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HD4A Healthy Diets 4 Africa

Combating Malnutrition in Africa Through Diversification of the Food System

HealthyDiets4Africa

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Deliverable Name: Food Environment Maps of Distinct Geographical Areas, Urban and Rural

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Introduction

Food environment is defined as the collective physical, economic, political and socio-cultural surroundings, opportunities and conditions that influence people's food and beverage choices and nutritional status (Swinburn et al. 1999; 2013). According to other definitions food environment is the interface that mediates people's food acquisition and consumption within the wider food system, or it is where consumers make decisions about which foods to acquire, purchase, and consume (Turner et al. 2018). Overall, food environments comprise the foods available to people in their surroundings as they go about their everyday lives and the nutritional quality, safety, price, convenience, labelling and promotion of these foods (FAO 2016; Herforth and Ahmed 2015).

The food environment is classified as having four types of food sources and these include wild harvested foods, own production, market-based food sources and transfers such as gifts and donations (Figure 1) (Turner et al. 2018). From this classification, food sources can be grouped into either market-based or non-market-based food sources.

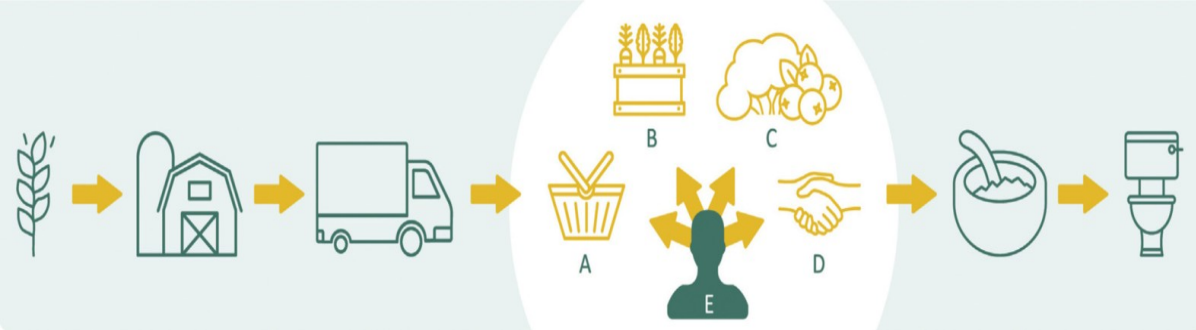


Figure 1: Placing food environment within the food system (Turner et al. 2018)
The Centre depicts food environment and how consumers acquire food from 4 different sources: A) Market sources (Built food environment); B) Own production (Natural food environment); C) Wild harvested food (Natural food environment); D) Food transfers (Built food environment); E) Individual mobility.

Market-based food sources are described as a built food environment and include both formal (e.g., supermarkets, hypermarkets, online vendors, restaurants) and informal markets (e.g., open-air markets such as farmers' markets, wet markets, street vendors, kiosks, mobile vendors) (Pingault et al. 2017; Downs et al. 2020a). The built food environment is more important in High-Income Countries, where most consumers fully depend on markets to access food (Downs et al. 2020a). In Africa, it is estimated that 80% of food produced goes through formal food supply chains, and 60% of the food produced is consumed in urban areas. Thus,

the built food environment is the main source of food in urban and peri-urban areas in developing countries, accounting for about 80% of all food costs in Uganda for example (Dolislager et al. 2022). Non-market-based food sources, such as own production and wild-harvested foods are grouped as natural food environments. Non-market based food sources are important when considering food environment in Low- and Middle-Income Countries (LMICs) and in some urban food environments, for example in the form of urban agriculture (Downs et al. 2020a). The natural food environment plays a key role in LMICs, especially in the rural settings that are typically characterized by limited food availability and accessibility, with many people acquiring at least part of their food from own production, wild harvested foods and in-kind transfers and gifts (Turner et al. 2020). However, in Africa, urbanization is rapidly ongoing and it is estimated that by 2050 about 60% of the population in Africa is living in urban areas (United Nations 2024), increasing the need for a healthy built food environment.

The food environment from the socio-ecological perspective is identified as having two main domains, i.e., an external domain and a personal domain. The external domain is defined as a collection of opportunities and constraints that are 'out there' within a given context, and includes dimensions such as food availability, prices, vendor and product properties, and promotional information. The personal domain, on the other hand, is defined as a set of individual-level dimensions that includes food accessibility, affordability, convenience, and desirability (Turner et al. 2018).

The food environment has an important role in population health by influencing food choices and making foods available (Osei-Kwasi et al. 2023). A changing food environment is implicated as a primary contributor to the increasing levels of non-communicable diseases (Branca et al. 2019). Several studies show that ensuring and promoting healthy food environments can address the problem of obesity and improve consumers' diets, while unhealthy food environments predispose people to unhealthy diets and energy over consumption (Nishida et al. 2004; Story et al. 2008; Alston et al. 2021; Gupta et al. 2022). For instance, lifestyles that involve greater difficulties in accessing food at home or food prepared at home (cooking and eating from home) are increasingly linked to the consumption of processed foods (including ultra-processed foods), particularly in rural and urban poor households, which is linked to the kinds of foods these people are exposed to away from home (Dolislager et al. 2022). These lifestyles may encompass working-class individuals, informal sector urban workers, as well as patients and/or caretakers admitted in hospitals. Furthermore, the effect of food environments on dietary intake has also become increasingly of great focus in the policy sector with the aim of achieving Sustainable Development Goal (SDG) 2 to end

hunger, achieve food and nutrition security, improve nutrition and promote sustainable agriculture (United Nations 2015; Pingault et al. 2017; Scott 2017).

Food environments are partly an outcome of the dynamics in the food supply chain, where consumer demand shapes supply chains and vice versa. Improving access to healthy foods therefore requires not only understanding the dynamics within the food environment but also the supply chains involved. This would allow for the identification of value chain interventions that could lead to improvements in the upstream food environments.

The aim of this deliverable is thus to show the diversity of built food environments for a priori identified sub-populations at risk of malnutrition by presenting maps of different geographical areas. By examining the external and internal food environments and the value chains that feed into these environments (other deliverable in HD4A), the results are envisaged to contribute to the identification of intervention points for designing sustainable and healthy food environments.

Objectives

This deliverable aims to develop context-specific propositions for achieving sustainable built food environments. The data contribute to mixed methods studies and were collected using an observational, semi-quantitative approach to assess food- and nutrition-sensitive infrastructure within selected geographic areas and food environments. The datasets include information on food accessibility, food availability, food safety, as well as on the availability and accessibility of water, sanitation infrastructure, and the natural food environment. Additional data on food diversity and food prices complement existing maps or are planned for future collection. The collected data will be further analysed to generate indicators and indices that describe food environments. This information is crucial for designing targeted policy interventions tailored to different types of food environments. The results will help identify context-specific actions to promote safe, diverse and healthy diets across the various study sites.

Methods

Data collection took place in selected sites in Kenya, Uganda, Ivory Coast and Benin (Figure 2).

Figure 2: Map of Africa indicating selected countries for food environment mapping (red dots indicate the countries where food environment mapping and value chain assessments will be carried out)

Kenya, a member of the East African Community, has the Port of Mombasa, an important seaport that serves not only Kenya but also neighbouring countries such as Uganda. In addition, the capital city, Nairobi, hosts an international airport that functions as key cargo hub for East Africa. In this study, the focus in Kenya was on urban poor settlements in Kisumu and Nairobi, as well as rural areas in Turkana, Busia and Makueni counties using various datasets. The analysis draws on various datasets generated by different projects, in which the authors were either involved in data collection, analysis or the design of research tools. The data collection efforts were supported by different donors. Specifically, the Kisumu data were generated under an EU-funded project, while the Turkana and Busia data were collected through a project funded by BMZ with support from GIZ, Germany. The Nairobi and Makueni datasets were assessed as part of a project funded by Biovision Switzerland. These different datasets were combined to enable comparative analysis across different agro-ecological

zones and urban-rural contexts, providing a broader understanding of food environments and related dynamics in Kenya.

Uganda, which shares borders with Kenya, is also a member of the East African Community. In this project, the mapping focused on the food environment at Mildmay Hospital. “Mildmay Uganda” is a non-governmental organization established in 1998, with its headquarters in Kampala, the capital city of Uganda. The organization specializes in providing comprehensive HIV and AIDS prevention, care, and treatment services. It delivers both quality outpatient and inpatient HIV care and also trains healthcare workers across Uganda and the region in the provision of such care. It also offers integrated health services and technical assistance to organizations and governments within and outside Uganda, as well as training and education courses for over 1,500 professionals per year and has numerous ongoing research projects involving international researchers. The hospital population and its surroundings include visiting patients, admitted patients, students, medical staff, support staff and care takers. Mildmay serves over 105,000 patients (15, 000 at the main site in Lweza and over 95,000 at supported health facilities in eight districts in the Central Region of Uganda). The food consumption patterns of these individuals are susceptible to being influenced by the environment to which they are exposed.

Côte d’Ivoire is a West African country located along the shores of the Gulf of Guinea. It lies between 4° and 10° North latitude, approximately 400 km north of the Equator and about 1,400 km south of the Tropic of Cancer. Located in the heart of Côte d'Ivoire, the city of Bouaké continues to face persistent food security challenges, despite its significant agricultural potential. The priority given to export crops, particularly cashew nuts, has reduced the land and available resources for food crops essential to local diets. This imbalanced agricultural priorities negatively affect nutrition of the population, particularly among children and in schools, where meals are often rare or insufficient (Echanges, 2024). To meet these needs, certain solidarity actions have emerged, such as the distribution of spirulina, to compensate for the missing nutritional intake (Koaci, 2024). In **Côte d'Ivoire** the mapping focused on a market centre in Bouaké with an elementary public school (Paris Bouaké) in the centre. Food provisioning in the elementary public schools with canteens are funded by the government and implemented by the World Food Program (WFP). More than 21,900 students in Côte d'Ivoire consume foods from school canteen programs.

