. 2019). For these reasons, the GKMA can be considered an illustrative case for rapidly changing SSA cities.

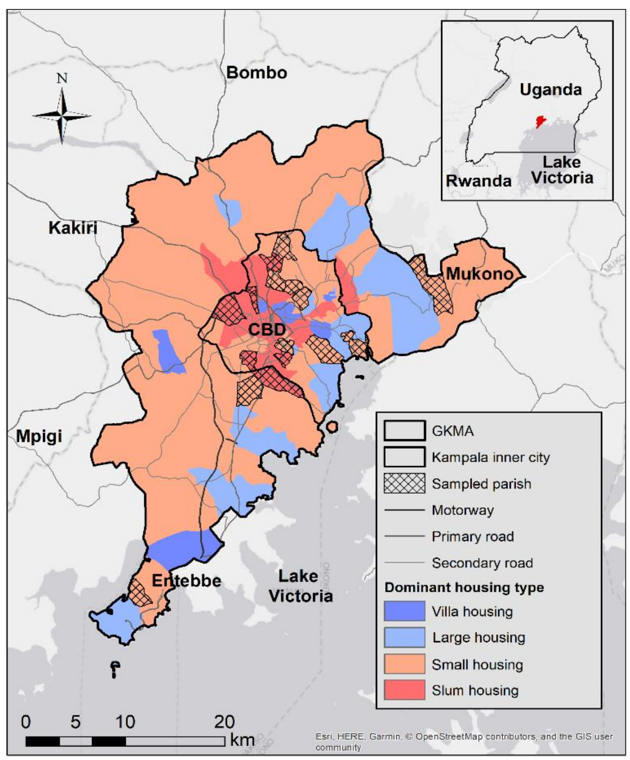

Fig. 2 Dominant housing type in (sampled) parishes of the GKMA (adapted from Hemerijckx et al., 2020).

In the GKMA, inhabitants of a higher socioeconomic position mainly reside on hilltops while low-lying wetland areas are dominated by slum housing (Hemerijckx et al. 2020; Vermeiren et al. 2016). Hemerijckx et al. (2020) have defined four socioeconomic clusters (SECs) in Kampala based on migration status and income. The 'established high income' (EH) are a relatively small group, living on hilltops in central Kampala, as well as at the easily accessible edges of the city. This group has the highest income and relatively large households. As they are well-established in the city, they usually have access to land for (peri-)urban farming activities. The 'established low income' (EL) and 'newcomers middle income' (NM) are spread out over the GKMA. Despite their low income, the EL also have larger households and most are active urban farmers. The NM are a dynamic group of smaller households, who more recently migrated to Kampala. They rely strongly on technology, are less involved in urban agriculture, and they live in less favourable locations compared to the established urban dwellers. 'Newcomers low income' (NL) are also found throughout the urban agglomeration, but are most concentrated in slums in the inner city. The NL have the lowest income and the least access to agricultural land of the four groups. Fig. 2 shows the result of their remote sensing analysis showing what housing types define the city layout[1] in Kampala (Hemerijckx et al. 2020). The present study analyses food accessibility and insecurity of urban dwellers through the lens of these four SECs.

While urban food insecurity in Kampala has been studied from various perspectives, most studies include urban farming activity, albeit as a proxy for access to land, as a possible determining aspect of food insecurity. The relationship between urbanisation and urban agricultural activities in SSA has received considerable attention in recent literature (Kuusaana and Eledi 2015; Swanepoel et al. 2017; Vermeiren et al. 2013). In this study, we incorporate urban agricultural activity as a factor that increases physical access to food. The diet and nutrition perspective on food security in Kampala tends to focus on specific vulnerable demographics such as women (Chaput et al. 2007; Yiga et al. 2020), children (Yeudall et al. 2007) or slum dwellers (Wanyama et al. 2019). In their recent survey, Yiga et al. (2020) found that affordability, socio-cultural norms and the physical food environment were, among other factors, important determinants of dietary behaviour in Kampala. Our analysis includes demographics by explicitly analysing food access vulnerability through the lens of socioeconomic differentiation.

3 Materials and methods

3.1 Household surveys

In order to obtain a better geographical understanding of food insecurity patterns and accessibility characteristics, 525 households were surveyed in the GKMA in 2019. The household surveys were carried out in 15 contrasting parishes (mapped in Fig. 2) of the GKMA. The survey protocol consisted of four parts: household demographics and socioeconomic characteristics (Appendix 1.A.), food security (Appendix 1.B.), dietary diversity (Appendix 1.C.) and food accessibility (Appendix 1.D.). To account for seasonality issues, households were interviewed in two different seasons: summer (dry season of August-September) and winter (wet season of November-December). More detailed information on the sample size can be found in Appendix 2 and in Hemerijckx et al. (2020).

3.2 Measuring food insecurity and household dietary diversity

To assess the overall state of the food consumption pattern for the surveyed households in Kampala, two measurement instruments by the FAO were used. First, we applied the Food Insecurity Experience Scale (FIES). The FAO aims to advance global food insecurity monitoring by facilitating and standardizing its measurement using the FIES (Cafiero et al. 2018). The instrument (protocol in Appendix 1.B.) is based on eight experience-based questions or 'items' (resulting in a raw score between 0 and 8), ranging from worrying about obtaining food, up to physically experiencing hunger (Ballard et al. 2014; Brunelli et al. 2014). As per the standard methodology, items that did not fit the Global Standard were left out of the FIES analysis. Wambogo et al. (2018) indicate that FIES model fit statistics are within the acceptable range for Uganda. The FIES scale is therefore suitable to measure food insecurity experience in the Ugandan context.

