



Rural–urban built food environment disparities in Kenya: Applying ‘vendor neighbourhood’ as a lens for built food environment characterisation

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ABSTRACT

The food environment offers a strategic entry point for promoting healthier and sustainable diets. However, studies on low- and middle-income countries (LMICs) focus predominantly on urban built food environments and use limited methods for assessing food availability and vendor density. This study developed scalable methodologies to assess built food environments: a novel approach for evaluating vendor neighbourhood-level food availability and vendor density, adjusted for population and area. Research was conducted in two contrasting settings in Kenya: Viwandani ward, an informal urban settlement in Nairobi, and Kiima Kiu ward, a rural setting in Makeni County. A total of 1192 urban and 894 rural vendors were geocoded and analysed. Food diversity was assessed at the vendor and neighbourhood levels, at distances of 50m, 100m and 200m radii from any given vendor. Urban vendor density was 118 times higher than rural vendor density, but decreased to 114 times after adjusting for population size. While vendor food diversity was higher ($p < 0.001$) among rural vendors (3.38) than urban vendors (2.58), the vendor neighbourhood food diversity was higher ($p < 0.001$) in the urban (9.16) than in the rural (8.53) built food environment within a 50m radius and beyond. This study highlights the importance of applying population- and area-adjusted density metrics and vendor neighbourhood-level diversity assessments for characterising built food environments in Kenya, typical of LMICs. Our methodological approach provides a replicable framework for guiding policy interventions aimed at improving diet quality through food diversity across both urban and rural settings.

1. Introduction

Food systems in low- and middle-income countries (LMICs) are undergoing rapid transformations, driven by shifts in food environments, which, in turn, shape dietary patterns [1,2]. In particular, diets among both urban and rural populations are transitioning away from traditional, nutrient-dense foods toward highly processed foods, which are energy-dense but nutrient-poor [3–7]. These changes are contributing to a growing burden of diet-related, non-communicable diseases (NCDs) [8]. The food environment, therefore, represents a critical leverage point within food systems for interventions aimed at promoting healthier dietary patterns [9,10].

The food environment serves as the food system interface, where consumers make decisions about acquiring and purchasing food, and comprises both external and personal domains [9,11,12]. According to the Innocenti framework, the external domain includes retail and commercial market vendors, restaurants, and other entities through which consumers obtain food. Key features of this domain include food availability, price, vendor and product characteristics, and marketing practices [7,13]. The external food environment can be further categorised into two broad typologies: the natural food environment, encompassing wild and farm production for own consumption, and the built food environment, encompassing market-based food acquisition [9]. In contrast, the personal domain encompasses individual and

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household factors that influence consumers' interactions with the food environment, including accessibility, (perceived) affordability, convenience and desirability [7,13].

Studies have shown that built food environments influence consumer food choices and consumption in both rural and urban contexts [14–17]. Although many African households engage in farming and produce some of their own food, markets play a pivotal role, contributing over 50% of total food consumption across countries, income strata and agroecological zones [18,19]. Evidence from studies conducted between 2009 and 2019 in Ethiopia, Ghana, Malawi, Niger, Nigeria, Senegal, Tanzania and Uganda indicates that rural households purchase more than 70% of the fruit and vegetables they consume [18,20,21]. This underscores that market purchases account for a significant share of foods consumed, including fruit and vegetables, even in remote, rural environments [22], challenging the common assumption that rural families primarily rely on their own production. These findings highlight the importance of the built food environment in meeting both urban and rural households' nutritional needs.

Despite the growing importance of built food environments in both rural and urban areas, most studies to date have focused on characterising urban built food environments [2,23–25]. This has limited the availability of context-specific data on built food environments for informing interventions related to both urban and rural settings. Research on characterising rural food environments has predominantly focused on how natural food environments (home-grown produce) affect diets, with studies showing mixed results on their contribution to dietary quality [21,26–29]. Expanding these assessments to include rural built food environments is therefore essential for generating insights for promoting healthier diets in both rural and urban settings [30].

Previous studies have also shown that market vendor type is a key driver of food choices and is associated with community-level dietary quality across various LMICs [12]. This association has been attributed to vendor type influencing the type of food offered [31]. However, most food environment studies in LMICs have focused only on selected vendor typologies [25,32–34]. Some have assessed vendor food diversity without identifying specific vendor types or their contributions to overall food diversity within the respective built food environments [4, 24,35]. This gap limits the availability of evidence linking vendor type to food diversity in different built food environments, thereby constraining the development of locally tailored food-environment policy interventions.

Methodological approaches for LMIC food environment characterisation are continually evolving, to better capture local contexts, as most of the existing approaches were originally developed for high-income countries [9,36]. Most of the literature reporting vendor food diversity has characterised the food environment based on the average vendor food diversity or the number of vendors offering a particular food item [4,16,23,24]. However, this methodological approach does not capture the food diversity available within specific vendor neighbourhoods, especially since many vendors in LMICs, particularly in sub-Saharan Africa (SSA), often occur in clusters [16]. Additionally, food acquisition in SSA typically does not rely on a single vendor, but involves visiting markets or shopping centres, where diversity is achieved through different vendors offering an array of foods [16]. Assessing diversity at the vendor neighbourhood level, rather than for individual vendors, may therefore provide more accurate insights into the food diversity available within the different built food environments.

Vendor density has been used as a proxy to assess vendor availability and as an indicator of consumer food accessibility; hence, it can inform interventions aimed at improving food availability [37]. In previous built food environment research, vendor density has been reported as the number of vendors per unit area [37] or as the number of vendors relative to the population size of the surveyed area [38]. However, these approaches do not account for population density within the specific built food environment, but rather consider the area or population

density of the surveyed areas as independent parameters. This makes comparing vendor density between rural and urban built food environments inaccurate, given the population density differences.

Thus, this study highlights four critical research gaps in characterising the built food environments in LMICs, which are the need to:

- (i) Include both rural and urban built food environment contexts in assessments, to strengthen evidence on food availability, its spatial distribution, and who supplies it. This would help unravel the complexities of the built food environment, promote healthy diets, and address malnutrition challenges in these LMIC contexts.
- (ii) Systematically identify all vendor types within each respective built food environment.
- (iii) Account for both population density and vendor area to determine vendor density in a particular built food environment. This would provide a more accurate measure of food availability, especially when comparing built food environments with differing population densities.
- (iv) Develop a methodological approach for characterising food diversity that considers the vendor neighbourhoods within the respective built food environments, to account for the clustered nature of vendors' occurrence in LMICs.

Addressing these gaps will strengthen built food-environment characterisation and support the design of context-specific public health and nutrition interventions. Our study addresses these four critical gaps by developing context-specific indicators that best capture and describe the situation in Kenya, to improve the characterisation of built food environments in LMICs.

2. Methodology

2.1. Study design and location selection

We conducted a cross-sectional market survey (see Section 2.2 for details), which included geo-coding of all food vendors and observational assessment of vendor type and foods on sale in both rural and urban settings [4,24,36,38]. The study was conducted between September and December 2023 in two locations in Kenya: Viwandani ward, an informal settlement in Nairobi County, representing a low-income, urban built food environment, and Kiima Kiu ward in Makeni, representing a rural built food environment. These sites were selected based on the diverse nature of their rural and urban food environment characteristics and as part of a larger project that links farmers from rural communities producing vegetables and fruit through agroecological practices for sale at a market in an informal settlement in Nairobi.