Benin, located in West Africa and bordered by Togo, Burkina Faso, Niger and Nigeria, lies between the Equator and the Tropic of Cancer, along the Gulf of Guinea, similar to Côte

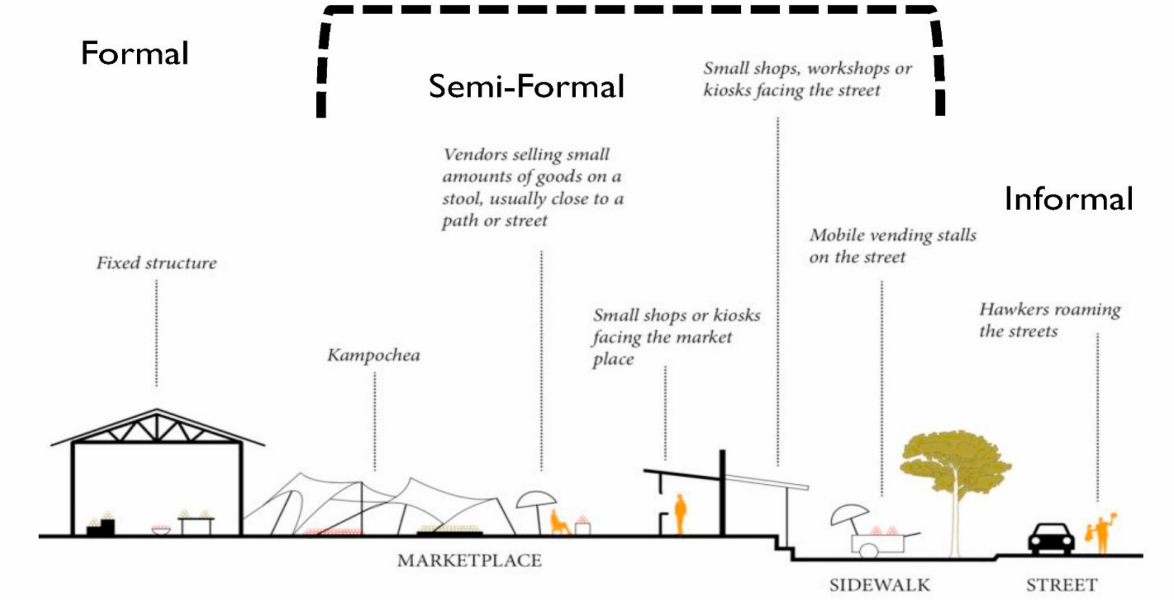
d'Ivoire. The **Benin** food environment maps focus on school food environments in the Atacora Department, a predominantly rural region in Northern Benin. The data were compiled by the FRESH initiative of the OneCGIAR. Two communes were selected for the study: Natitingou (urban) and Boukombé (rural). In each commune, the largest secondary school, based on student enrolment, was identified, and its food environment was mapped using GPS coordinates within a one-kilometre radius. Additionally, data were collected in the Littoral Department, specifically in its capital city, Cotonou, which is Benin's largest city and main economic hub. The city's economy is largely driven by trade (MEPD 2019). Cotonou's food environment is undergoing a dietary transition, characterized by the growing dominance of fast food and processed foods (Houngla 2020).

Food environment mapping and assessment

In all selected geographical areas, all food vendors were geo-coded, and the foods they offered were listed according to the food groups relevant to a healthy diet. In a few sites, the ProColor Tool was used to gain a deeper understanding of the diversity of fruits and vegetables offered at the vendor level. The colours of the fruits and vegetables indicate different bioactive plant components that are important for a healthy diet. The assumption is that the more colours are present at vendor level, the more likely it is that these nutrients are accessible to consumers.

In **Kenya,** food environment data were collected within selected administrative units (e.g. community, ward, settlements). In **Uganda, Côte d'Ivoire and Benin,** the food environment was mapped within a one-kilometre radius of a selected centre (e.g. school or hospital). In Uganda, the chosen centre was Mildmay Hospital. A photo transect survey was conducted to document all the different types of food vendors in each study area. Enumerators then categorized the vendors based on observed characteristics. Vendors were defined as broadly as anyone selling perishable foods, prepared meals or snacks, fresh foods, and/or processed foods. This included street hawkers, bicycle vendors, umbrella/stall/pallet/basket vendors, shops, kiosks, stores, butchers, and supermarkets. The photos collected during the transect survey were later analysed by investigators to refine the typology of vendors. Food vendors in each food environment were further classified according to two criteria: (1) physical infrastructure, and (2) consistent daily location. Vendors operating from permanent physical infrastructure such as cement-built stores and are consistently present in the same location are tagged as formal vendors. Vendors with semi-permanent structures (e.g. wooden stalls and umbrellas), but who maintain a consistent daily location, are categorized as semi-formal

vendors. Mobile vendors who either walk or use bicycles or carts are informal vendors. These three typologies of vendors in the food environment are illustrated in Figure 3 (Ambikapathi et al. 2021).



Formal vendors	Semi-Formal vendors	Informal food vendors
- Fixed structures (super-market, wet market) - Fixed location.	- Semi-permanent structures (umbrella, pallets) - Consistent location daily	- Baskets/Bicycles - Mobile through space and time.
Gender of the vendor 6 types of vendors: 1) Shops, 2) Restaurants, 3) Semi-permanent prepared food vendors, 4) Umbrella food vendor, 5) Butchers, 6) Mobile hawkers		- Gender of the vendor - 31+ Food items sold - Survey length: <1 min
- 3 types of food: cooked, uncooked, both - 8+ types of prepared vendors: sit-down, café, juice bar, bakery, bar, fast-food, takeout only, fresh produce, other - 8 food groups (produce/eggs/dairy, grains, legumes, nuts, meat, ready-to-eat food, unprocessed food, processed food) - 58+ food items (15 produce, 6 grains, 5 legumes, 4 nuts, 7meat/dairy, 13 unprocessed food, 8 processed food) - Survey length: 2-3 mins		

Figure 3: Illustration of food vendors grouped by formal, semi-formal and informal categories (Ambikapathi et al. 2021)

A tablet-based food environment questionnaire was administered by the enumerators while walking. All vendors were geotagged, including mobile vendors that are present at the time of

data collection. Places were visited at least twice during the day to ensure that vendors who are more likely to be available in the morning and those more likely to be available in the evening were captured. Market halls or places with special market days were captured where possible twice, i.e., on the official market day and on a day with limited market activities. The survey consisted of questions on food groups, food items and in some sites also the food safety infrastructure. In selected sites, public water and sanitation systems related to food safety and public food sources such as food trees accessible on public or school compounds were also assessed and geocoded.

ProColor tool

The Produce Color Diversity (ProColor) Tool has been, and continues to be, used to better understand the variety of foods offered by vendors. It provides an objective and rapid method for measuring fruit and vegetable diversity, as well as the presence of phytochemicals, which are associated with a specific color in a food environment (Heber and Bowerman 2001; FAO 2003; Guitart et al. 2014; Ahmed et al. 2019a; Ahmed 2020a). It was developed and primarily invented as a paper- and -pencil or web-based food environment survey that records the type and number of fresh fruits and vegetables in the retail sector based on colour categories (Herforth and Downs 2019). It generates a score that counts the numbers of "colours" of *fruits and vegetables* sold by the vendors in this study. The count does not include beverages, processed foods, meat, grains, nuts and legumes. At the vendor place, the colour of the flesh or edible part of the fruit and vegetables is detected and grouped into one of six colour categories: dark green, other green, red, orange and yellow, purple and blue, and white for vegetables; green, red, orange and yellow, purple and blue, and white for fruits. The number of items and colour categories is used to calculate different diversity measures (Ahmed et al. 2019a; Ahmed 2020a).

Work Done

In **Kenya**, secondary data analysis of food environment data from Kisumu (informal settlement) Busia (rural) and Turkana County (rural, semi-arid and arid area) was used to assess the availability of fruits and vegetables at vendors using the ProColor Diversity Tool. Healthy Food Africa Project, funded by the EU, provided the Kisumu data, while Busia and Turkana food environment maps were generated by the ImproDiet-Co project funded by BMZ with support of GIZ. Viwandani (Nairobi County, Kenya) and Makueni County (Kenya) data were mapped in September to December 2023. Both Viwandani and Makueni data collection were funded

by Biovision Switzerland. In **Uganda**, the food environment of the Mildmay Hospital was mapped by HD4A in November 2023, and analysis is ongoing. Data collection in Bouaké (**Ivory Coast**), also by HD4A, is ongoing and data will be available for analysis at the end of December 2023. Data from **Benin** include the school food environment of two schools in Atacora Department, Northern Benin. Additional sites will be identified in collaboration with other Work Packages and Living Lab leaders in the upcoming years.

The maps differ depending on the project context in which they were developed. However, in a next step, the different data sets were reviewed and aligned to allow for more complex analysis investigation in whether the food environments link with population health outcomes. These results were published by Akingbemisilu et al (2025). The study team showed that observational food environment mapping data is associated with various forms of malnutrition. A summary of the methodologies used is presented below.

First priority was given to test whether information about various built food environments by integrating information on food availability, accessibility, and infrastructure conducive to food safety is associated with populational health outcome data. Second priority was to develop a measure that is a) less costly than existing tools to measure malnutrition risks and b) which can easily be expanded with additional indicators depending on the settings and the objective of the overall study. As a result a nutrition-sensitive food environment index (N-FEI) was designed to serve primarily as a simple, yet robust instrument to inform policy decision-making across diverse settings (Downs et al. 2020b; Akingbemisilu et al. 2025).

Food Environment indicators contributing to the N-FEI index

As described by Akingbemisilu et al. (2025) “The focus was put on indicators describing which food groups are offered by the vendors at which time, their spatial distribution, and whether public water and sanitation facilities are available. In total, nine indicators (Figure 4) were identified to provide a detailed understanding. The selection criteria were that they are i) easy to understand and interpret, ii) linked to indicators widely used in Demographic and Health Surveys (DHS) and other health related consumer surveys, iii) do not require interviews but rely on observations only.” The indicators used are:

(1) Minimum dietary diversity among women (W-MDD) (FAO 2021) a standardized dietary-diversity indicator that is well and widely known to provide the list of healthy food groups at vendor level.

(2) Indicator 1 with a spatial dimension included

(3) The ProColor tool from the Montana State University ProToolBox. It estimates the diversity of vegetables and fruits, focusing on food groups which offer a range of health-beneficial bioactive plant compounds (Ahmed 2020b; Ahmed et al. 2019b; 2021).

(4) Indicator 3 with a spatial dimension included

(5) Access to sanitation facilities to determine if mobile vendors can maintain hygiene, relevant especially for informal food vendors, mobile vendors. .

(6) Vendor availability used as a proxy for accessibility, addressing opening hours,

(7) Vendor density,

(8) Vendor distribution, and

(9) Count of unhealthy foods linked to overweight, obesity, and diabetes.