[1] As wealthier groups reside on larger plots of land, this map corresponds to the dominant housing type in terms of area coverage and not in terms of population.

The FIES was applied and validated for each SEC, using the Rasch model in R 3.6.2. The validation was also carried out separately for two groups that roughly split the dataset in half: non-farming versus farming households, and households of the majority tribe (Muganda) versus minority groups.

Second, the Household Dietary Diversity Score (HDDS) was calculated for each household. This instrument (protocol in Appendix 1.C.) is based on a 24-hour recall period and inquires whether or not the respondent had consumed items in 16 food groups (FAO 2010; Swindale and Bilinsky 2006). As shown in Appendix 3, food groups of fruits, vegetables and meats are aggregated to calculate the HDDS as per FAO protocol. Hence, the final HDDS ranges from 0 (no food consumed the day before) to 12 (all aggregated food groups consumed). The HDDS indicator is typically reported as average values along with a standard error, as there are at present no standards in place to convert raw scores into categories (Swindale and Bilinsky 2006). The ANOVA approach was used to test the null hypothesis that the mean HDDS values of the populations of each SEC are all equal. The same analysis was done for the non-farming versus farming groups and the majority versus minority tribes. To verify whether the mean HDDS differs significantly between socioeconomic groups, a two-sample t-test was carried out using the Excel 2016 Data Analysis tool.

3.3 Spatial analysis of physical food access

While there are numerous ways of measuring the physical food environment using GIS (Charreire et al. 2010), proximity measures that include the Euclidean distance remain popular for their simplicity. We propose the formal food system potential (FFSP) as a relative measure of geographic accessibility to supermarkets and registered markets in the study area. The FFSP was mapped out using Python 3.7.1 on a 100m resolution raster of the study area based on the employment potential framework (Poelmans and Van Rompaey 2009), using the gravity-based mathematical equation (1) by Hansen (1959):

$$E_i = \sum_{j=1}^{n} \frac{J_j}{D_{ij}} \tag{1}$$

Where:

- E_i is the formal food access potential at pixel i.
- J_j is the size of the formal food activity, expressed as the total weight of formal food sources (registered in OpenStreetMap) in pixel j in the year 2020.
- D_{ij} is the Euclidian distance between pixel i and the food source at pixel j.
- n is the number of nearest nonzero weight pixels j used (for this study, n=20).

To assess the total weight of formal food sources in a 100 by 100m pixel, (super-) markets are assigned a weight of 1.0, motorways and primary roads a weight 0.5, and secondary and tertiary roads 0.25. If multiple weighted items (e.g. a market and a road) occur on the same pixel, these values are summed to obtain the total weight of that pixel. All road and (super-) market locations were obtained via OpenStreetMap (2020). Unlike in the classic employment potential calculations, main roads are included in this analysis for two reasons. First, travel times to formal food sources are shorter for inhabitants living near a large street or motorway. Second, assigning a weight potential to main roads compensates for the possibility that some (super-) markets or informal food vendors in the GKMA may not (yet) be registered in OpenStreetMap, assuming these have a high chance of being located near a main road.

An advantage of the FFSP method is that it can quickly provide a city overview of food access. It is a relatively simple method relying on the Euclidean distance which is a popular measure to map the food environment in various areas of the world (Charreire et al. 2010). A disadvantage of the method is its dependency on city-wide records, which leads to uncertainties especially when relying on open-source data such as OSM. In addition, the visualisation of raster-based approaches can look scattered for large study areas. For this reason, the mean FFSP of all pixels within each parish (the smallest administrative unit in in the GKMA) was considered in ArcMAP 10.7.1 for visualisation purposes.

3.4 Vulnerability

To summarise and enable a clear visualisation of the findings regarding food security, dietary diversity and physical, social and economic accessibility to food, a vulnerability radar chart is produced. For each of the five indicators, a score between 0 and 100% is calculated based on the variables in Table 1. To avoid biases, variables are given equal weight in calculating a score for each indicator. For variables that are originally not expressed as a percentage, the score was calculated between the responses at the 25^{th} and 75^{th} percentile.

Table 1 Five indicators of the food vulnerability radar and the variables taken into account.

Indicator	Variables	Weight
Economic accessibility	Daily food expenditure per person (SEC average)	50
	Percentage of household income available for non-food items (SEC median)	50
Physical accessibility	Proximity (travel time) to most used household food source (SEC average)	34
	FFSP score at household location (SEC average)	33
	Percentage of households partaking in agricultural activities	33
Social accessibility	Percentage of households that are part of food sharing network	50
	Percentage of households that are part of the majority tribe (Muganda)	50
Food security	Percentage of households that are food secure (FS) according to the FIES	100
Dietary diversity	Mean HDDS, as a percentage of the maximum score of 12	100

4 Results and discussion

4.1 Food insecurity and household dietary diversity

The food consumption pattern was analysed for each SEC using the FIES and HDDS indicators. Table 2 shows the prevalence rates of moderate or severe ($FI_{mod+sev}$) and severe (FI_{sev}) food insecurity for each SEC, after responses were fit to the Rasch model. The results of the Rasch model are shown in Appendix 4. Other households are considered food secure (FS). The ANOVA analysis and two-sample t-test both resulted in all mean HDDS values being significantly different ($p < 0.05$) from one another, except for the EL when compared to the NM or NL. The EH are the most food secure (74.3%), and have the widest range of foodstuffs (mean HDDS of 6.4) in their diet. Most of the NM are food secure as well (55.5%), though a relatively large proportion (15.4%) is severely food insecure. The mean HDDS of 5.9 of the NM is above the dataset average. The lower income groups (EL and NL) are the least food secure, with FS values of 46.5% and 45.8% respectively and below-average HDDS values. With a FI_{sev} of 22.4% and a HDDS of 5.1, the NL are the most food insecure group of the dataset. Note that the NL form the largest group consisting of about one third of the dataset.