2.2. Data collection

Our data collection tool was adapted from a validated tool used in previous food environment assessment studies in a similar setting [38] and refined by a multidisciplinary team with expertise in food environment mapping tool development (Supplementary material A). This collaborative approach ensured the tool's reliability in comprehensively capturing all foods available within their respective food groups at the vendor level. The tool was then programmed in Open Data Kit (ODK) and deployed on the Alliance FormShare data management platform to ensure data privacy and security [39,40]. Enumerators were selected based on their familiarity with the study areas and the local language to support the tool's application in the field. Enumerators were trained on the tool's content and data collection techniques prior to data collection, to ensure data quality and consistency.

Vendor mapping was based on an administrative approach, where all food vendors present in the respective administrative ward boundaries

at the time of the study were assessed, regardless of their origin [38]. Vendors were defined as individuals selling any food commodity, either exclusively or in combination with non-food commodities [32]. The study identified 12 vendor typologies—Ambulant vendors, Butchers, Cereal shops, Cooked-food street vendors, Direct farmgate sales, Home vendors, Kiosks, Modern restaurants, Mom-and-pop shops, Stalls/Tabletop vendors, Supermarkets, and Wholesalers. It also identified vendor characteristics, in terms of the kind of foods offered and outlet type (Table 1), based on the existing literature and the authors’ knowledge of Kenyan vendors’ characteristics [9,23,25]. The authors added three vendor typologies to those not included in previous studies, but which were relevant to the local food environments being assessed, namely Direct farmgate sales, Home vendors, and Wholesalers.

All vendors within the respective ward administrative boundaries were geo-coded, including ambulant vendors who were geo-coded at the location where the enumerator found them [38]. Each vendor was then categorised into a specific typology. Additionally, enumerators recorded the vendor’s sex, food space at the vendor’s outlet at the time of observation, the food groups sold by the vendor and the individual foods in the respective food groups. A photograph of the outlets was also taken to help classify the vendors [32]. Fig. 1 summarises the methodology used for assessing the built food environment in the study locations.

2.3. Data processing for built food environment metrics

The different food environment indicators we computed to describe the rural and urban built food environments are summarised in Table 2.

First, we categorised the vendors as formal, semi-formal, or informal vendors, based on the (i) type of physical structures from which they operate, and (ii) whether or not they operate in a fixed location. 1) Formal vendors were categorised as operating in permanent structures (fully enclosed structures with a roof and walls); 2) Semi-formal vendors were characterised as operating in semi-permanent structures (with a roof of any kind, without walls or walls covered halfway) in a fixed location; and 3) Informal vendors were identified as mobile vendors operating from no fixed structure [32]. This characterisation deviates from other studies that have characterised vendors as either only formal or informal, based on the legal framework of the country in which they operate [9].

Second, we computed vendor density by dividing the number of vendors within the respective administrative boundaries by the land areas (km²) as defined by the Kenya National Bureau of Statistics [42]. To jointly account for the area covered and population size, we defined exposure as the product of land area (km²) and population size within each study area. Using this denominator, we calculated the vendor exposure density as:

$$\text{Vendor exposure density} = \frac{\text{Vendor count}}{\text{Population size} \times \text{Area (km}^2\text{)}}$$

This metric expresses the number of vendors per unit of combined population–area exposure. It penalises sparsely populated rural areas, where large land areas and small populations yield lower rates, while reflecting both geographic spread and population size.

Third, we computed the food group diversity score to describe the food availability [36,38]. The score was based on the 10 food groups used to compute the dietary diversity scores for women of reproductive age (W-DDS) as used in previous food environment assessments [38,40]. The 10 food groups include: grains; roots and tubers; pulses (beans, peas, lentils); nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruit and vegetables; other vegetables; and other fruits [41]. Foods that did not fall within the 10 W-DDS food groups were categorised as “other foods”, including: mixed foods; oils and fats; snacks; and SSBs. The “Mixed foods” category comprises foods or vendors’ cooked-food dishes that contain more than one food group and was added to more comprehensively represent the built food

Table 1

Categorisation and characterisation of the food vendors in the study locations, based on the existing literature and the authors’ knowledge of Kenyan vendors’ characteristics.

Vendor type/ category	Characteristics	Main food items sold
Ambulant vendors	Do not operate from fixed locations, but move from place to place on the streets and in residential areas. Offer a single or a few food varieties.	Fruit, nuts, sweets and vegetables.
Butchers	Sell animal-source foods, especially raw meat. May cut the raw meat for customers on request.	Beef, lamb, mutton, offal, pork and poultry.
Cereal shops	Operate from permanent or semi-permanent structures. They sell in small quantities based on customer demand. Mostly owned by individuals.	Legumes (beans, cowpeas, green grams and lentils), grains and flour (maize, millet, rice and sorghum).
Cooked-food street vendors	Small, temporary roadside stands, offering cooked foods. Most are set up daily; operating hours are based on the types of food sold.	A diversity of foods from all the food groups.
Direct farmgate sales	Offer fresh produce at the farm gate. Mostly family-owned.	Fruit and vegetables.
Home vendors	Operate within their home compound, mainly in a rural setting and from semi-permanent structures. They offer a variety of products from fresh to processed foods, including non-food items.	Fruit and vegetables, milk, oils, salt, sifted maize, sugar, and sugar-sweetened beverages (SSBs).
Kiosks	Offer over-the-counter service with a minimal variety of both food and non-food items. They sell in small quantities. They are mostly individually owned. Operate mostly in semi-permanent structures.	Fats and oils, milk, sifted maize salt, sugar and wheat flour.
Modern restaurants	Offer cooked, ready-to-eat dishes and/or set meals. They operate in permanent or semi-permanent structures. Customers enter the structure and take a seat to eat. Some offer a takeaway service.	A diversity of foods from across all 10 food groups*.
Mom-and-pop shops	Offer over-the-counter service from permanent structures. They sell in small quantities of both food and non-food items. Mostly individually owned.	Fats and oils, milk, sifted maize salt, SSBs, sugar and wheat flour.
Stall/Tabletop vendors	Operate from temporary stands and are mostly individually owned. They shred vegetables for customers on request.	Fruit and vegetables.
Supermarkets	Offer self-service shopping. They offer a wide variety of fresh produce and processed foods, including ultra-processed foods, as well as non-food products. Operate mostly in permanent structures.	Fats and oils, milk, sifted maize salt, SSBs, sugar, and wheat flour.
Wholesalers	Sell food and non-food products in bulk to retailers or directly to customers. They offer lower prices for products sold in bulk. Wholesalers operate in permanent structures.	Fats and oils, milk, sifted maize salt, SSBs, sugar, and wheat flour.

Source: Own presentation based on previous characterisation by Refs. [9,23,25].

*Food group diversity in this study is based on the 10 food groups—grains; roots and tubers; pulses (beans, lentils, peas); nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruit and vegetables; other vegetables; and other fruits—used to compute the dietary diversity scores for women of reproductive age (W-DDS) [43].