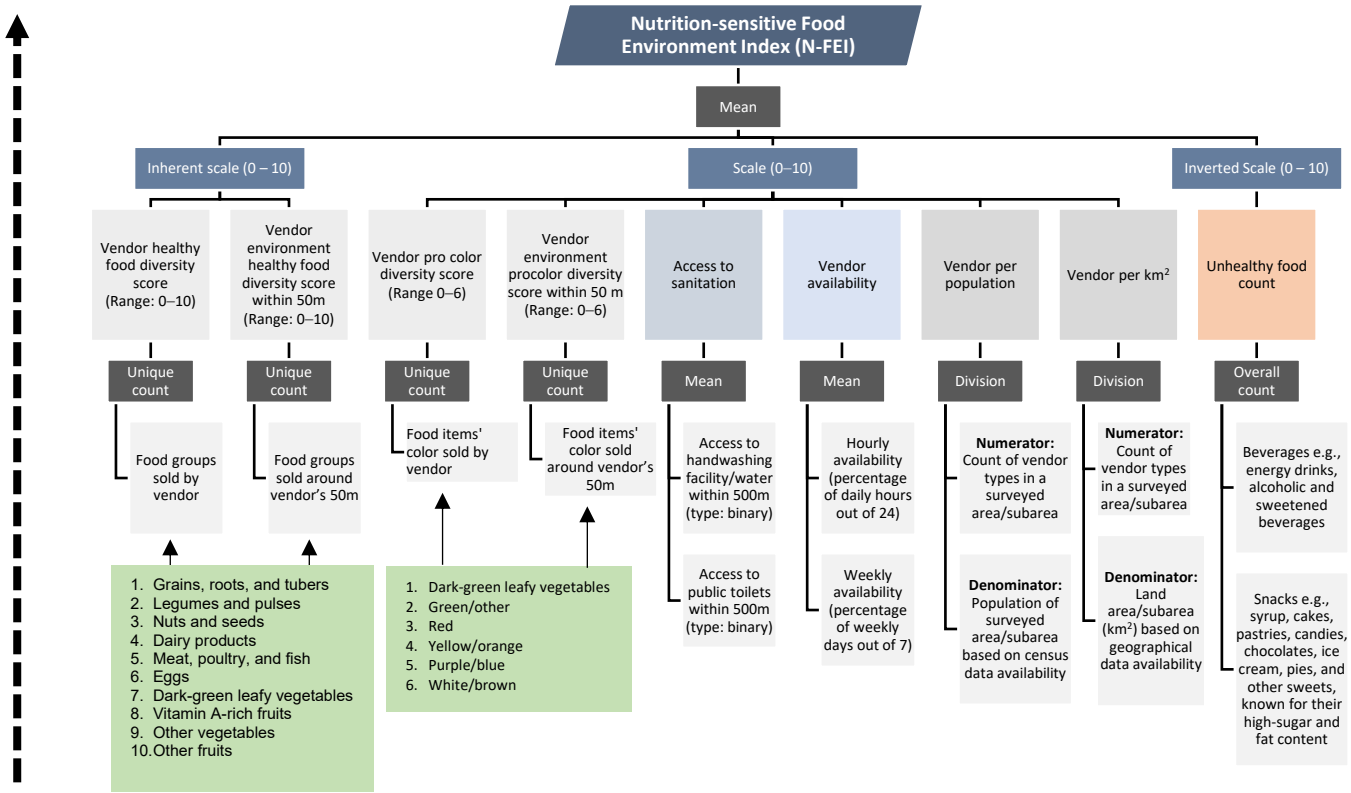


Figure 4:Overview of the nine indicators and scores (*used to compute the Nutrition-sensitive Food Environment Index (N-FEI) (color code for indicators: green is related to healthy food options, blue reflects availability of water and sanitation facilities, purple to vendors' opening hours, gray to the spatial indicators, and orange to unhealthy food options)* (Akingbemisilu et al. 2025)

Results

Food environment map informal settlements in Kisumu, Kenya (HFA funded by EU)

The Healthy Food Africa Project established a Food System Lab in four informal settlements in Kisumu, Kenya. The mapping was part of the project baseline activity and listed more than two thousand vendors in the selected settlements. The most vendors were found in Manyatta A (n= 1,342) followed by Manyatta B (n=907). Obunga and Bandani are much smaller settlements with less vendors (n=423 and n=255, respectively). However, the distribution of the vendors differed between the places (Table 1). In Manyatta and Bandani, the vendors were rather scattered throughout the villages in the informal settlement, whereas in Obunga they were located along the main street (Figure 5). Manyatta A listed the most supermarkets, while in Bandani the number of open-air markets in relation to the total vendors listed in the settlement was highest (12%). In Obunga, more than half of all vendors assessed in Obunga were classified as roadside vendors (55%).

Table 1: Vendor types assessed in four different informal settlements in Kisumu town, 2022 (HFA funded by EU)

Vendor Type	Manyatta A	Manyatta B	Obunga	Bandani	Total
Roadside vendor	576	388	231	84	1279
Kiosk	403	303	104	70	880
Open Air Market	128	74	16	31	249
Street hawker	65	39	29	16	149
Restaurant	70	36	14	17	137
Mobile	59	33	15	8	115
Home	23	25	13	14	75
Direct farm	3	6	0	11	20
Wholesaler	8	2	0	3	13
Supermarket	7	1	1	1	10
Total	1342	907	423	255	2927

Source: van der Meulen (2023)

ProColor Analysis

According to van der Meulen (2023), of the 2927 vendors who were assessed in the four informal settlements in Kisumu, 956 (=33%) vendors sold fruit, vegetables, or both. For the purposes of the ProColor analysis, only this subset of vendors, i.e. who sold fruits and vegetables, were analysed. All colour categories (max=6) were represented in Manyatta A, Manyatta B and Obunga, but only 5 in Bandani where no purple and blue fruits or vegetables were offered by the vendors. However, when the scores were averaged,

vendors sold a mean of 7.8 different fruits or vegetables regardless of colour, but only a mean of 2.6 colours per vendor. On average, vegetables had higher diversity scores and colour diversity scores than fruits in all settlements. However, none of the places reached a mean score of 3 or above indicating that most often only 2 or even less different vegetable colour groups and about 1 fruit colour group was offered in the different settlements (Table 2). Most of the residents in the settlement live in rented housing with very limited space to produce own vegetables and fruits. As the vendors offer only limited diversity of vegetables and fruits it can be assumed that the consumption of vegetables and fruits is also limited.

Table 2: Mean colour diversity across all for settlements for vegetable and fruits and overall (HFA, funded by EU)

Informal Settlement	ProColor diversity (max=6)		
	Vegetables	**Fruit**	**Fruits & vegetables**
Manyatta A	2.01	1.02	2.60
Manyatta B	2.18	1.06	2.76
Obunga	2.14	1.05	2.73
Bandani	1.84	0.83	2.36
Overall	2.07	1.02	2.64

van der Meulen (2023)

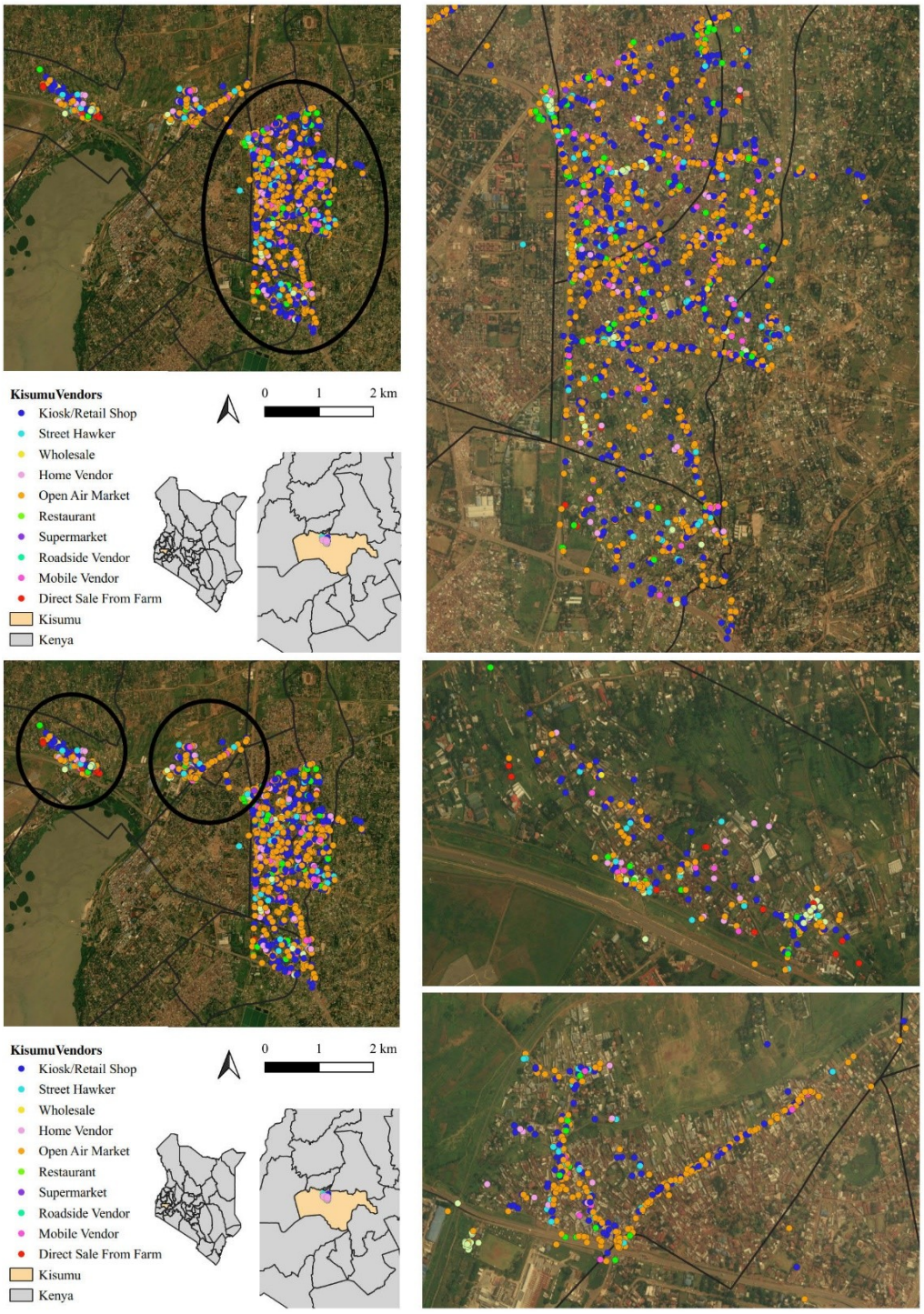


Figure 5: Vendor distribution in Manyatta A and B (top), Bandani (middle) and Obunga (bottom), Kisumu Town, Kenya (HFA project 2022, funded by EU)

Food environment map Busia, Kenya (funded by BMZ with support from GIZ)

In total, 20 communities were selected in Teso North and South, Busia County, by the ImproDiet-Co Project. Out of the 676 mapped vendors (Figure 6), only 334 sold fruits and vegetables with a low color diversity (Figure 7 and Table 3).