The same analysis (Table 2) was done for the households involved in urban agriculture and those not involved in urban agriculture, as these groups each make up about half of the dataset. The ANOVA result indicates there is a significant difference in mean HDDS for the farming versus non-farming households. Those practicing urban agriculture have a larger diversity of foodstuffs in their diet (mean of 6.0 compared to 5.3 for non-farming households). However, the FIES values indicate there is little difference between the food security of these two groups. Another variable analysed separately is the household tribe. In total, 71 different tribes were recorded in the dataset. 58.3% of the surveyed households belong to the majority tribe, the Muganda. This social variable appears to play a minor role in the food insecurity of Kampala's households. While the Muganda are slightly more food secure, minority tribes have a somewhat (though not significantly) higher HDDS. The latter could be related to different food type preferences of various tribes (Mackay 2019). Note that both tribe and involvement in agriculture are included in the variables that indicate vulnerability (Table 1). For these reasons, this paper further analyses the food system in the framework of the SECs rather than focussing on tribe or urban agricultural activities, as scholars have done before (Sabiiti and Katongole 2014; Yeudall et al. 2007).

In Uganda, the prevalence rate for moderate or severe food insecurity ($FI_{mod+sev}$) is 69.8%, and the prevalence rate for severe food insecurity (FI_{sev}) is 36.1% (FAO 2016). Yet, relatively few recent studies explicitly measure food insecurity levels for the capital city Kampala. Caley (2016) surveyed 490 households in informal settlements in Kampala in 2014 to assess the performance of various food insecurity measurement instruments. Their research resulted in FIES scores suggesting that nearly 80% is moderately or severely food insecure. Pottier (2015) interviewed 118 Kampala households in 2012, but did not aim to explicitly "'*measure' food insecurity*". 20.3% of the interviewed households experienced hunger (Pottier 2015), which can be compared to being severely food insecure on the FIES. With a FI_{sev} value of 15.6% for the entire dataset, the food insecurity levels resulting from our analysis are considerably lower than those calculated for these prior studies in Kampala (Caley 2016; Pottier 2015). Our questionnaire was carried out respectively 8 and 5 years after these studies. A possible explanation is therefore that the food security in the rapidly evolving city of Kampala has improved since. More importantly, however, we deliberately aimed at studying food insecurity across the socioeconomic spectrum, while for example Caley (2016) surveyed in informal settlement areas only. Combining our findings with these prior studies, we can conclude Kampala's urban population is relatively food secure compared to the national average for Uganda.

Table 2 FAO Food Insecurity prevalence rates (output of Rasch model fit) and mean HDDS for each SEC and the total dataset separately. * indicates a significant difference from other groups at $p < 0.05$. SE, standard error.

Socio-economic group		FIES			HDDS	
	N	FS (%)	$FI_{mod+sev}$ (%)	FI_{sev} (%)	Mean	SE
Established high	143	74.3	25.7	5.3	6.4*	0.182
Established low	97	46.5	53.5	18.8	5.5	0.180
Newcomers middle	111	55.5	44.5	15.4	5.9*	0.152
Newcomers low	174	45.8	54.2	22.4	5.1*	0.147
Urban farmers	262	57.4	42.6	14.1	6.0*	0.123
Non-urban farmers	261	53.9	46.1	17.0	5.3*	0.118
Majority tribe (Muganda)	306	57.0	43.0	14.6	5.6	0.110
Minority tribe (other)	219	54.3	45.8	17.0	5.9	0.141
Dataset (total)	525	55.8	44.2	15.6	5.7	0.091

Unfortunately, no country-level (Uganda) or city-level (Kampala) census records explicitly include the HDDS tool. However, the national census (UBOS, 2018) inquires about 9 food groups (the number of days each group was consumed on a 7-day recall period) which enables a comparative analysis (3). When these data are transformed to daily probabilities, assuming equal chances for aggregated categories, this results in mean HDDS values of 5.6 for Uganda and 5.8 for the sub-region of Kampala. The average HDDS in our dataset is 5.7 food groups consumed per day, which is consistent with the census data provided by UBOS (2018). Comparison of our outcomes with the dietary diversity analysis described by Caley (2016) or Wanyama et al. (2019) is not possible, because these studies report total HDDS values in a 7-day recall period resulting in systematically higher scores.

4.2 Economic food access

Fig. **3** displays the economic access to food of the different SECs. The median daily food expenditure per person is around 2,500 UGX (about 0.70 USD) for the entire dataset (M = 3,694 UGX, SD = 5100 UGX). The average values for each SEC, however, vary from over 4,800 UGX/person/day for EH (SD = 7879 UGX), and less than 2,800 UGX/person/day for EL (SD = 2001 UGX). Our findings compare to the UBOS (2016b) census, where the mean daily consumption expenditure for a Kampala resident was 4,451 UGX in 2012/2013. Logically, while the groups with middle (NM) or high (EH) income spend the largest net amounts on food, this comprises a smaller portion of their household income. This enables them to have more disposable income. In addition, the EH and EL might purchase food in bulk as they have larger household sizes, which may explain why their daily food expenditure per person is somewhat lower than that of the NM and NL respectively. Respondents better recalled their food expenditure than their combined household income, which may explain why the former often exceeds the latter. For instance, the fact that the food expenditure of the NL is, on average, 112% of their household income, suggests that in reality their income level might be higher than reported. This hypothesis is further validated by the UBOS (2016b) census results where the share of household expenditure on food, drink and tobacco was 37.6% for urban Uganda in 2012/2013. Another possibility is that food could be bought on a credit arrangement with the market vendors (Mackay 2019; Pottier 2015) which may have skewed the responses. Nevertheless, the overall pattern shown in Fig. **3** (b) remains valid; low income residents, whether they are established or newcomers, spend a larger percentage of their income on food.