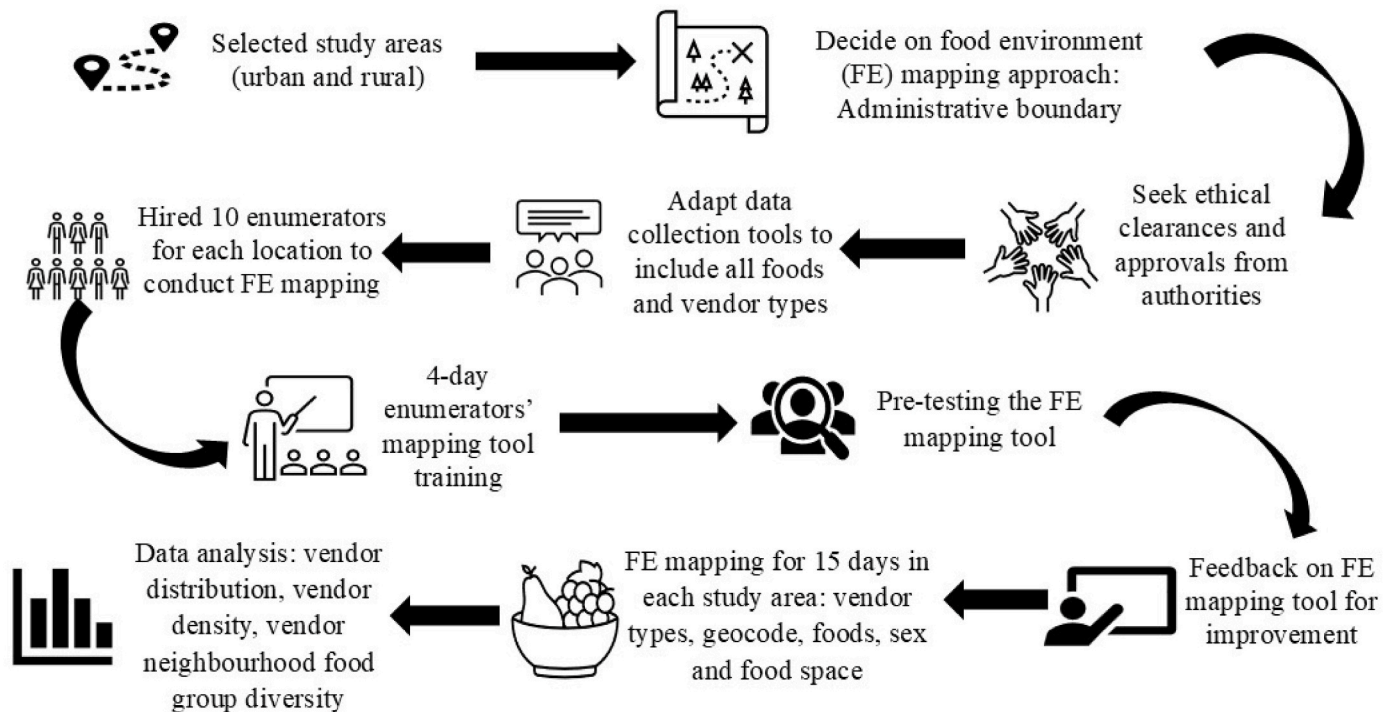


Fig. 1. Process flow of the study methodology applied for assessing the built food environment in the study locations.

environment assessed. These four “other foods” categories were excluded from the food group diversity computation.

Fourth, we used the ‘ProColor’ Produce Colour Diversity Tool to assess fruit and vegetable diversity present within the food environment. The tool categorises and scores fruit and vegetables based on their flesh colour [4,47]. Vegetables are categorised into six colour groups: dark leafy green; other green; red; yellow and orange; purple and blue; and white and brown. Fruits are categorised into five colour groups: green; red; yellow and orange; purple and blue; and white [4]. For vegetables, the maximum score obtainable is six, while for fruits, the maximum score is five. The ProColor diversity score per vendor type was computed to establish which vendor types offer the highest fruit and vegetable diversity. Furthermore, the frequency of the different colour categories of fruit and vegetables sold per vendor type was calculated to help identify which colour categories are lacking in the different food environments.

Fifth, to assess the food diversity within vendor neighbourhoods, we computed vendor neighbourhoods at multiple buffer distances around each vendor. In this context, *vendor neighbourhood* refers to the food diversity available within a specified radius of a given vendor. Using spatial analysis, we examined food environment indicators within buffer radii of 50m, 100m and 200m, calculated from each vendor’s geographic coordinates relative to others. The 50m radius buffer was chosen to represent the immediate built food environment, where purchase cues (including aroma, display, and signs) and point-of-sale outlets influence impulse decisions within the consumers’ immediate visual field [38,45]. The 200m radius buffer was selected because prior studies have shown that households operating within this vendor neighbourhood radius are more likely to purchase a higher diversity of foods [32]. We intentionally also incorporated a 100m radius buffer to assess robustness across multiple scales and to identify the most policy-relevant threshold in settings characterised by dense, street-level retail, which is typical of African markets.

Within each vendor neighbourhood, defined by the three buffer distances, the food diversity indicators were grouped to assess the available food options within that area, using the GeoPandas library in Python [38]. For binary indicators (such as the presence or absence of

specific food groups), we grouped the data by maximum value to indicate whether a specific food group was present within each vendor’s buffer zone. A new column was then generated to record these binary outputs, representing the presence (1) or absence (0) of various food groups or ProColor categories within each buffer zone. Finally, these values were summed to calculate the overall food group diversity and ProColor score for each vendor across the three buffer zones.

2.4. Data analysis

Data analyses were conducted in R 4.4.2. The food environment vendor neighbourhood and the vendor distribution map computations were performed in Python. The R packages used for cleaning and data analysis were dplyr, gtsummary, Hmisc, readxl and stringr [46]. Food environment indicators were stratified by location (urban versus rural). Descriptive analysis included frequencies, means, and standard deviations. Differences between urban and rural food environment indicators were assessed using Fisher’s exact test and Kruskal-Wallis rank sum test.

To compare vendor exposure density between the urban and rural study sites, we applied a two-sample Poisson rate test using the *test_poisson_2indep* function from the statsmodels Python package. Vendor counts were modelled as Poisson-distributed events, with the previously defined exposure term (population size x area) used as the denominator. The test estimated the rate ratio (urban versus rural), along with a Wald z-statistic and two-sided p-value, to evaluate statistical significance. Confidence intervals for the rate ratio were computed using the large-sample (Wald) approximation on the log scale.

Based on the vendors’ GPS coordinates, maps were developed using the Geopandas package in Python to show vendors’ distribution in the respective surveyed built food environments. The data was visualised using tables, bar charts and heat maps, with colour gradients used to highlight variations and support results interpretation.

Table 2

Summary of food environment metrics and indicators computed to describe the rural and urban built food environments.

Metrics	Indicator	Description
Vendor density	Vendor typology	Proportion of ambulant vendors, butchers, cereal shops, cooked-food street vendors, direct farmgate sales, home vendors, kiosks, supermarkets, mom-and-pop shops, stalls/tabletops, and wholesalers operating in the rural and urban food environment.
	Vendor categorisation	Proportion of formal, semi-formal and informal vendors.
	Vendor distribution	Spatial distribution of vendors in the respective geographical areas.
	Vendor exposure density	Concentration of vendors relative to the geographical area and population served by the food vendors.
Vendor neighbourhood	Food group diversity ^a	Diversity of foods offered among the 10 Women's Dietary Diversity Score (W-DDS) food groups, within vendor neighbourhoods within the 50m, 100m and 200m buffer zones. Score count was from 0 to 10, with 1 attributed to each food group counted.
	Vegetable ProColor Score	Vegetable colour diversity within the vendor neighbourhood in the 50m, 100m and 200m buffer zones. Score count was from 0 to 6, one for each vegetable colour counted, based on the CGIAR ProColor score: dark green leafy; other green; red; yellow and orange; purple and blue; and white and brown.
	Fruits ProColor Score	Fruit colour diversity within the vendor neighbourhood within the 50m, 100m and 200m buffer zones. Score count was from 0 to 5, one for each fruit colour counted, based on the CGIAR ProColor score: green; red; yellow and orange; purple and blue; and white.