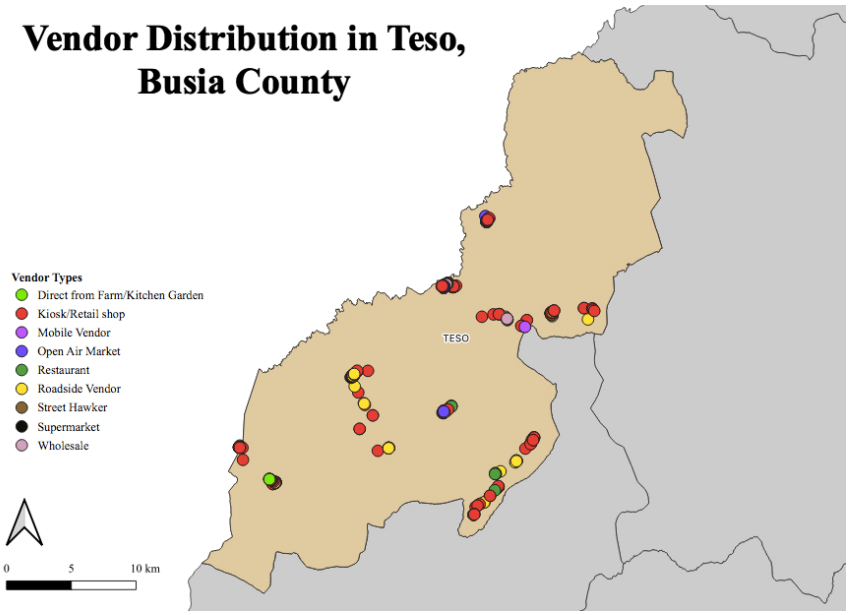


Figure 6: Vendor Type distribution in 20 selected communities in Teso North and South, Busia County, Kenya (ImproDiet-Co Project 2021, funded by BMZ with support of GIZ)

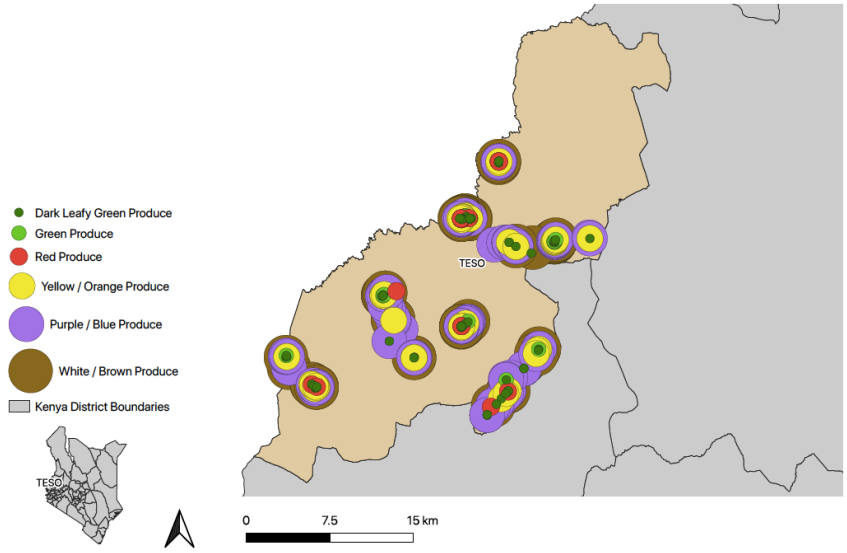


Figure 7: Fruits and Vegetable Diversity in 20 selected communities sold by vendors in Teso North and South, Busia County, Kenya (ImproDiet-Co-Project, 2021, funded by BMZ with support of GIZ)

Table 3: Prevalence of vendors selling fruits or vegetables in 20 selected communities in Teso North and South, Busia County, Kenya (ProColor Tool*, n=334) (ImproDiet-Co Project 2021, funded by BMZ with support of GIZ)

	Number of vendors	Number of vendors, selling any fruits & vegetables[ǂ]	TOTAL Color Category Diversity[$]	Dark Leafy Green (%)	Green (Other) (%)	Red (%)	Yellow/ Orange (%)	Purple/ Blue (%)	White/ Brown (%)
Home**	2	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Wholesale	25	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Supermarket	8	0	0	0.0	0.0	0.0	0.0	0.0	0.0
Street Hawker	19	19	1.5	5.3	10.5	32.6	21.1	5.3	73.7
Open Air Market	208	125	2.3	41.6	12.8	67.2	22.4	60.8	24.8
Mobile Vendor	19	10	1.6	20.0	20.0	10.0	30.0	20.0	60.0
Restaurant	44	31	1.8	90.3	9.7	32.3	12.9	19.4	16.1
Roadside Vendor	187	115	2.7	44.4	20.0	62.6	41.8	52.2	47.8
Kiosk/Retail shop	199	34	2.6	26.5	14.7	82.4	23.5	82.4	29.4
Total incl. home vendor	711	334	1.4	25.3	9.7	31.9	16.9	26.7	28.0
Total excl. home, wholesaler and supermarket	676	334	2.1	32.6	12.5	41.0	21.7	34.3	36.0

*ProColor Tool: Kennedy et al. (2019); dark leafy green: e.g. spinach, amaranth, Ethiopian kale; green (other): e.g. avocado, broccoli, peas; red: e.g. beetroot, guava, strawberry, tomato; yellow/ orange: e.g. Carrots , Apricots, Pineapple, Pumpkin, Sweet Potatoes, Yellow Maize; purple/ blue: eggplant, plums, grapes, blueberries; white/ brown: garlic, onions, dates, mushrooms;
** vendor who sold food at his/her home; ǂ all vendors sell any fruit or vegetable; $ the number of color categories represented by at least one item (max = 6)
Prevalence above 50% have been highlighted signaling the most offered "colors" by the different vendor types.

Food environment map Turkana County, Kenya (funded by BMZ with support from GIZ)

In Turkana, a semi-arid and arid region, ten communities were randomly selected in Loima and Turkana South Sub-County. Lodwar, the County Capital, was included as it functions as a major marketplace for the county (Figure 8).

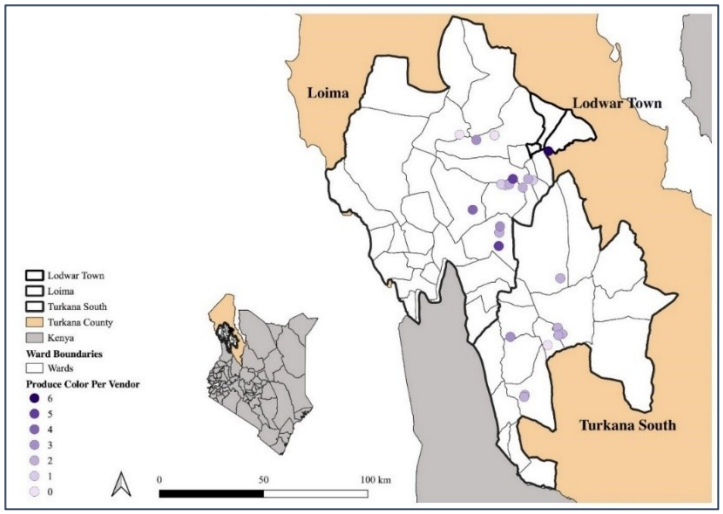


Figure 8: Study site and available number of fruits and vegetables in various "colours" based on ProColor tool in 20 communities in Loima and Turkana South Subcounty, Turkana County, Kenya (ImroDiet-Co Project, 2020, funded by BMZ with support of GIZ)

In total, 384 food and/or drink vendors were mapped, 44% of the vendors offered fruits and vegetables, 42% of the vendors offered dark green leafy vegetables, mainly restaurants (76%) and roadside vendors (65%) (Table 4).

Table 4: Prevalence of vendors selling fruits or vegetables in 20 selected communities in Loima and Turkana South, Turkana County, Kenya (ProColor Tool*, n=170) (ImproDiet-Co Project, 2020, funded by BMZ with support of GIZ)

	Share of female vendors (%)	Number of vendors‡	TOTAL Color Category Diversity$	Dark Leafy Green (%)	Green (Other) (%)	Red (%)	Yellow/ Orange (%)	Purple/ Blue (%)	White/ Brown (%)
Home**	0	1	4.0	100.0	100.0	100.0	0.0	100.0	0.0
Wholesale	12	3	2.3	0.0	0.0	66.7	66.7	0.0	100.0
Supermarket	43	4	4.3	25.0	75.0	100.0	75.0	75.0	75.0
Street Hawker	75	6	1.3	0.0	16.7	33.3	50.0	0.0	33.3
Open Air Market	72	7	2.4	28.6	71.4	85.7	28.6	0.0	28.6
Mobile Vendor	35	14	2.2	28.6	35.7	71.4	14.3	35.7	35.7
Restaurant	62	21	2.4	76.2	33.3	66.7	23.8	23.8	19.0
Roadside Vendor	92	51	3.8	64.7	74.5	74.5	82.4	51.0	31.4
Kiosk/Retail shop	62	63	2.7	22.2	42.9	81.0	52.4	39.7	34.9
Total incl. home vendor		170	2.9	41.8	51.2	**75.3**	54.1	38.2	33.5
Total excl. home vendor		169	2.9	41.4	50.9	**75.1**	54.4	37.9	33.7

*ProColor Tool: Kennedy et al. (2019); dark leafy green: e.g. spinach, amaranth, Ethiopian kale; green (other): e.g. avocado, broccoli, kiwi, peas; red: e.g. beetroot, guava, strawberry, tomato; yellow/ orange: e.g. Carrots , Apricots, Pineapple, Pumpkin, Sweet Potatoes, Yellow Maize; purple/ blue: eggplant, plums, grapes, blueberries; white/ brown: garlic, onions, dates, mushrooms;
** vendor who sold food at his/her home; ‡ all vendors sell any fruit or vegetable; $ the number of color categories represented by at least one item (max = 6)
Prevalence above 50% have been highlighted signaling the most offered "colors" by the different vendor types.

Food environment map Viwandani, Nairobi County, Kenya (funded by Biovision Switzerland)

Viwandani is a densely populated informal settlement within Nairobi County, Kenya. It is characterized by very narrow streets with open drainage system, no or poor access to safe drinking water and sanitation. A total of 1,189 vendors were mapped. Preliminary analysis showed that out of the 1189 vendors mapped, 374 were "cooked food street vendors", 320 vendors were classified as selling from a kiosk, 291 were "Mama mboga shops/ stalls/ tabletop vendors"; 116 were selling foods from a mobile construction like a wheelbarrow; 38 were butchers, 14 were cereal shops. The team also mapped 14 wholesalers, 6 wet markets (open air markets), 4 home vendors, 4 modern restaurants, 4 poultry sellers, 2 "mom-and-pop shops". 1 sold directly from the farm and 1 mini-supermarket in the informal settlement. However, because of the very narrow streets in the residential area, vendors mainly sell on one road (Figure 9-11, 12 top). The same is valid for the built infrastructure regarding public drinking water and sanitation places (Figure 12, bottom). These are often only open during daytime. At