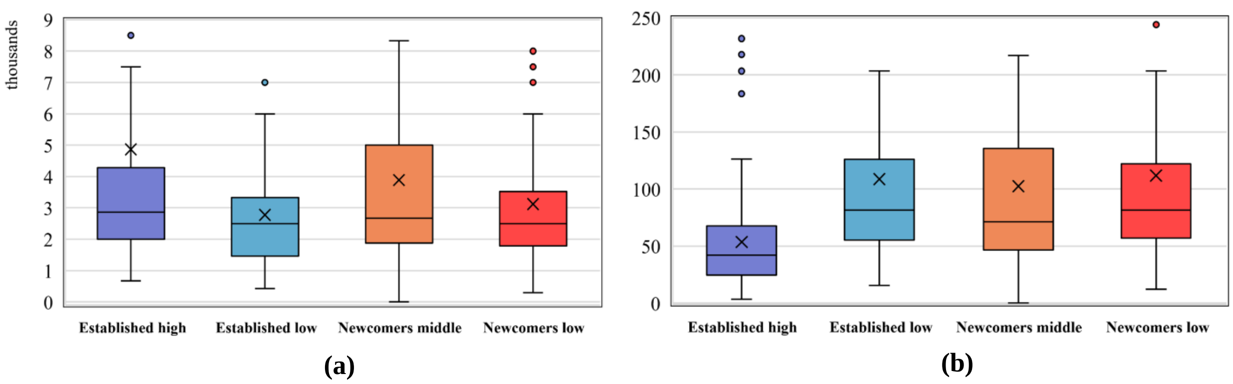

Fig. 3 Economic food accessibility measured as: **(a)** Daily food expenditure in UGX per person for each SEC. **(b)** Household food expenditure expressed as a percentage of the household income for each SEC. Outliers above the 95th percentile were removed from visualisation.

4.3 Physical food access: formal food system potential

Fig. 4 shows the resulting map for the FFSP of the GKMA. Parishes in the city centre have the best physical access to formal food sources. Larger parishes with a low population density outside the centre provide the worst access. Nonetheless, the pattern is not uniform with distance to central Kampala. Former satellite towns like Entebbe and Mukono have relatively high FFSP scores. Despite rapid horizontal urban growth, most formal food sources and key access roads are still located in the inner city of Kampala. As the population density is significantly higher in the inner city, over one million inhabitants of central Kampala have a high or very high FFSP. This implies that food markets are accessible at walking or cycling distance. Nonetheless, approximately 700 thousand GKMA residents live in parishes with a low or very low FFSP, indicating that they likely need a motorized vehicle to access a main food market or supermarket. The mean FFSP values at the point locations of the 525 surveyed households are highest for the EH (3.4), in-between for the NM (3.0) and lowest for the NL and EL (both 2.6), which suggests that income is a deciding factor when choosing a location with good physical accessibility in the city.

The FFSP result is constrained by the lack of the informal food sources in the input data, although access roads were given a weight to compensate for this drawback. However, as indicated in recent research in other sub-Saharan African cities (Battersby and Marshak 2016; Davis et al. 2022) the informal and formal food vendors are likely to be geographically clustered within similar areas. This further validates our approach to map the FFSP in absence of the exact point locations of the actors in the informal food sector. Future studies could tackle this lack of data on informal vendors by choosing a smaller yet rapidly growing city as their case study, where it would be possible to manually record all informal and moving food vendor locations. Within large cities like Kampala, to be able to include the informal food system researchers could focus on an area within the city that is somehow representative of the socioeconomic dynamics of the greater metropolitan area.