^a "Food group diversity" in this study is based on the 10 food groups used to compute the dietary diversity scores for women of reproductive age (W-DDS) [41]. These include: grains, roots and tubers; pulses (beans, peas, lentils); nuts and seeds; dairy; meat, poultry and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruit and vegetables; other vegetables; and other fruits.

3. Results

3.1. Vendor characteristics

Most (~71%) of the vendors in both rural and urban built food environments were women (Table 3). A majority (~58%) of them sold only food items. Vendor typology distributions differed significantly between rural and urban settings ($p < 0.001$). Across both environments, the most common vendor types were kiosks, stalls/tabletop vendors, and cooked-food street vendors. The rural built food environment had a higher proportion of formal vendors, whereas the urban food environment had higher proportions of both semi-formal and informal vendors.

Vendor clusters in the rural areas were generally widely separated, while the reverse was noted in urban settings, where vendor concentrations were closely grouped (Fig. 2).

In the urban built food environment, we recorded 1192 vendors across 5 km², resulting in a vendor density of 237.8 vendors per km². In contrast, the rural built food environment comprised 894 vendors spread across a much larger area of 446.2 km², corresponding to a much lower vendor density of 2.0 vendors per km². The vendor exposure density, which accounts for both population and spatial extent, was 5.57×10^{-3} in the urban compared with 4.83×10^{-5} in rural contexts. A two-sample Poisson rate test confirmed that this difference was highly significant, with a rate ratio of 115.5 (95 % CI: 105.9–125.9, Wald $z = 34.22$, $p < 0.001$).

Table 3

Vendor characteristics in the rural and urban built food environments.

Vendor characteristics	Proportion of vendors in percentage		p-value ^a
	Rural N = 894	Urban N = 1192	
Sex^b			0.017
Female	70.69	71.81	
Male	27.18	23.99	
Both male and female	1.57	2.52	
Multiple females	0.34	0.42	
Multiple males	0.22	1.26	
Vendor Food Space^c			<0.001
100 % food space	55.70	58.22	
Between 75 % and 100 %	27.40	26.76	
Between 50 % and 75 %	13.65	8.89	
Between 25 % and 50 %	2.46	4.28	
Below 25 %	0.78	1.85	
Vendor typologies			<0.001
Kiosks	38.81	26.76	
Stalls/tabletop vendors	28.30	25.08	
Cooked-food street vendors	16.89	31.71	
Butchers	4.70	3.36	
Ambulant vendors	2.46	9.73	
Cereal shops	2.46	1.17	
Wholesalers	1.79	1.17	
Restaurants	1.68	0.34	
Direct farmgate sales	1.34	0.08	
Home vendors	0.89	0.34	
Supermarkets	0.45	0.08	
Mom-and-pop shops	0.22	0.17	
Vendor Categories			<0.001
Formal vendors	50.11	33.05	
Semi-formal vendors	46.09	57.13	
Informal vendors	3.80	9.82	
Vendor density			<0.001 ^d
Number of vendors	894.00	1192.00	
Vendor density (vendors per km)	2.00	238.40	
Population density (people per km)	93.00	8554.00	
Vendor exposure density	0.000048	0.0055	

^a Obtained using Fisher's exact test.

^b Sex of the person selling food at the vendor outlet; "both male and female" indicates that the outlet is operated by both male and female persons; "multiple females" indicates that the outlet has more than one female vendor, and "multiple males" indicates that the outlet has more than one male vendor.

^c Vendor food space is the proportion of the outlet space occupied by food.

^d Vendor exposure density was assessed using a two-sample Poisson rate test.

3.2. Food group diversity

Table 4 presents food groups, fruit and vegetable diversity across the respective built food environments. Grains were the most available food group in both rural and urban areas, followed by other vegetables, while offal and fish were the least available food group. A higher proportion of rural vendors offered SSBs and snacks compared with urban vendors. Generally, the proportion of rural vendors availing the different food groups was higher compared to urban vendors, except for fish and mixed foods.

Variability in the diversity of vegetables across rural and urban built food environments occurred mainly at the vendor level. Approximately 43% of rural vendors and 61% of urban vendors offered no vegetables at all. None of the vendors in either setting offered all six colour categories of vegetables. The most common vegetables were white- or brown-coloured vegetables (e.g. cabbage, onions), while purple- or blue-coloured vegetables (e.g. eggplant, purple cabbage) were the least available. Only one urban vendor offered purple- or blue-coloured vegetables, and none were observed in the rural food environments.

Fruit availability was even lower than vegetable availability in both environments. About 69% of rural vendors and 77% of urban vendors offered no fruits. While none of the vendors in the built rural food