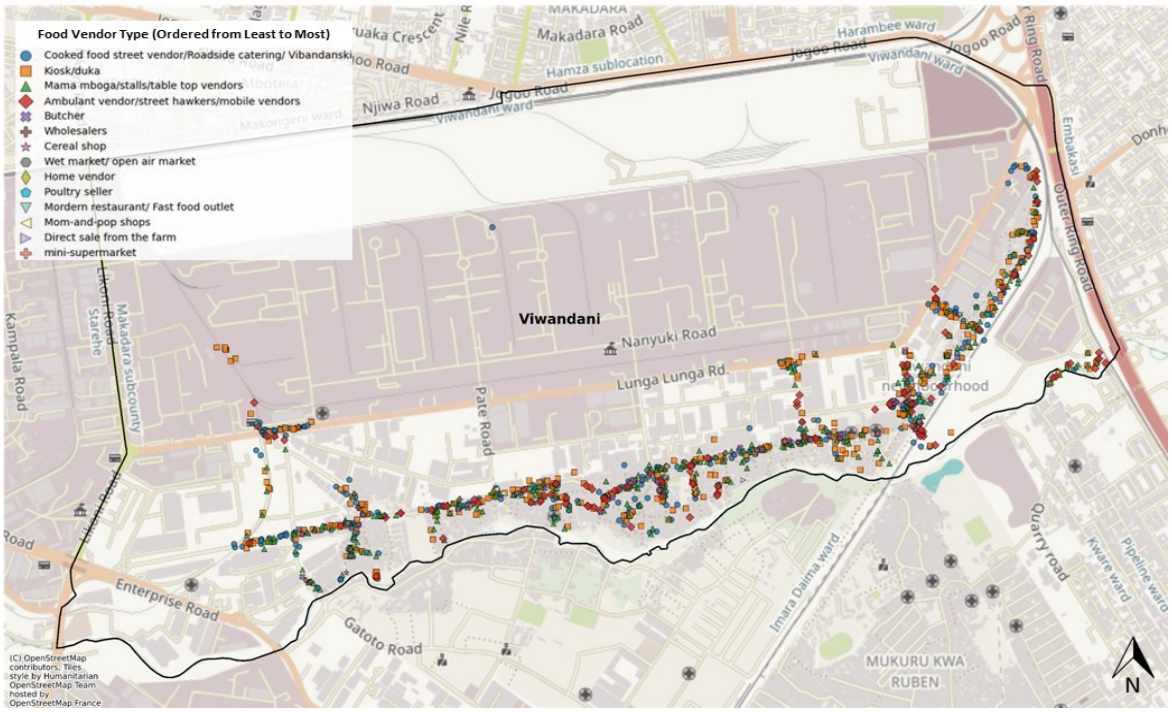
night the residents must find their own means or did rent portable toilet buckets which are collected regularly for making manure. This has implications on hygiene in the overall settlement and subsequently on food safety.

Figure 8: The picture shows Mama Mboga and a road side vendor respectively in Viwandani.

Figure 9: The picture shows Viwandani cooked food vendor kiosk respectively

Figure 10: The pictures show cereal shop and a mobile vendor in Viwandani respectively

Food Environment Mapping (Viwandani Ward, Nairobi County)



Infrastructure Mapping (Viwandani Ward, Nairobi County)

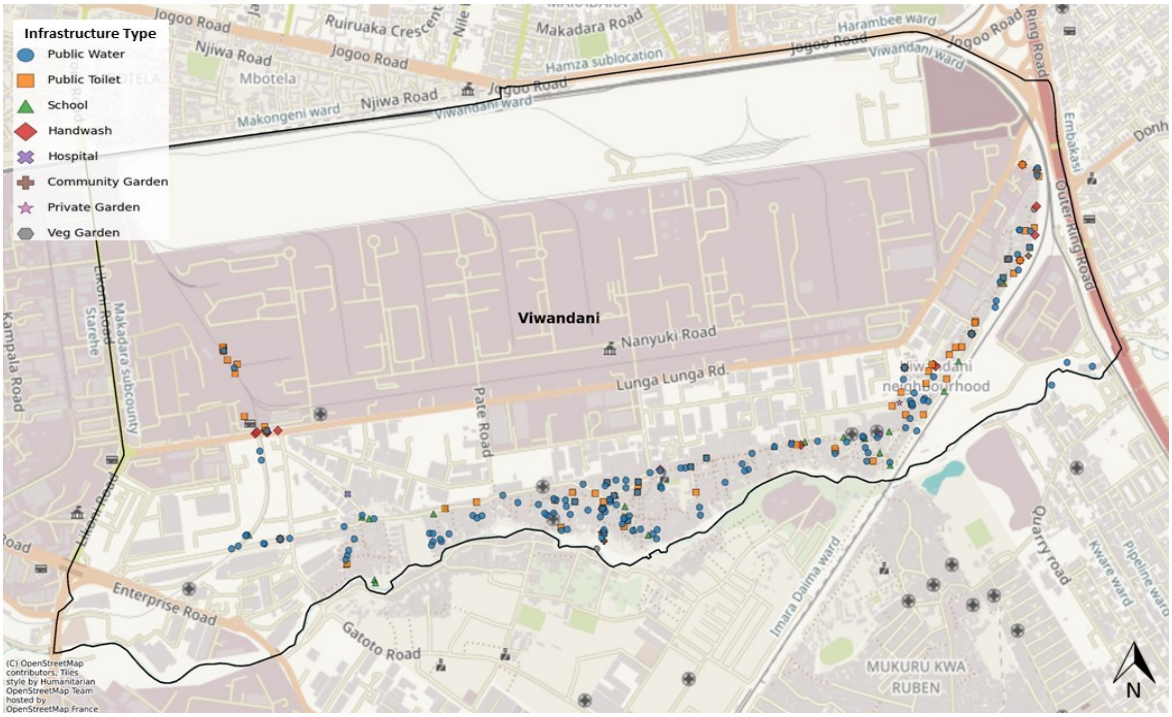


Figure 11: Food environment (top) and infrastructure bottom) map of Viwandani, informal settlement, in Nairobi County, Kenya (funded by Biovision Switzerland)

Hospital food environment map - Mildmay Hospital, Kampala, Uganda (HD4A funded by EU)

The food environment mapping was conducted in a 500-metre radius around the Mildmay Hospital and a main road to an important marketplace, which is one kilometre away from the hospital. “Mildmay Uganda” is a Non-Governmental Organization established in 1998 with headquarters in Uganda’s capital city Kampala which specializes in the provision of comprehensive HIV and AIDS prevention, care, and treatment services. All food vendors within a 500-metre radius were mapped through an observational survey, GPS coordinates were taken and a picture of the premises/ structure of the vendor was taken with the permission of the vendors. The initiative, conducted by five enumerators over seven days, unfolds a dynamic chronicle. Beginning at the crack of dawn (6:00pm) and stretching into the night (10:00pm), the mapping encapsulated varied activities of the vendors, from vegetable and fruit stalls in the morning to late-night fast-food establishments (Figure 13).

Figure 12: A fruit and vegetable vendor on Wankulukuku road, Ndejje division, Wakiso District, Uganda, November 2023

Furthermore, a market mapping was done in Seguku market and Kajjansi market. These are key hubs where patients and communities source their food (Figure 14).

Figure 13: A picture of different market vendors at Kajjansi market, Uganda, November 2023

In total, 337 vendors were captured around the hospital. Out of these 87 were classified as “Mama mboga/ stalls/ tabletop vendors”, 58 Mom-and-pop-shops, 55 mobile vendors using for example a wheelbarrow, 33 kiosks, 23 cooked street food vendors, 18 roadside vendors, 13 local food restaurants, 12 modern restaurants, 9 supermarkets, 8 butchers, 7 min-supermarkets, 6 wholesalers, 5 poultry sellers, 2 home vendors and 1 café. The café was next to the main gate. Within the hospital was a fast-food outlet and a kiosk. Ambulant vendors were found close to the gate but also along the nearby main road. The supermarkets were scattered along the main roads while in the residential area were few or no vendor (Figure 15).

Of all the vendors mapped, 40% sold grains or grain-based foods, 34% sold snacks, 32% roots and tubers, and 31% eggs. Between 30 and 20% of the vendors sold animal source foods like eggs, dairy, or flesh meat. Also, 26% of the vendors sold pulses, 24% nuts and seeds. Vegetables and fruits were sold by less than 20% of the vendors. Fish (despite Kampala’s proximity to Lake Victoria, a fish-producing area) was sold by only a few vendors (14%). The least sold foods were vitamin-A-rich vegetables and fruits (12%), dark green leafy vegetables (10%) and organ meat (8%). Mixed dishes were served or sold by 13% of the vendors surveyed.

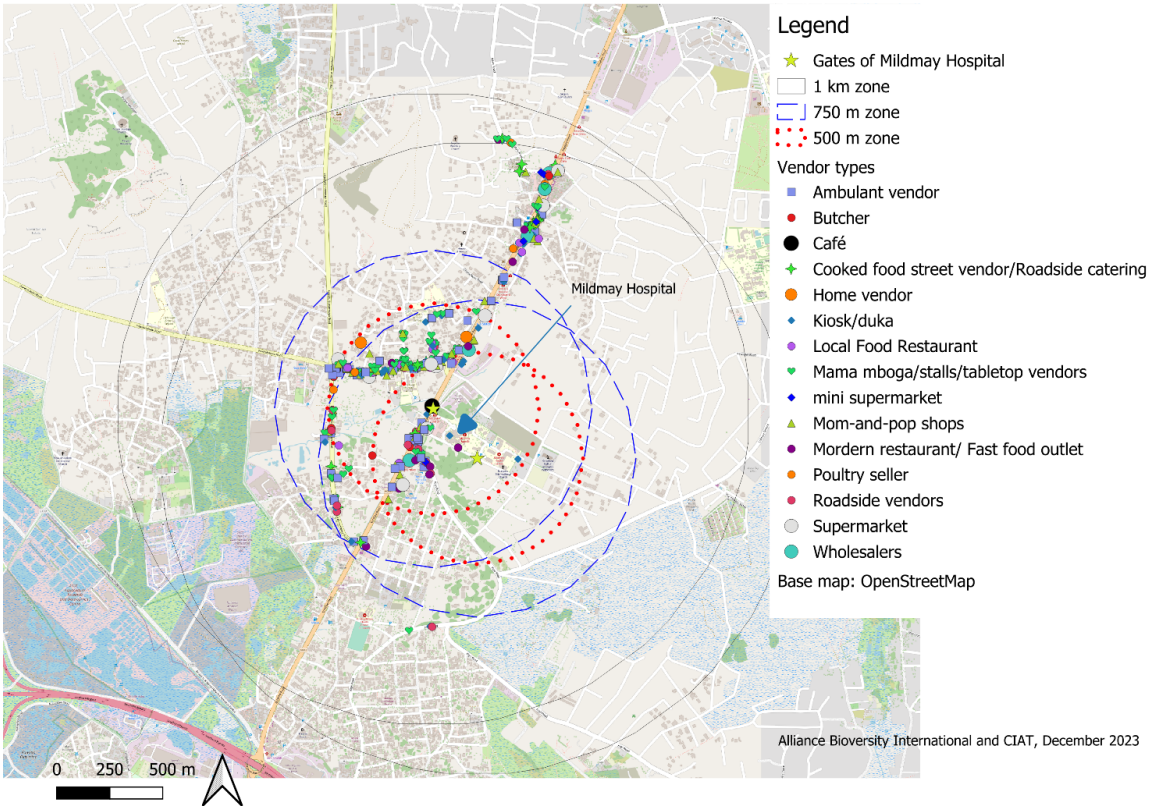


Figure 14: Vendor distribution around Mildmay Hospital, Kampala, Uganda, December 2023 (HD4A funded by EU)

The infrastructure mapping showed limited access to public safe sanitation facilities and drinking water sources. Most of these are located within or close to the Mildmay Hospital. Several jackfruit trees were found within the hospital compound, which are regularly harvested by children from the neighbourhood. There are also a few publicly accessible fruit trees along the main road to the nearest permanent market. Billboards were everywhere and quite numerous available in in front of the hospital while there were none in the residential area behind the hospital (Figure 16).