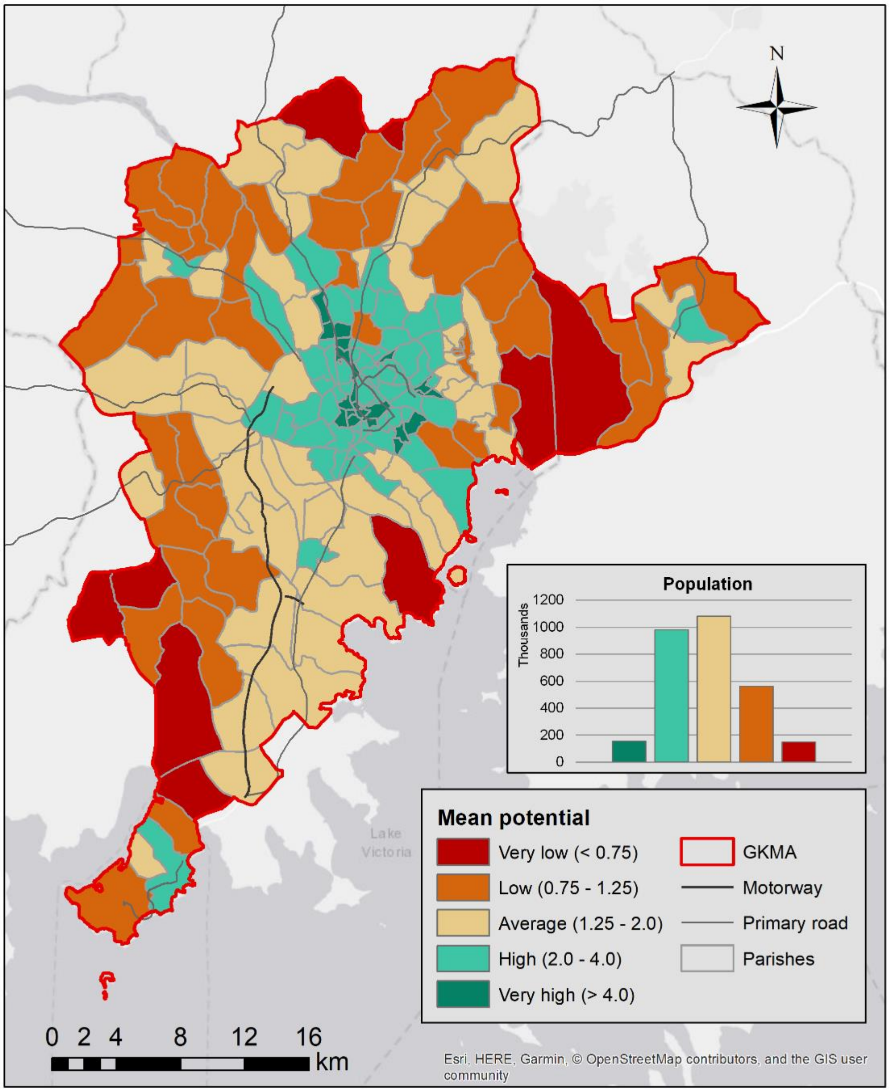

Fig. 4 Formal food system potential (FFSP) based on the proximity of (super-)markets and motorways or major roads (spatial data OpenStreetMap contributors, 2020; population census data UBOS, 2016a).

4.4 Social food access

We analyse social accessibility based on ethnicity and participation in food sharing networks. The Muganda ethnic group is well represented in the EL (77%) and EH (64%) and NL (60%) SEC, yet to a lesser extent in the NM (32%). While vulnerable groups with a low-to-middle income actively engage in food sharing networks, these groups lack financial resources to purchase sufficient, diverse foodstuffs. Newcomers in Kampala involved in food sharing often do so with family members living in rural areas (Caley 2016). Overall, most (73.7%) surveyed households are actively engaged in food sharing with, for instance, neighbours or family members. Urban dwellers of EL groups are highly dependent (78.4%) on social networks and food support. The NM, on the other hand, are the least involved in food sharing networks (69.4%).

4.5 Vulnerability

Fig. 5 portrays how each SEC in the Kampala dataset performs on five vulnerability indicators of a sustainable city food system. As FFSP values are highest around the inner city of Kampala, newcomers or low income residents settling at the edges of the GKMA experience poorer physical as well as financial access to food. In this analysis, involvement in urban agricultural activities is included in physical food accessibility. This can (partly) explain why newcomer groups, who have less access to (peri-) urban land and are less involved in these farming initiatives, have decreased physical accessibility despite being located predominantly in the city centre. Our findings contradict the old assumption that urban farming is a remnant of the rural lifestyle brought to Kampala by new rural-urban migrants (Atukunda and Maxwell 1996). Mainly the established SECs are engaging in urban agriculture, and this is how the EL compensate for their relatively long travel times to food sources.

In addition, physical access to food is also directly determined by financial power through the dimension of transport. Even though vulnerable SECs tend to reside in the city centre, their physical accessibility to food is restricted by their limited access to transportation. Higher income groups are located at closer proximity to formal food sources, and those outside the inner city compensate this with private transport, which explains their high scores for physical accessibility. These findings correspond to prior research showing that affordable transport options are an important factor shaping the livelihoods of Kampala's inhabitants (Janusz et al. 2019). This finding is consistent with that of Frayne and McCordic (2015) showing that the urban poor, especially when newly migrated, are disproportionally affected by a lack of infrastructural, physical access. Unsurprisingly, the established SEC with the highest income scores best overall. In general, we confirm the results of Mackay (2019) who shows that socioeconomic status can strongly shape urban food access strategies and thus, in turn, dietary diversity and food security.