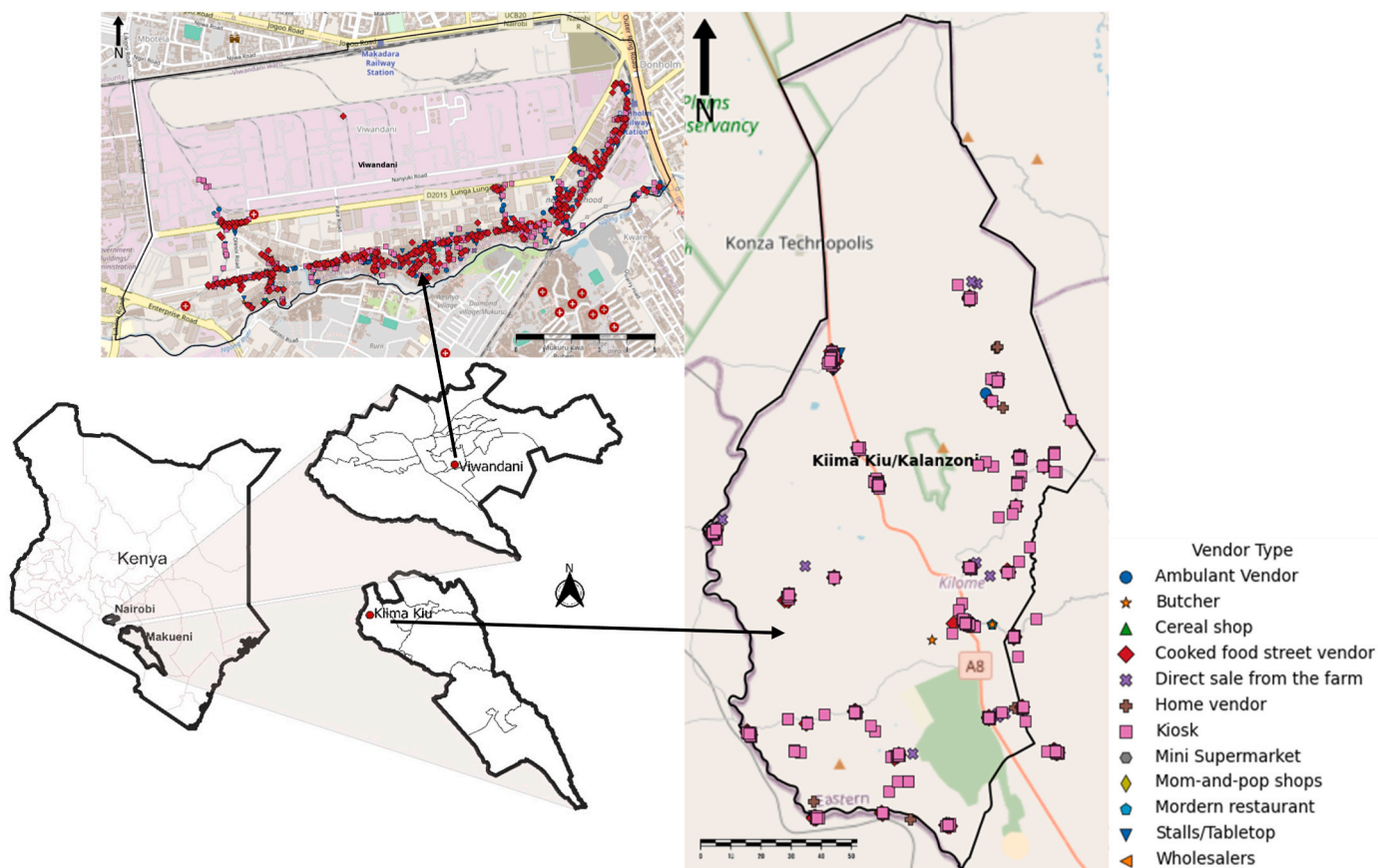


Fig. 2. Map of the selected study areas in Kenya and the distribution of food vendors in the rural (Kiima kiu) and urban (Viwandani) food environments.

environment offered fruits of all five colours, except one vendor in the urban food environment. The most common fruits were white or brown (e.g., bananas), while purple- or blue-coloured fruits (e.g., grapes) were the least available. Only one vendor in the urban areas sold purple or blue fruits compared with none in rural areas.

3.3. Neighbourhood vendor diversity

Fig. 3 shows the vendor diversity within a given neighbourhood, within a 0m, 50m, 100m, and 200m radius. Rural vendors exhibited a significantly higher ($p < 0.001$) mean food group diversity compared to urban vendors at 0m neighbourhood. However, when considering the food-group diversity within a 50m, 100m, and 200m radius of the vendor's neighbourhood, the urban food environment surpassed the rural food environment in terms of food-group diversity. Within a 100m radius, both rural and urban food environments offered more than nine distinct food groups.

The diversity of fruit and vegetables sold by vendors showed similar patterns, exhibiting significantly ($p < 0.001$) low ProColor scores at the 0m vendor level in the rural food environment. However, when considering vendor neighbourhood radii of 50m, 100m, and 200m, the diversity in the urban built food environment significantly increased ($p < 0.001$), surpassing that of the rural built food environments.

Table 5 shows vendor-level food-group diversity, including fruit and vegetables, across rural and urban built food environments at varying vendor neighbourhood distances. Restaurants recorded the highest food-group diversity among vendors in the urban built food environments, while mom-and-pop shops recorded the highest food-group diversity in the rural built food environments. Ambulant vendors showed the lowest food-group diversity in both the rural and urban built food environments. Home vendors and direct farmgate sales in the rural built

food environment seemed to be isolated from other vendors due to a lack of improvement in the vendor food-group diversity within a 200m radius compared to other vendor types.

Tabletop vendors showed a higher diversity of fruit and vegetables among the rural and urban vendors. Butchers and supermarkets sold no fruit or vegetables in the rural built food environment. In the urban built food environment, home vendors and supermarkets did not sell vegetables, while butchers and supermarkets did not sell fruit.

4. Discussion

Overall, the diversity of food, fruit and vegetables offered by the different vendors across all the studied built food environments was very low. Vendors such as supermarkets, mom-and-pop shops and restaurants showed higher food diversity than the other vendor types, but also exhibited the least diversity in fruit and vegetables. At the same time, our results show how quickly the built food environment improves if the vendor neighbourhood is considered compared to the individual vendors. This approach can be applied in various built food environment settings and used for global-scale comparisons to highlight differences in built food environments. The study also highlights the importance of reporting vendor density in relation to the population size served and the area covered in the built food environment. The findings show that the vendor density is high in urban food environments, the population served is correspondingly large. In rural built food environments the opposite is true.,

4.1. Vendor characteristics

Understanding vendor density in the different food environments is essential to understanding the diversity of food availability and

Table 4
Food group, fruit and vegetable diversity recorded in the study’s rural and urban built food environments.

Indicators	Food Category	Proportion of vendors in %		p-value ^a	
		Rural, N = 894	Urban, N = 1192		
Food group diversity^b	Grains	59.17	52.85	0.004	
	Roots and tubers	23.94	16.95	<0.001	
	Legumes and pulses	26.73	17.95	<0.001	
	Nuts and seeds	21.92	11.33	<0.001	
	Dairy	36.69	25.25	<0.001	
	Raw meat	14.99	12.75	0.200	
	Offal	6.38	3.78	0.007	
	Fish	4.81	7.38	0.018	
	Eggs	28.19	25.50	0.200	
	Dark green vegetables	33.89	24.66	<0.001	
	Vitamin A-rich fruit and vegetables	17.56	12.75	0.003	
Other foods^c	Other vegetables	51.12	32.72	<0.001	
	Other fruits	31.10	23.57	<0.001	
	Oils and fats	31.88	16.28	<0.001	
	Mixed foods	9.17	14.26	<0.001	
	Snacks	66.22	44.13	<0.001	
	Sugar-sweetened beverages	39.93	27.52	<0.001	
	Fruit diversity^d	ProColor score			<0.001
		0	69.13	76.85	
		1	12.42	8.14	
		2	9.40	9.23	
3		6.15	5.37		
4		2.91	0.34		
Vegetable diversity^d	Colour diversity				
	White/brown, e.g., banana, pineapple	25.62	18.88	<0.001	
	Yellow and orange, e.g., mangoes	19.13	12.92	<0.001	
	Red, e.g., watermelon, guava	8.84	2.60	<0.001	
	Other green, e.g., avocado, kiwi	7.72	9.98	0.076	
	Purple and blue, e.g., grapes, plums	0.00	0.08	>0.900	
	ProColor score			<0.001	
	0	42.84	60.91		
	1	13.42	10.49		
	2	17.00	10.49		
	3	11.52	7.63		
	4	8.05	7.72		
	5	7.16	2.77		
6	0.00	0.00			
Colour diversity	White/brown, e.g., cabbage, onion	48.32	29.53	<0.001	
	Red, e.g., tomato, beetroot	38.37	27.01	<0.001	
	Dark leafy green, e.g., spinach, cowpeas	33.89	24.66	<0.001	
	Other green, e.g., broccoli, French beans	17.11	9.40	<0.001	
	Yellow and orange, e.g., carrots, pumpkin	12.30	8.47	0.005	
	Purple and blue, e.g., eggplant, cabbage	0.00	0.00		

^a Fisher’s exact test.

^b Food group diversity is based on the 10 food groups for women’s dietary assessment.

^c Any food that does not fall within the 10 food groups for women’s dietary assessment is categorised as “Other foods”.

^d Vegetable diversity assessment is based on the ProColor six-colour diversity for vegetables.