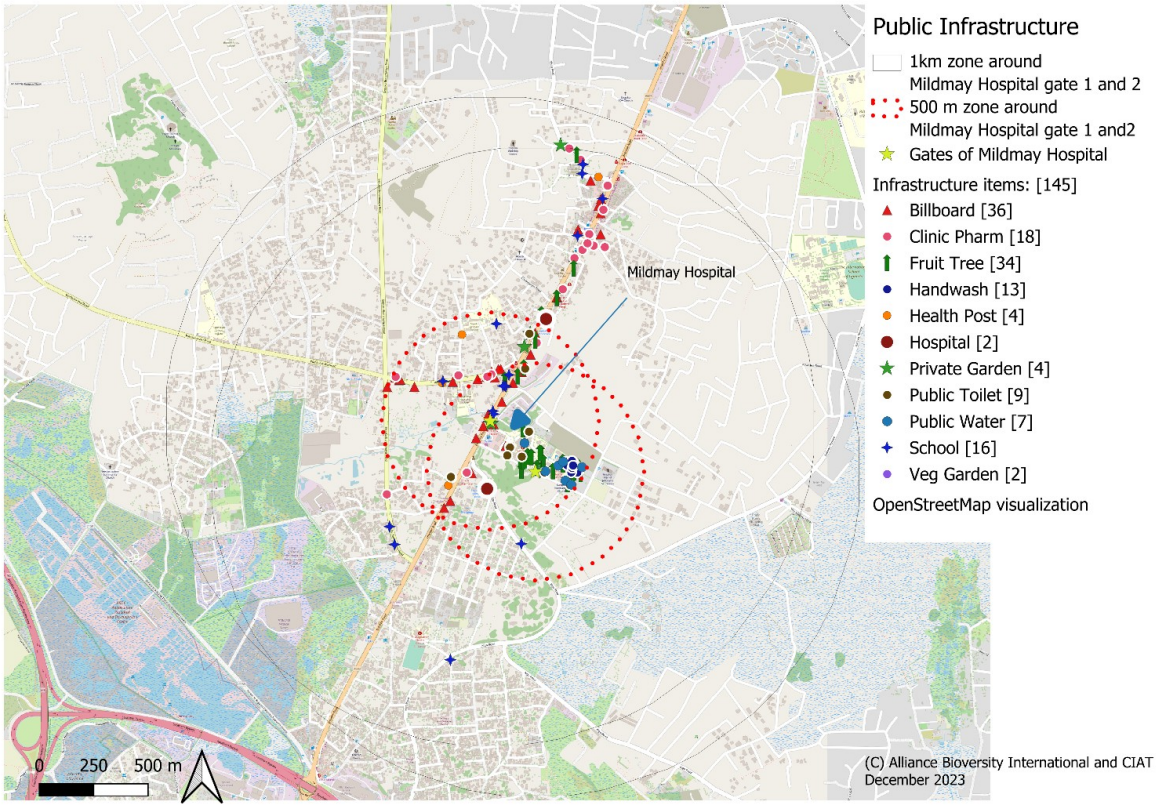


Figure 15: Public Infrastructure within and around Mildmay Hospital, Kampala, Uganda, December 2023 (HD4A funded by EU)

Food environment map Bouaké, Ivory Coast (HD4A funded by EU)

The mapping was done in December 2023 and captured one structured marketplace, 396 “single” vendor places and 211 items in the infrastructure mapping. Vendor mapping revealed a high density of mama mboga/ stalls/ tabletop vendors (n=124, 31%) (Figure 17). Mom-and-pop shops (16%) and cooked food street vendors (13%) were the second most common vendor types. All others, mobile vendors, kiosks, modern restaurants, mini-supermarkets, wholesalers, cereal vendors, home vendors, open air markets and butchers had a share of less than 10%. The enumerators identified one poultry seller and one farm selling food directly to customers. In the same area, 128 billboards advertising any food or beverage/ drink, were identified as well as 34 fruit trees, 3 public toilets, 2 public drinking water sources, 18 schools, 3 vegetable gardens, 3 private gardens, 5 hospitals and 11 health posts.

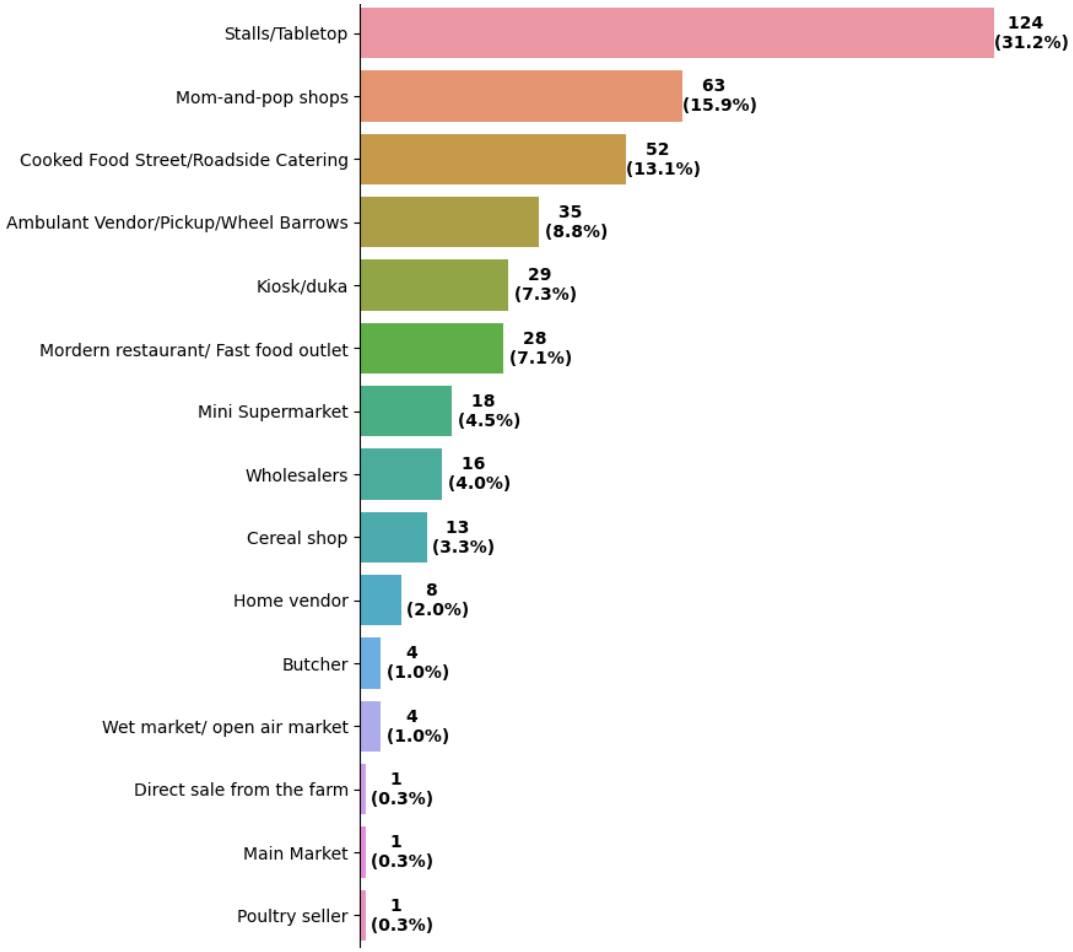


Figure 16: Distribution of vendors in the study site of Bouaké, Ivory Coast, December 2023 (HD4A funded by EU)

Not all vendors use all their space to sell food. Especially, supermarkets used some of their space for non-food items. Butchers and poultry sellers are the only vendors who use all their space to sell foods (Figure 18).

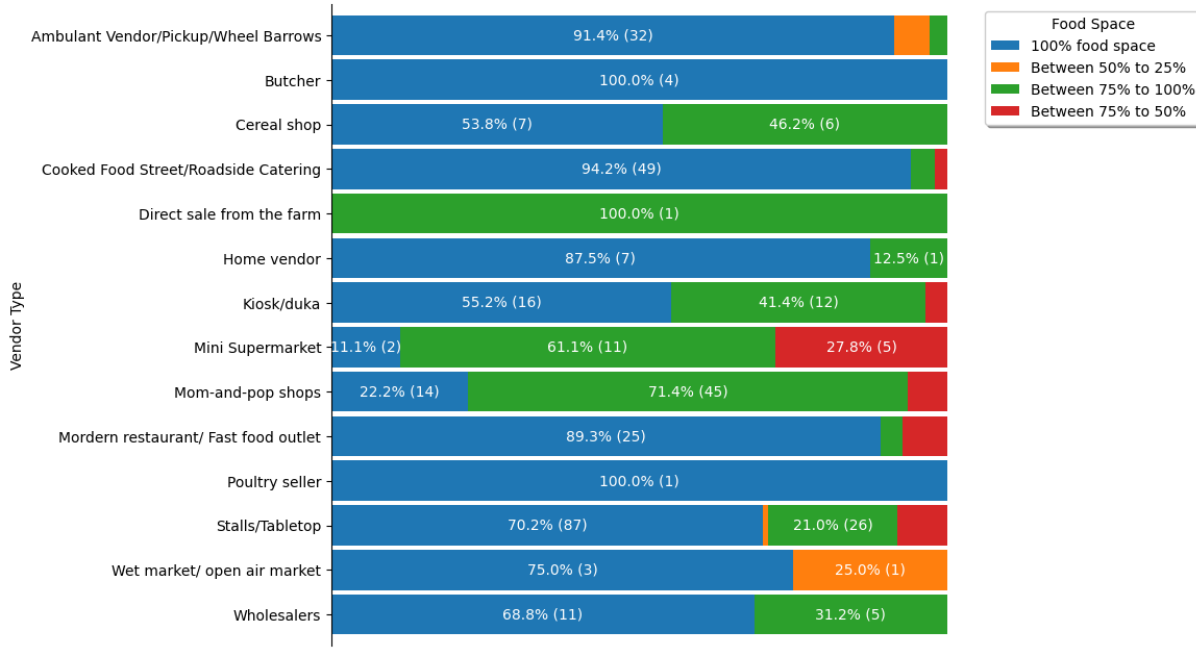


Figure 17: Estimated space used to sell food by vendor type, December 2023 (HD4A funded by EU)

The following two maps show the distribution of vendors within a 1-kilometer radius around a primary school. There were no street food vendors or snacking opportunities found directly around the school. Nevertheless, a main market is close to the school. The food selling centre was rather around another school with several mom-and-pops shops as well as street food catering options. The enumerators also found along main streets several different vendors. (Figure 19).