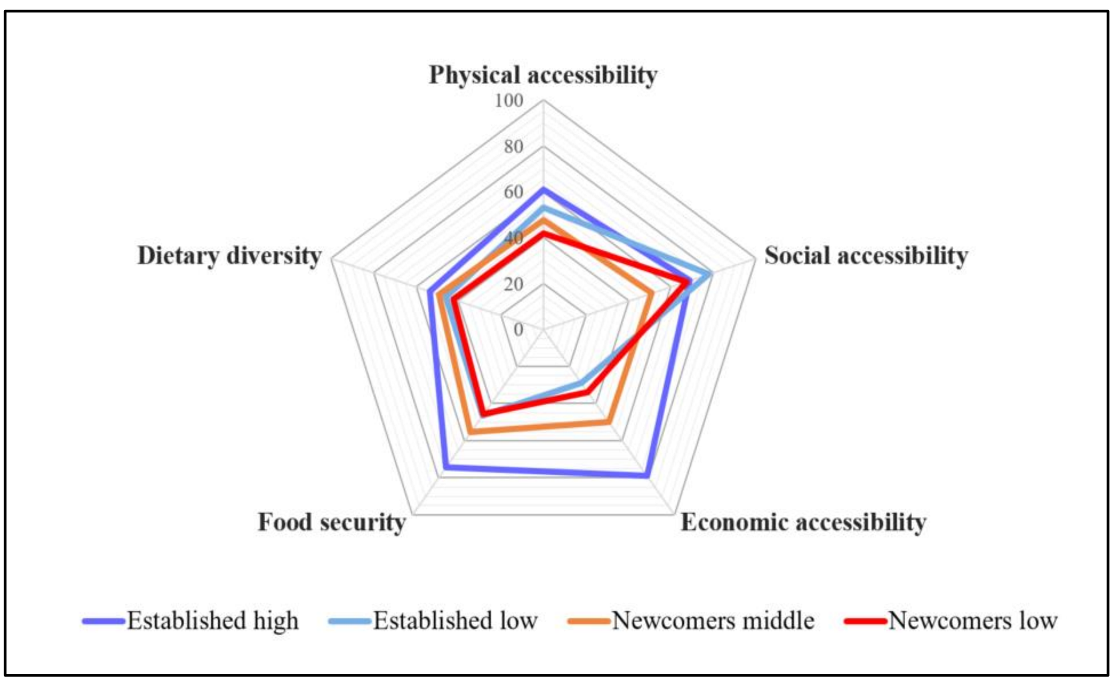

Fig. 5 Vulnerability radar, showing how each SEC scores on dietary diversity, food security as well as the three pillars of food accessibility: physical, social and economic.

5 Conclusion

In order for the world to meet its food security SDG, it must solve issues of food access as well as food production. Urban accessibility to food is the product of socioeconomic factors and geographical access, and understanding the links between these is the first step to solving urban food access and meeting the SDGs. This study assessed the impact of urbanisation dynamics on food accessibility and, in turn, food insecurity of different socioeconomic groups in the Greater Kampala Metropolitan Area. Existing academic literature has focused on urban agricultural practices being the main impact of rapid urbanisation in sub-Saharan African (mega-) cities on the food system. Nonetheless, this study has demonstrated that socioeconomic dynamics that go beyond income or farming activity are underlying determinants of physical, social and economic food accessibility. While income is the main restraint for some, the lack of social embeddedness in the city as well as a remote household location can contribute to food insecurity. This information can be valuable to policy makers and scholars, both for short term crisis management and for long term planning purposes, as it gives an overview of the food accessibility issues of urban residents.

As different socioeconomic groups are experiencing different accessibility issues, making them vulnerable in various ways, there can be no uniform solution to the problem of urban food insecurity. Hence, more research beyond the consumer perspective will need to be conducted regarding access to food in Kampala. Adding the perspective of (informal) food vendors can be valuable to get a comprehensive grasp of the vulnerability of the city food system. More specifically, future research should investigate how to adequately consider informal food vendors in the GKMA, as their locations are not registered in public databases. Moreover, while the present study provides an insight into the current status of food access in the rapidly growing GKMA, future research should assess how the food system of Kampala is expected to evolve alongside the rapidly changing built environment.

Appendix

Appendix 1. Survey protocol

1.A. Socio-economic variables used for defining the SEC

Categorical variables are indicated as either binary (B), ordinal (O) or nominal (N). Table from Hemerijckx et al. (2020, p.7).

Variable Collection	Numeric Variables	Categorical Variables
Household characteristics	Total number of household members Number of children (< 18 y.o.) Number of adult women (≥ 18 y.o.) Average commuting time Average education level Number of years lived in Kampala	Household tribe (N) Most spoken language (N) Urban agricultural activity (B) Housing type (N) Roofing type (N) Toilet type (N) Road type in front of home (N) Water source (13 dummy var.) (B) Energy source (9 dummy var.) (B) Cooking energy source (7 dummy var.) (B)
Neighborhood characteristics	Distance to nearest water source	Parish name (N) Neighborhood reputation (O) Neighborhood cleanliness (O) Neighborhood safety (O) Gated home infrastructure (O) Tarmacked road infrastructure (O) Flooding prevalence (O) Overall happiness in neighborhood (O)
Income and ownership	Income (2 var.) Workers employed at household Food expenditure (2 var.) Vehicle ownership (5 var.)	Tenure status (N) Ownership of air-conditioning (B) Ownership of a radio (B) Ownership of a television (B) Online activity (3 var.) (B) Ownership of a telephone (3 var.) (B)

1.B. Food Insecurity Experience Scale questionnaire

FAO questionnaire (Ballard et al. 2014, p.39), English version. Answers are yes/no.

During the last 12 months, was there a time when:

Question number	Variable	Survey Question
1	WORRIED	You were worried you would not have enough food to eat because of a lack of money or other resources?
2	HEALTHY	You were unable to eat healthy and nutritious food because of a lack of money or other resources?
3	FEWFOOD	You ate only a few kinds of foods because of a lack of money or other resources?
4	SKIPPED	You had to skip a meal because there was not enough money or other resources to get food?
5	ATELESS	You ate less than you thought you should because of a lack of money or other resources?
6	RUNOUT	Your household ran out of food because of a lack of money or other resources?
7	HUNGRY	You were hungry but did not eat because there was not enough money or other resources for food?
8	WHLDAY	You went without eating for a whole day because of a lack of money or other resources?

1.C. Household Dietary Diversity Score questionnaire

FAO questionnaire (FAO 2010, p.7), English version. Answers are yes/no for each food group.

Please describe the foods (meals and snacks) that you ate or drank yesterday during the day and night, whether at home or outside the home. Start with the first food or drink of the morning.