^e Fruit diversity assessment is based on the ProColor five-colour diversity for fruits [4,43,44].

concentration. For comparison, it is essential to evaluate vendor density in relation to the population size and area. To include these elements in reporting vendor density, we computed the exposure vendor density, which encompassed both the area and population covered. By explicitly incorporating both of these elements within a spatial unit, the vendor exposure density more accurately captures the competition intensity for food access in areas where people and vendors are unevenly distributed. This allows for more nuanced comparisons between dense urban neighbourhoods and sparsely populated rural settings, where a simple count per population may obscure meaningful variation. The vendor density may be influenced by consumers’ purchasing power, which is dependent on income (poverty) levels in the different built food environments. In Kenya, poverty levels in urban areas are lower than in rural areas, indicating that urban dwellers have a higher consumer purchasing power [47,48]. This could explain why the exposure vendor density in the urban built food environment was higher than in the rural built food environment. Additionally, even though market purchases are high across rural and urban areas alike, rural households produce more of their own food than urban households [47]. This on-farm production could reduce reliance on market purchases in rural areas, hence, the higher exposure vendor density in the urban built food environment. The vendors across the rural and urban built food environments were mostly women (~71%). This could be because the most predominant vendor types—kiosks, stalls/tabletop vendors and cooked-food street vendors—are mostly operated by women, while the least predominant vendor types, such as butchers and direct farmgate sales, are mostly associated with men in many parts of Kenya and Africa at large. These findings are similar to those of a study conducted in Tanzania (East Africa), reporting that more women sold foods, particularly vegetables, in the urban settings [32]. Another study in Ghana (West Africa) also reported that more women were involved in selling street foods compared to men [49]. Women provide vital services in the built food environment, particularly by selling cleaned, chopped vegetables, which reduces households’ food preparation time. Such a built food environment convenience influences whether households opt for purchasing nutrient-dense or nutrient-poor foods [50]. Policymakers should therefore consider the services associated with consumer choices related to healthy/unhealthy food consumption when designing policies to promote healthier diets.

The high presence of cooked-food street vendors may suggest a high dependence on ready-to-eat, pre-cooked or convenience foods, especially among urban/city dwellers, who may have less time available for meal preparation [51,52]. Cooked street foods could also be cheaper than home-prepared food [53]. Therefore, regulatory agencies should take a keen interest in ensuring food safety among street vendors selling cooked food, who continue to face significant food-safety challenges across various African countries.

It is striking to note that the rural built food environment had a higher proportion of formal vendors compared to the urban built food environment. This suggests that in rural built food environments, vendors tend to prefer permanent structures for their operations. Most of the vendors in both rural and urban built food environments were semi-formal and informal vendors, highlighting their importance as a food source. These results align closely with those reported in Tanzania for urban vendors [32]. These semi-formal and informal vendors played a crucial role in providing fruit and vegetables in both rural and urban built food environments. This aligns with findings from previous studies, which reported informal vendors’ contributions to providing consumers with fruit and vegetables [32,54]. Our vendor categorisation differs from previous studies, which used the legal framework as the basis to categorise vendors [9]. Our results indicate that the legal framework may not apply to local built food environments in many LMICs. This is because vendors in many African countries often operate without being registered as licensed business entities, despite paying taxes to their respective governments. We therefore posit that the vendor outlet structure and mode of operation can be a universal way to characterise

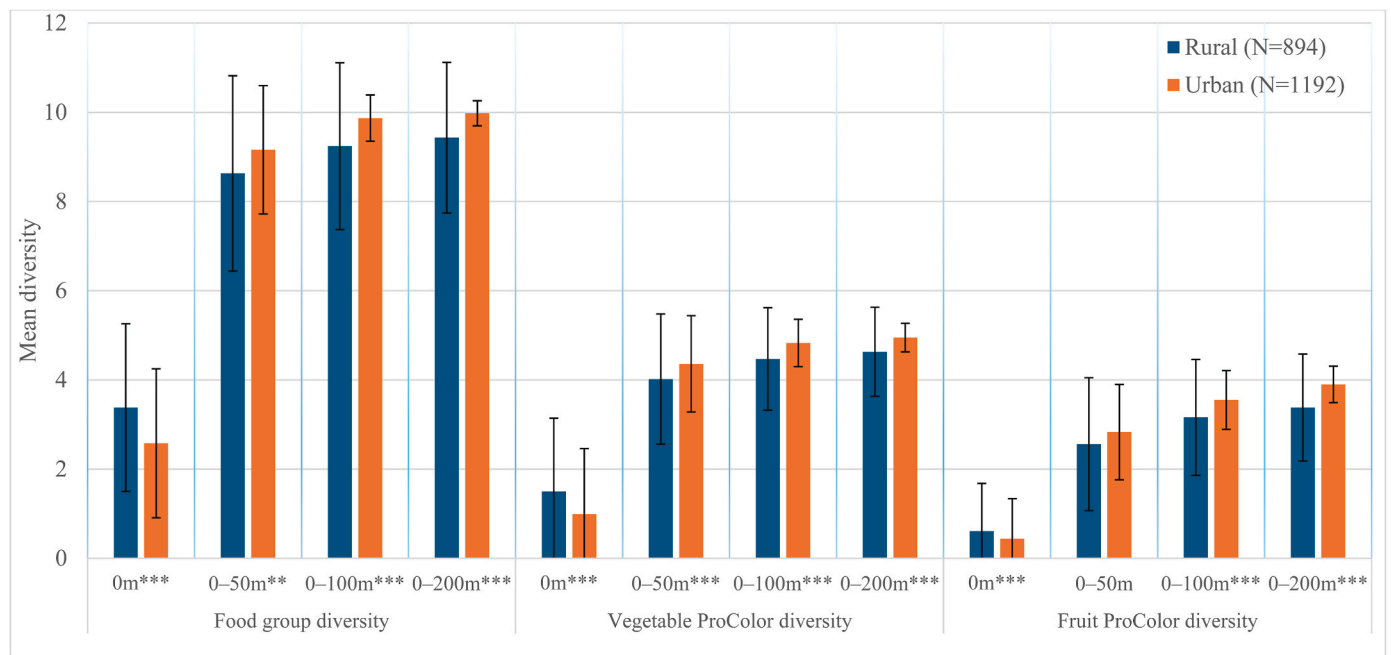


Fig. 3. Food group, vegetables and fruits diversity at different vendor neighbourhood distances in the rural and urban built food environments studied. Error bars indicate the standard deviations.

Food group diversity is based on the 10 food groups for women’s dietary assessment; the vegetable ProColor diversity score is based on six colour diversities for vegetables, while the fruit ProColor diversity score is based on the colour diversities for fruits.

Kruskal-Wallis rank sum test was used to compare the average food group diversity and ProColor score for vegetables and fruits in the rural and urban built food environments at different vendor neighbourhood distances. *** indicates p-value <0.001, ** indicates p-value <0.01, and * indicates p-value <0.05. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Table 5

Food group, fruit and vegetable diversity sold by vendors at different distances to other vendors across the study’s rural and urban built food environments.