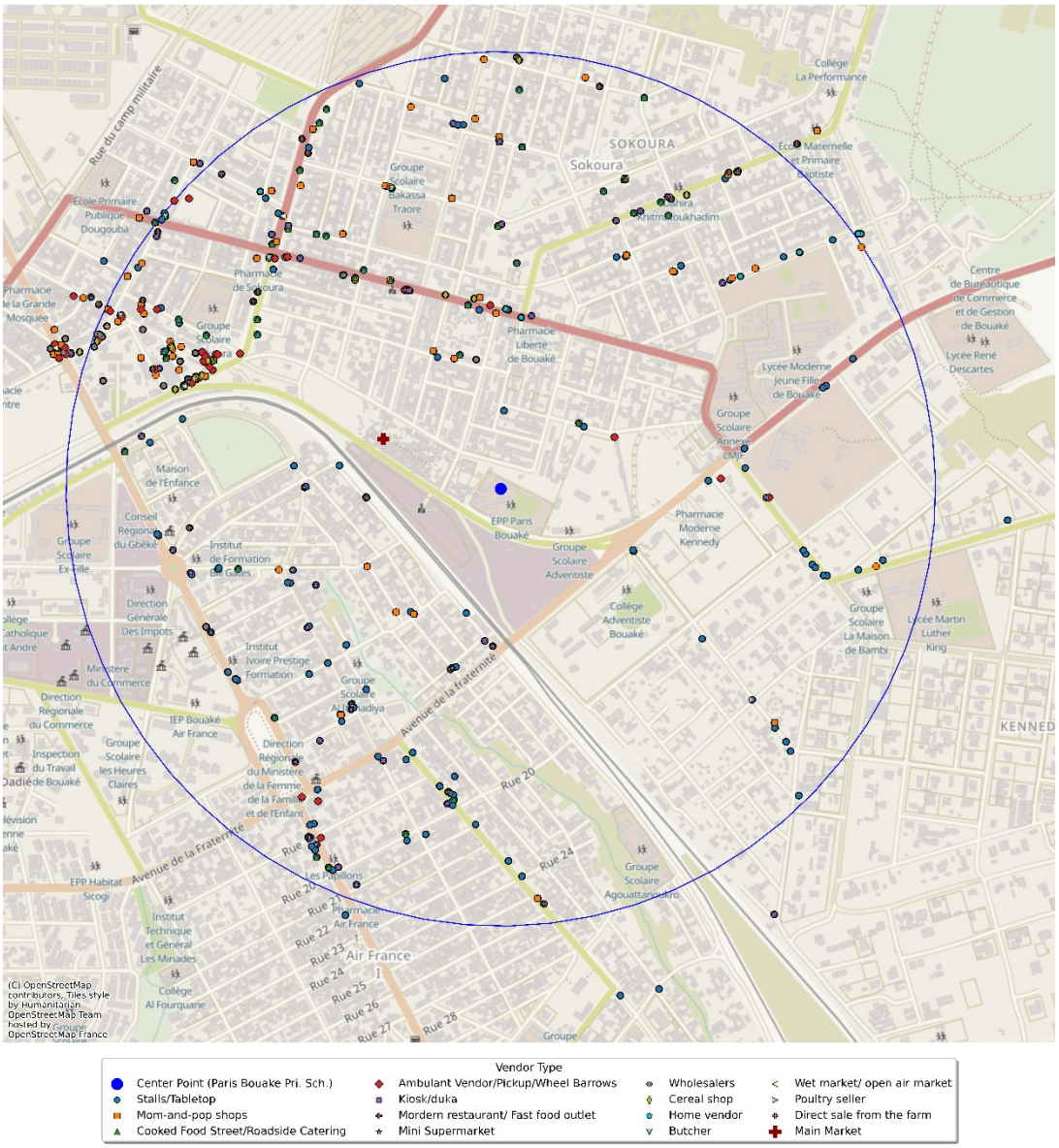


Figure 18: Vendor assessed in Bouaké around 1 km from Bouaké Paris Primary School (Census), Ivory Coast, December 2023 (least prevalent vendor type on top, HD4A funded by EU)

School food environment mapping in Benin, (collaboration between HD4A and FRESH initiative, oneCGIAR)

Four types of food outlets were identified in the food environment of Boukombé Secondary School. The most important was an open-air market vendor (n=90); 4 canteen vendors, 1 restaurant and 1 roadside vendor were also found. The three most important food groups which were sold by the vendors were vegetables, available at 21.5% of outlets, cereals (16.5%) and dry fish (12.4%). Fruits were only available in 9.1% of food outlets. Fruits and vegetables were only available on market days. The inventory registered 32 publicly accessible fruit trees within

1km of the school. Mango trees were the most common trees (19 mangoes trees, 5 cashew trees, 2 lemon trees, 2 Coromandel ebony trees, 2 ackee trees, 1 Black Plum tree and 1 African palm tree).

The school food environment of the main Natitingou secondary school was more diversified compared to Boukombé. The most important food outlets were roadside vendors (n=24), followed by canteen vendors (n=14), retail shops (n=10), kiosks (n=3), and 2 restaurants as well as 1 mobile, 1 home vendor, a supermarket, and a market. Cereals (23.8%), legumes (13.4%) and sugar products (10.5%) were the three most important food groups sold by the vendors. Fruits were available in 7.6% of food outlets. All food groups identified were available every day. We documented and geocoded 9 fruits trees in the secondary school food environment of Natitingou: again, predominantly mango trees and bananas trees with (Figures 20-29).

The school food environment observed in Cotonou (in the South of Benin) (Figures 30 - 32) is distinguished by a greater availability and a greater diversity of food outlets, compared to those observed in Natitingou and Boukombé (in the North of Benin). Certain types of outlets, such as supermarkets and specialized poultry sellers, were only identified in the geographic space observed in Cotonou but not in Natitingou nor in Boukombé. The other categories of outlets were present in all studied areas.

Figure 20: Ambulant vendors in Benin

Figure 21: Street food vendors selling fruits and vegetables in Northern Benin

Figure 19: Kiosk (left) and supermarkets (right) selling alcoholic drinks in Southern Benin

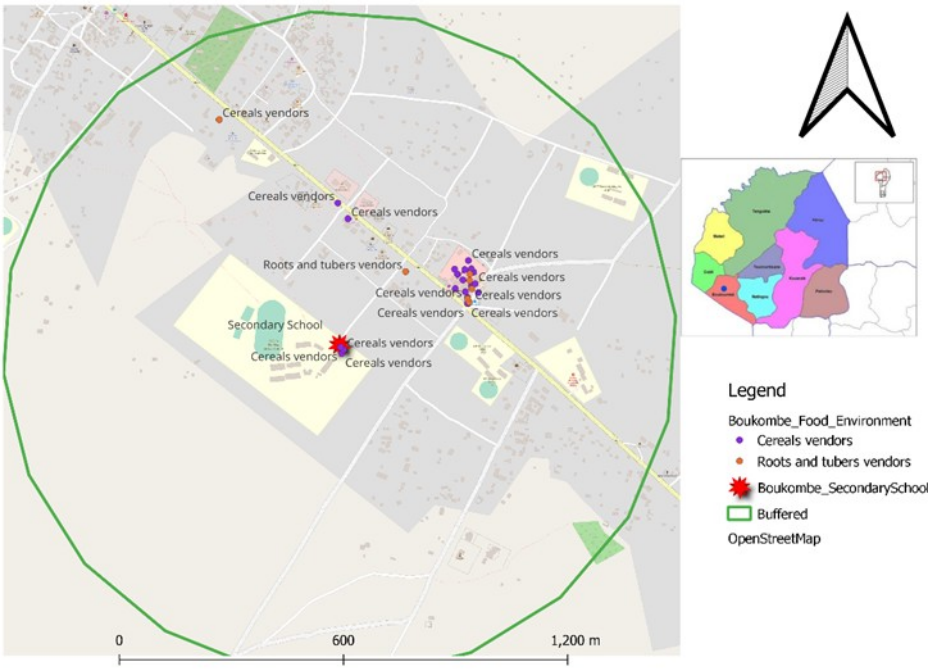


Figure 20: Cereals, roots and tuber in secondary school food environment of Boukombé, Benin

Figure 21: Proteins rich foods available in the secondary school food environment of Boukombé, Benin

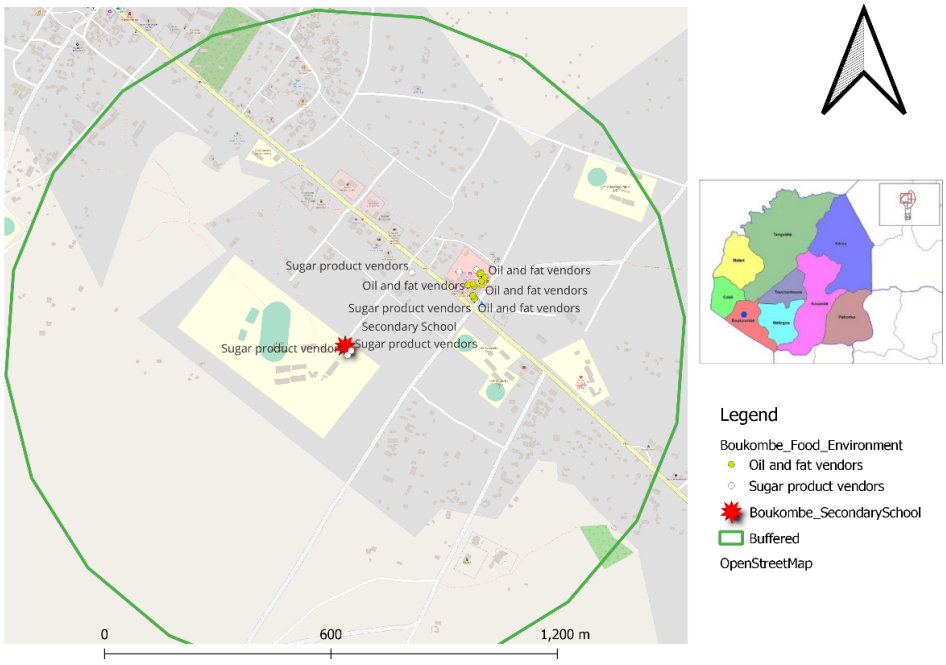


Figure 22: Oil and sugar products available in the secondary school food environment of Boukombé, Benin

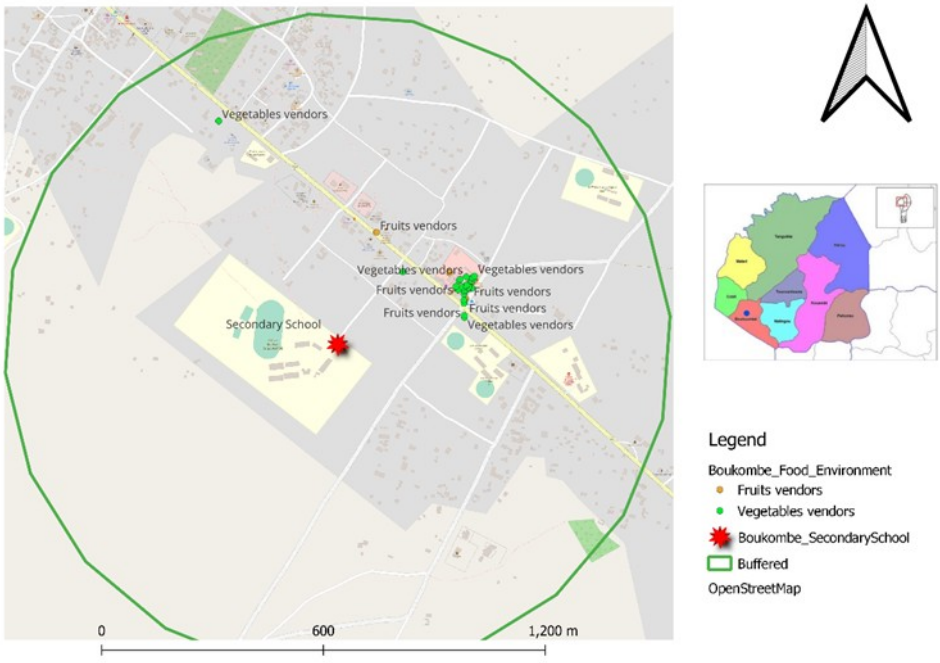


Figure 23: Fruits and vegetables available in the secondary school food environment of Boukombé