Question number	Food group	Examples
1	CEREALS	corn/maize, rice, wheat, sorghum, millet or any other grains or foods made from these (e.g. bread, noodles, porridge or other grain products) + insert local foods e.g. ugali, nshima, porridge or paste
2	WHITE ROOTS AND TUBERS	white potatoes (in any form), white yam, white cassava, Matooke, Irish Potatoes, or other foods made from roots
3	VITAMIN A RICH VEGETABLES AND TUBERS	pumpkin, carrot, squash, or sweet potato that are orange inside + other locally available vitamin A rich vegetables (e.g. red sweet pepper)
4	DARK GREEN LEAFY VEGETABLES	dark green leafy vegetables, including wild forms + locally available vitamin A rich leaves such as amaranth, cassava leaves, kale, spinach
5	OTHER VEGETABLES	other vegetables (e.g. tomato, onion, eggplant) + other locally available vegetables
6	VITAMIN A RICH FRUITS	ripe mango, cantaloupe, apricot (fresh or dried), ripe papaya, dried peach, watermelon, passion fruit and 100% fruit juice made from these + other locally available vitamin A rich fruits
7	OTHER FRUITS	other fruits, including wild fruits and 100% fruit juice made from these
8	ORGAN MEAT	liver, kidney, heart or other organ meats or blood-based foods
9	FLESH MEATS	beef, pork, lamb, goat, rabbit, game, chicken, duck, other birds, insects
10	EGGS	eggs from chicken, duck, guinea fowl or any other egg
11	FISH AND SEAFOOD	fresh or dried fish or shellfish
12	LEGUMES, NUTS AND SEEDS	dried beans, dried peas, lentils, nuts, seeds or foods made from these (eg. hummus, peanut butter)
13	MILK AND MILK PRODUCTS	milk, cheese, yogurt or other milk products
14	OILS AND FATS	oil, fats or butter added to food or used for cooking
15	SWEETS	sugar, honey, sweetened soda or sweetened juice drinks, sugary foods such as chocolates, candies, cookies and cakes
16	SPICES, CONDIMENTS, BEVERAGES	spices (black pepper, salt), condiments (soy sauce, hot sauce), coffee, tea, alcoholic beverages

1.D. Food accessibility

Variable	Survey Question
Food expenditure	What is your household’s average daily expenditure on food?
Household income	What is the total monthly household income in UGX?
Proximity to most used food source	How long does it take you to travel to [most frequented market by respondent]?
Urban agricultural activity	Does this household produce any kind of food or other agricultural products, whether sold or consumed?
Food sharing activity	Do you receive or give food from/to neighbours, family members or other sources?
Tribe	Which tribe (or if not Ugandan: nationality) do the members of your household identify as?

Appendix 2. Sampling information (Hemerijckx et al. 2020).

Between July and December 2019, six surveyors approached homes in 15 contrasting parishes (the small administrative units, SAU) of the Greater Kampala Metropolitan Area (GKMA). We aimed to survey households at SAU that are contrasting both in terms of their location within the GKMA and in terms of socioeconomic population dynamics. The socioeconomic information was based on prior geographic research on the population of the SAU by Vermeiren et al. (2016), combined with consulting local experts at the Urban Action Lab of Makerere University. In addition, to select the final sampled parishes, we considered neighbourhood accessibility and surveyor safety. The sample size was thus limited by the practical access to the SAU. Within the selected SAU, a snowball strategy was adopted to sample households. This implied that a local council representative, after giving their informed consent, led the surveyors to households and assisted surveyors to clarify the purpose of the research.

As such, a convenience sampling method was adopted on the field. However, as a guideline to target sample size we calculated that with a desired confidence interval of 95%, the sample size of 541 households results in a margin of error of 1.97% based on Cochran's (1963) sample size formula for estimating prevalence:

$$n_0 = \frac{Z^2 p(1-p)}{e^2} \qquad \text{(A1)}$$

Where:

- n is the sample size (541 households, with 2487 individuals).
- p is the population proportion (assumed at 0.5 for complete uncertainty).
- Z the Z-score (1.96 for a confidence interval of 95%).
- e is the error margin (1.97%).

The final sample contained 541 households. Information was gathered on a total of 2487 individuals within these households. Prior to clustering the households by socioeconomic group, 16 households that exceeded a threshold of 37% of missing data (i.e. the respondent did not respond to over 37% of the survey questions) were excluded from analysis. Participants had an average of 4.25% missing data (SD = 10.91%, range = 0-95%). This threshold minimises the number of households that would be excluded, while also balancing adequate sampling per participant. This way, 525 households were included in the final dataset that was used for the present study. Fig. 6 below shows the spatial distribution of the sampled households compared to the formal food markets as registered on OpenStreetMap.