Location	Indicators	Neighbourhood distance	Vendor Types												
			Ambulant Vendors	Butchers	Cereal shops	Cooked-food street vendors	Direct farmgate sales	Home vendors	Kiosks	Supermarkets	Mom-and-pop shops	Modern restaurants	Stalls/ Tabletop Vendors	Wholesalers	
Number of vendors			22	42	22	151	12	8	347	4	2	15	253	16	
Rural	Food group diversity (Max = 10)	0	1.1	1.2	2.9	3.8	2.3	3.4	3.9	4.5	5	4.7	3.1	1.6	
		50m	9.2	8.7	8.7	8.8	2.7	3.4	8.2	7.5	10	8.9	9.5	9.1	
		100m	9.4	9.3	9.9	9.6	2.8	3.6	8.9	10	10	9.2	9.8	10	
		200m	9.4	9.4	9.9	9.8	3.4	4.3	9.2	10	10	9.4	9.9	10	
	Vegetable ProColor Score (Max = 6)	0	0.5	0	0.3	1.2	1.4	2.1	1	0	0	1.5	2.8	0.9	
		50m	4.2	3.8	4	4	1.6	2.1	3.6	2.5	5	4.2	4.8	4.5	
		100m	4.5	4.4	4.9	4.6	1.7	2.3	4.2	5	5	4.5	4.9	5	
		200m	4.6	4.5	5	4.7	2	2.6	4.5	5	5	4.7	5	5	
	Fruit ProColor Score (Max = 5)	0	0.2	0	0.4	0.2	0.5	0.8	0.4	0	0.5	0.2	1.4	0.3	
		50m	3.1	2.2	2.7	2.3	0.7	0.8	2.1	2	3.5	2.7	3.4	2.9	
		100m	3.5	3.1	3.4	3.1	0.7	0.8	2.8	4	4	3.3	3.7	3.7	
		200m	3.7	3.2	3.8	3.4	1	0.9	3.1	4	4	3.5	3.9	3.9	
Number of vendors			116	40	14	378	1	4	319	1	2	4	299	14	
Urban	Food group diversity (Max = 10)	0	1.1	1.2	2.9	2.4	4	2	3.1	5	4	5.3	3	2.1	
		50m	8.6	9.7	9.7	9.2	5	9.3	9.2	10	10	8.5	9.2	9.4	
		100m	9.8	10	9.9	9.9	10	10	9.8	10	10	10	9.9	9.9	
		200m	10	10	10	10	10	10	10	10	10	10	10	10	
	Vegetable ProColor Score (Max = 6)	0	0.4	0.1	0.1	0.6	3	0	0.5	0	2	1.5	2.4	0.1	
		50m	3.9	4.8	4.7	4.4	4	4.3	4.3	5	5	3	4.5	4.6	
		100m	4.8	5	4.9	4.8	4	5	4.8	5	5	4.8	4.9	4.9	
		200m	5	5	4.9	4.9	5	5	4.9	5	5	5	5	5	
	Fruit ProColor Score (Max = 5)	0	0.6	0	0.1	0.1	0	0.5	0.2	0	0	0.3	1.2	0.1	
		50m	2.9	3	3.1	2.8	2	2.5	2.6	3	4	1.3	3	2.9	
		100m	3.7	3.6	3.5	3.5	3	3.5	3.4	4	4	2.5	3.6	3.6	
		200m	4	3.9	4	3.9	3	4	3.8	4	4	3.8	4	3.9	

Food group diversity is based on the 10 food groups for women’s dietary assessment; the Vegetable ProColor Score is based on the six-colour diversity for vegetables, while the Fruit ProColor Score is based on the five-colour diversity [4,43,44]. The chart colour gradients range from red, indicating low diversity, to yellow, indicating medium diversity, to green, indicating high diversity.

vendors in LMICs.

The vendor distribution map (Fig. 2) shows a clustering of vendors in the rural food environment at specific locations. This means some

consumers must walk long distances to the clusters to purchase food, which, in some cases, can be associated with physical fitness, hence better health outcomes [55]. However, the distances may also limit

access to food, especially during adverse weather conditions, due to poor road networks that are prevalent in most rural communities across Africa. We observed that the vendors were mostly clustered far away from households, while food for urban dwellers was more easily accessible, as vendors were fairly evenly distributed and close to households. Research from SSA consistently demonstrates that market access has a significant influence on households' dietary diversity and food security. Studies in Ethiopia show that households located closer to market centres consume more diverse foods and spend more on food consumption compared to those further away [56,57]. Similarly, analysis of nationally representative data from Ethiopia and Tanzania confirms that proximity to markets is associated with higher consumption expenditure, greater dietary diversity, and reduced food insecurity [57]. However, the relationship varies depending on the local context and household characteristics. These findings suggest that infrastructural investments to improve rural road connectivity and market accessibility are essential for enhancing food security.

4.2. Food diversity

Sugar-sweetened beverages and salty snacks, which are considered unhealthy due to their high content of sugar, salt and oils [58,59], were significantly present in both rural and urban built food environments. Our study results indicate that these foods are increasingly prevalent in rural built food environments. Other studies conducted in LMICs, including Brazil, Côte d'Ivoire, Ethiopia, Malawi, Mali, Mexico, Niger, Nigeria, Senegal and South Africa have also reported an increased presence of ultra-processed foods in the rural built food environment. These indicate a negatively transitioning food environment in both urban and rural areas in LMICs [22,60]. Studies in similar settings suggest that accessing healthy processed food remains challenging, highlighting the prevalence of ultra-processed foods [61]. However, the increasing prevalence of these foods could exacerbate NCD-related outcomes in the respective food environment [60]. Therefore, undertaking comprehensive studies to assess the concentration of unhealthy foods within different built food environments could be used to inform policy and interventions aiming to replace them with alternative healthy options.

Some of the reasons for the increased presence of SSBs include the growing number of retail outlets across both urban and rural areas, such as supermarkets and kiosks, which often primarily sell processed foods [62]. In the rural areas studied, increased consumption of SSBs can be associated with a limited variety of food options available, leading to a greater reliance on SSBs for energy. One study pointing to this fact reported that processed foods may contribute to improving children's dietary diversity scores, particularly in local food environments where food variety is limited [16]. This suggests that processed food may play a compensatory role in contexts with limited food diversity. For example, a study conducted in Bolivia associated increasing SSBs availability in rural areas with climate-driven desertification, which has reduced diverse farm production, leading to increased market purchases of cheap, processed foods [63]. In addition, the increasing prevalence of SSBs can also be associated with a nutrition transition from wholesome, nutrient-dense foods to cheap, energy-dense foods such as SSBs, across both rural and urban contexts [3–7].

Individual vendors in the rural built food environment exhibited a greater diversity in foods sold compared to those located in the urban contexts, suggesting that urban vendors may be more specialised in what they sell, hence offering lower diversity than rural vendors. Additionally, due to the limited number of vendors in the rural built food environment, the vendors may tend to stock a wider variety of foods to compensate for what is lacking in their neighbourhood. Nonetheless, the diversity offered by individual vendors was generally low in both rural and urban built food environments. The vendor diversity significantly increases when examining vendor neighbourhoods in the respective food environments. This helps to clarify the overall food environment's

contribution to food diversity, rather than relying solely on the vendors' average food diversity. Different authors have focused solely on average vendor diversity and overlooked the neighbourhood's impact on food availability in built food environments [4,16,23]. Although vendors in the rural built food environment showed individual higher diversity, the urban vendor neighbourhood showed greater diversity. This may indicate that average vendor diversity is not an accurate method for characterising built food environments. The vendor neighbourhood approach appears to be a more robust method for characterising the food diversity present in built food environments.

The vendor neighbourhood analysis also showed that home vendors and farmgate sales in rural built food environments are usually isolated from other vendor types. This suggests that these vendor types play a key role in providing food in areas where households are unable to access other types of vendors. Initiatives targeting these vendor types could offer a viable strategy to promote healthy food distribution in remote areas where market accessibility is a challenge.

ProColor diversity scores offer a unique and effective method for assessing fruit and vegetable diversity within a given built food environment. In both rural and urban built food environments, the higher number of vendors selling vegetables rather than fruit suggests that vegetables are more readily available than fruit. This also suggests a strong demand for vegetables among consumers, with many households relying on markets to source them [20,21]. Overall, fruit and vegetables were more readily available in urban than in rural built food environments. This finding mirrors those reported from 18 countries, cutting across high-income, upper-middle-income, lower-middle-income and low-income countries, which reported greater availability of fruit and vegetables in urban than in rural areas [64]. However, overall, fruit and vegetable availability was low among the LMICs, resulting in low consumption of this food group in LMICs.

Our findings show that the highest ProColor diversity was observed among tabletop vendors in both rural and urban contexts. Despite supermarkets showing high food-group diversity in both rural and urban areas, they recorded zero ProColor diversity, indicating that they do not sell any fruit or vegetables. These findings mirror those reported in a similar setting, which reported more fruit and vegetable availability among tabletop vendors and open-air markets [23]. With the increasing presence of supermarkets across the African region [62], it is becoming increasingly important to ensure a continuous supply of fruit and vegetables through these outlets. Vendor-type diversity, therefore, provides insights into the different types of foods that could be available in the built food environments. Policymakers can harness these insights to develop policies aimed at transforming built food environments to provide healthier food options, particularly greater fruit and vegetable availability in rural built food environments. However, the interventions need to be context-sensitive, combining supportive strategies such as training and provision of infrastructure in combination with the gradual introduction of regulatory frameworks. Such approaches may minimise unintended adverse consequences and ensure continued food availability.

Among the different colour diversity, purple/blue-coloured fruit and vegetables were the least available, indicating a low availability of anthocyanin-rich food sources. Other studies conducted in Kenya and the UK, among socially deprived populations, also reported similar findings [4,65]. Low availability of anthocyanin-rich food may lead to nutritional inadequacies in the population and heighten the potential for diet-related health risks, particularly NCDs. This underscores the need for interventions such as promoting local, neglected and underutilised fruit and vegetable varieties, thereby enhancing the anthocyanin availability and supporting greater agrobiodiversity.

Low consumption of fruit, legumes, nuts and seeds, vegetables, and whole grains, together with high consumption of red and processed meats, has been reported as contributing to one of the greatest health burdens in most regions, including LMICs [58,66]. Globally, approximately 60% and 50% of the population consume less than the

recommended quantities of fruit and vegetables, respectively, based on WHO recommendations. Legume and nut intake is also more than two-thirds below the recommended daily serving [66]. In LMICs, over 80% of individuals aged 15 years consumed fewer fruits and vegetables than the recommended levels [67]. Additionally, the availability of and accessibility to fruit and vegetables in LMICs is associated with reduced malnutrition risk [38]. These realities underscore the need to monitor the built food environment to ensure that healthy foods, such as fruit, legumes, nuts and vegetables, are readily available and accessible to consumers. The ProColor diversity score and food-group diversity assessment provide the basis for policy formulation that promotes foods with sub-optimal intake levels and reduces those that are consumed in excess of optimal levels. This may exert a greater impact than current policy interventions, which primarily target sugar and fat consumption. This underscores the urgency for comprehensive food system interventions to promote the production, distribution, sale and consumption of healthy foods while limiting the availability of unhealthy, ultra-processed options. Achieving this paradigm shift requires collaboration among food system stakeholders, alongside policies that address multiple sectors of the food system.

4.3. Study limitations

The study did not include data on the *natural food environment*, which may be particularly important for vulnerable families living in rural communities. However, the current study's focus on the built food environment is justified as it significantly contributes to household dietary consumption and consumer choices in both rural and urban communities [18,19].

Due to its cross-sectional design, this study was unable to capture *seasonal variations* in food availability. Nevertheless, this limitation is unlikely to substantially affect the study's validity, as built food environments often buffer seasonal effects by providing year-round access to alternative food items. While some foods may be seasonally unavailable, others remain accessible year-round, ensuring relative stability in food availability except under extreme weather conditions such as droughts or flooding.

The food environment assessment, including vendor classification, relied on enumerator observations, which may introduce potential bias, despite the use of standardised tools. To mitigate this, enumerators were trained, and the tools were pre-tested to enhance consistency and accuracy in data acquisition. However, as data represent a single time-point, temporary or itinerant vendors—who often operate seasonally or irregularly—may not have been adequately captured.

This study focused on food availability and vendor characteristics, excluding individual- and household-level factors such as consumer preferences and purchasing power. These factors strongly interact with vendor diversity to influence actual food access and consumer choices. Nevertheless, the study's primary aim was to characterise the built food environment as an indicator for food availability.

Finally, this study captures data from two wards in Kenya, which may limit the findings' applicability to other regions of the country or to rural and urban settings in other LMICs. Nonetheless, these case studies highlight patterns that may reflect broader dynamics in rural and urban Kenyan environments. Further research across multiple and more diverse contexts is needed to validate and strengthen these findings.

5. Conclusion

This study contributes to advancing food environment research by introducing vendor neighbourhood food availability as a systematic approach for assessing food diversity. Unlike single-vendor assessments, this method captures the collective contribution of multiple vendors. It thus provides a more realistic measure of availability of both healthy and unhealthy foods. By applying this approach in both urban and rural Kenya, the study challenges the common urban bias in food environment

assessments and shows that rural areas are also experiencing a rapid nutrition transition, with a high prevalence of ultra-processed foods such as SSBs. Ignoring rural built food environments risks generating partial evidence and undermining the design of interventions that must be effective across diverse settings.

Methodologically, the study introduces a novel vendor density metric that integrates area, population size and vendor presence into a single indicator. This holds potential for cross-context comparisons, thereby strengthening the evidence base for designing targeted and more equitable interventions. By combining methodological innovation with empirical insights, the study provides a framework that is sensitive to local realities yet adaptable across diverse contexts.

The findings highlight the urgency of strategies that simultaneously expand access to healthier food groups and address the rising penetration of unhealthy products in both urban and rural areas. Future research should focus on validating the vendor density threshold across contexts, linking food environment measures with dietary and health outcomes. Monitoring how urban and rural vendor neighbourhood dynamics evolve over time through longitudinal studies also needs to be prioritised. Such work will deepen the evidence base for policies that aim to foster healthier, more resilient food environments for all populations.

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Nicanor Obiero Odongo: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Tosin Harold Akingbemisilu:** Software, Formal analysis. **Irmgard Jordan:** Writing – review & editing, Funding acquisition. **Sam Bodjrenou:** Writing – review & editing. **Juliana Kiio:** Writing – review & editing, Supervision. **Ramona Teuber:** Writing – review & editing, Supervision. **Céline Termote:** Writing – review & editing, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jafr.2025.102434>.

Data availability

The dataset underpinning the findings of this study has been published and is openly accessible through Harvard Dataverse [68]. Making the dataset publicly available enhances transparency and allows for replication, secondary analyses, and comparative research on retail food environments in Low- and Middle-Income Countries.

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