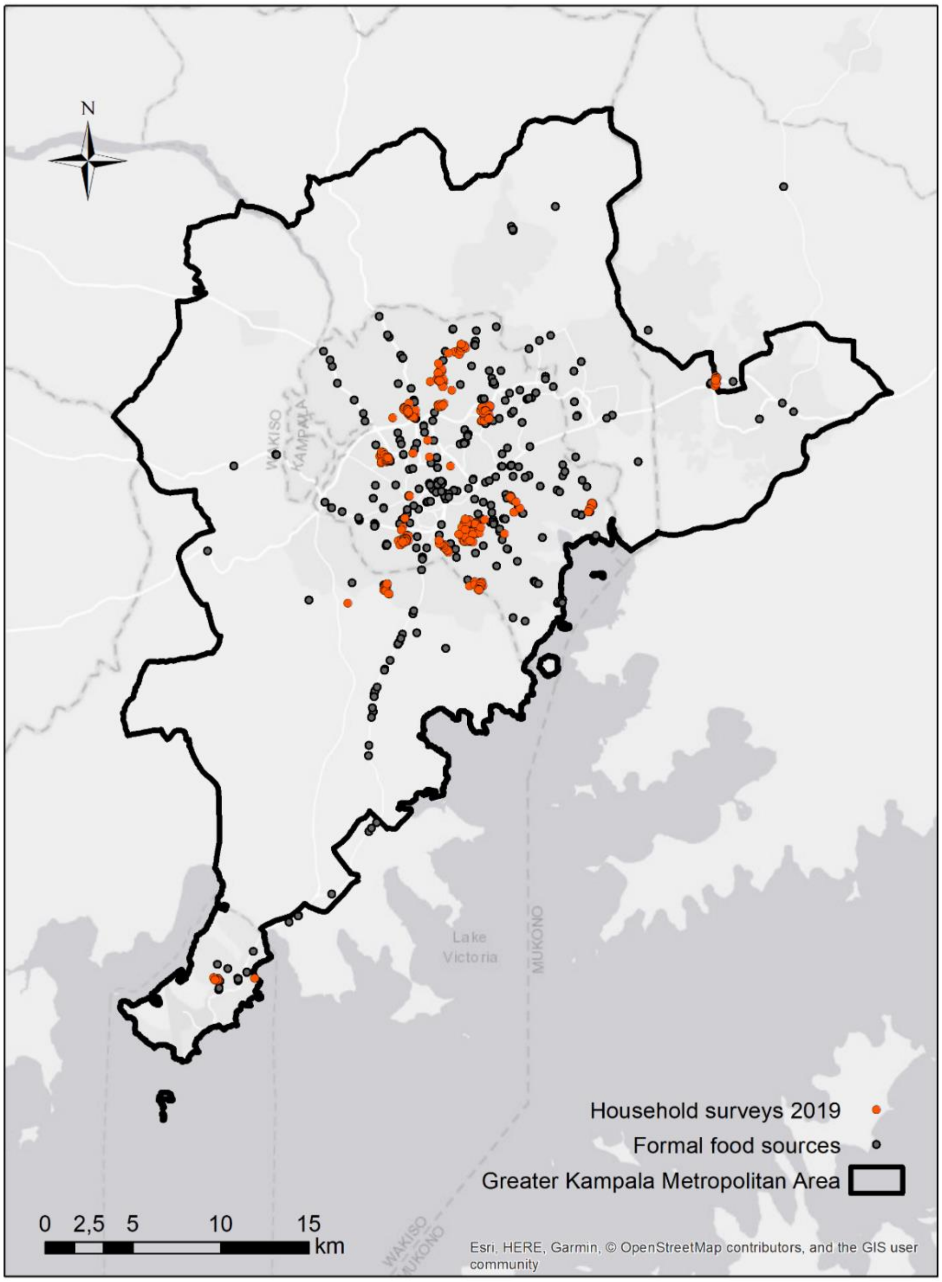

Fig. 6 Spatial distribution of the input data.

Appendix 3. Comparison of the food group categories used in the FAO dietary diversity questionnaire (16 food groups), the required aggregation to obtain the Household Dietary Diversity Score (HDDS, 12 food groups) (FAO 2010), and the Uganda food consumption census data from the national household survey 2016/2017 (9 food groups) (UBOS 2018).

FAO dietary diversity questionnaire	**HDDS aggregation**	**Uganda national household survey**
Cereals	Cereals	Staples (cereals, roots and tubers)
White roots and tubers	White roots and tubers	
Vitamin A rich vegetables and tubers	Vegetables	Vegetables
Dark green leafy vegetables		
Other vegetables		
Vitamin A rich fruits	Fruits	Fruits
Other fruits		
Organ meat	Meat	Meat, fish, eggs
Flesh meats		
Eggs	Eggs	
Fish and seafood	Fish and seafood	
Legumes, nuts and seeds	Legumes, nuts and seeds	Pulses and nuts
Milk and milk products	Milk and milk products	Milk
Oils and fats	Oils and fats	Oil and fats
Sweets	Sweets	Sugar
Spices, condiments, beverages	Spices, condiments, beverages	Spices

Appendix 4. Results of the Rasch model

Item	**Severity**				**Standard Error**				**Infit**			
SEC	EH	EL	NM	NL	EH	EL	NM	NL	EH	EL	NM	NL
WORRIED	-2.32	-1.75	-1.55	-1.61	0.31	0.41	0.38	0.30	0.99	1.10	1.14	1.12
HEALTHY	-0.78	-0.72	-1.10	-0.20	0.31	0.38	0.36	0.26	1.08	**1.68**	1.14	**1.51**
FEWFOOD	-1.70	-1.35	-1.55	-1.11	0.31	0.40	0.38	0.28	0.99	0.75	0.82	0.83
SKIPPED	0.51	-0.36	0.32	0.13	0.35	0.37	0.35	0.25	0.82	0.79	0.97	0.83
ATELESS	-0.36	-0.84	-0.48	-0.49	0.32	0.38	0.34	0.26	1.06	0.83	0.89	0.87
RUNOUT	1.08	0.81	0.94	0.55	0.38	0.38	0.36	0.25	1.26	**0.62**	0.71	0.82
HUNGRY	1.08	1.40	0.62	0.97	0.38	0.39	0.35	0.25	0.86	0.83	1.05	0.83
WHLDAY	2.50	2.82	2.78	1.76	0.48	0.51	0.50	0.27	1.12	1.25	1.19	1.25

SEC	**Rasch reliability**
EH	0.748
EL	0.751
NM	0.732
NL	0.715

All infit statistics within the range of 0.7 – 1.3 imply that the scale is adequately assuming equal discrimination between items. Although 3 infit statistics exceed this range (indicated in bold) overall the scale performed well. The Rasch reliability, which describes the proportion of the total variance accounted by the model, exceed the minimum acceptable value of 0.7 for each SEC.

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Compliance with ethical standards

Declaration of conflicting interests The authors declare that they have no conflict of interest.

Ethics approval The household survey protocol was approved with approval number G-2019 06 1664 by the KU Leuven Social and Societal Ethics Committee (SMEC) on June 19th 2019.

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