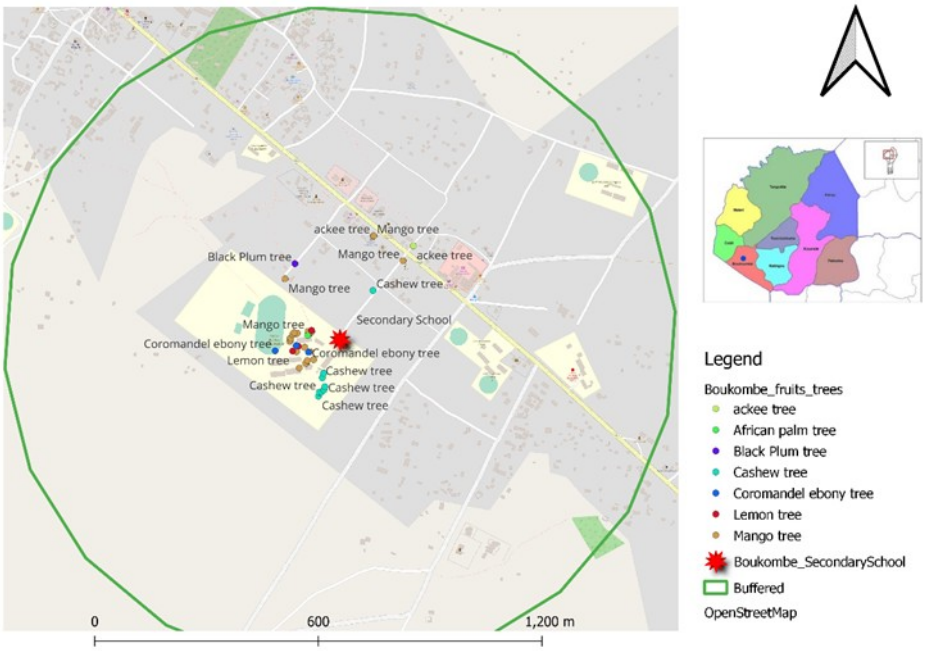


Figure 24: Fruits trees available in the secondary school food environment of Boukombé

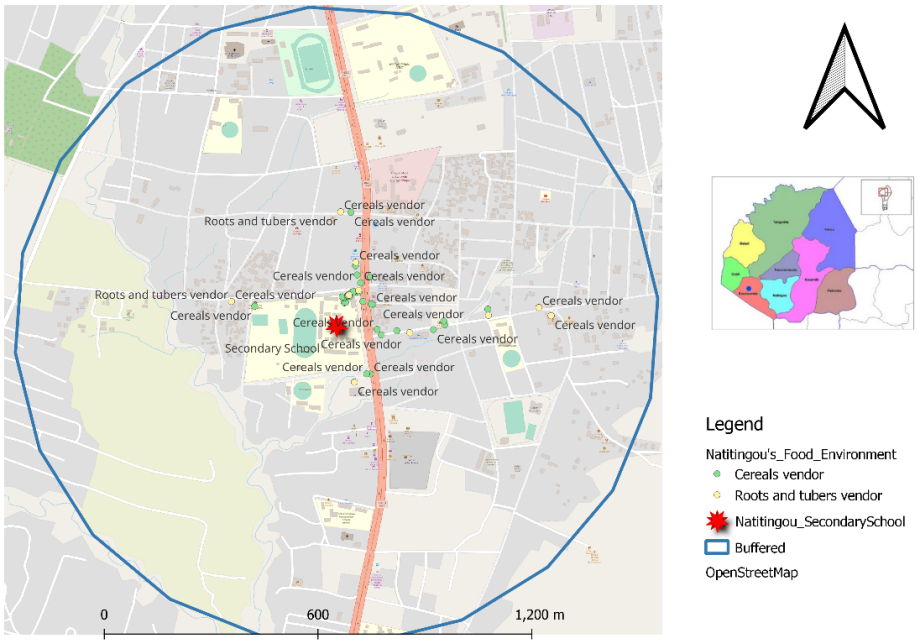


Figure 25: Cereals, roots and tuber available in the secondary school food environment of Natitingou

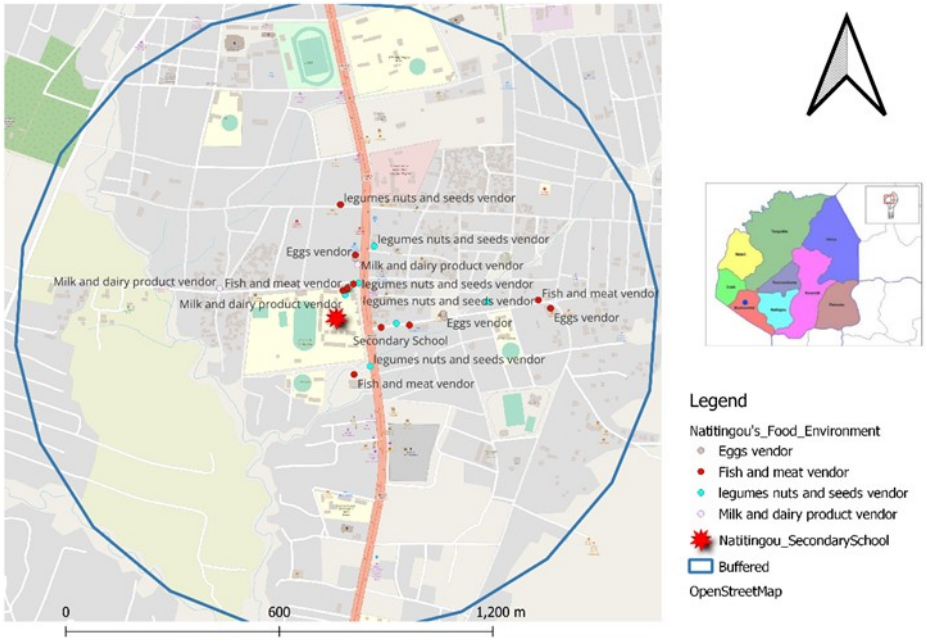


Figure 26: Proteins rich foods available in the secondary school food environment of Natitingou

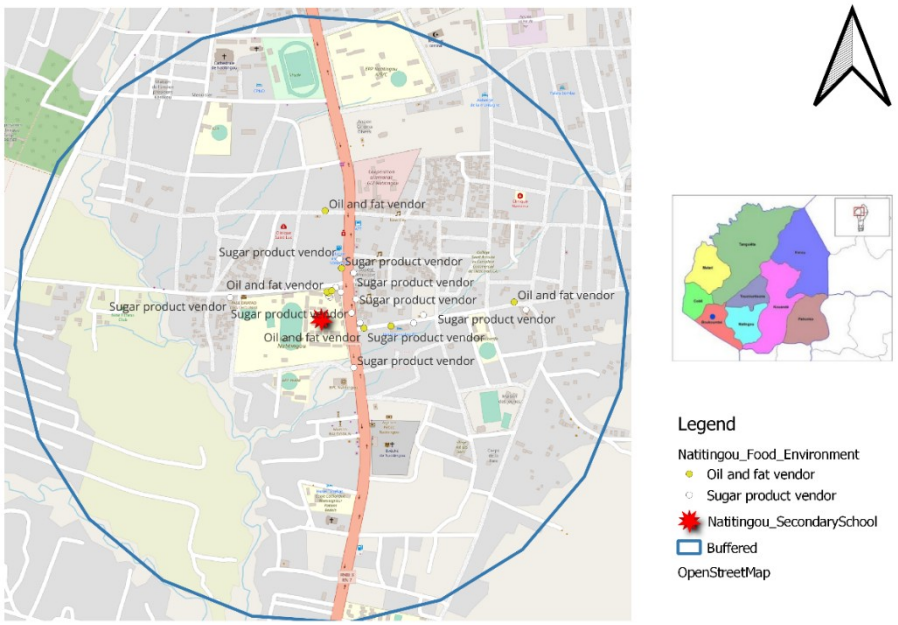


Figure 27: Oil and sugar products available in the secondary school food environment of Natitingou

Funded by
the European Union

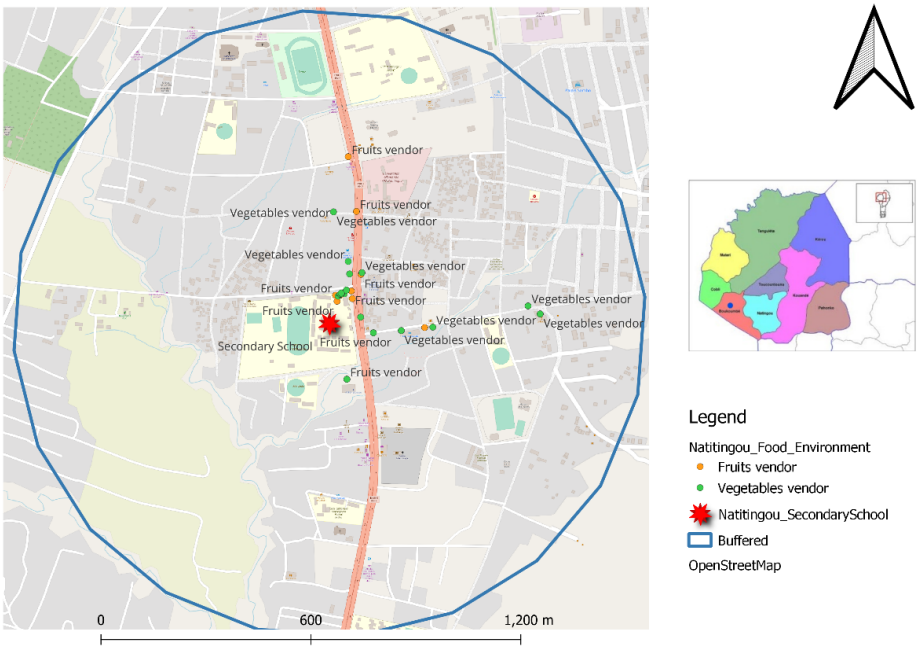


Figure 28: Fruits and vegetables available in the secondary school food environment of Natitingou

Figure 29: Fruits trees available in the secondary school food environment of Natitingou

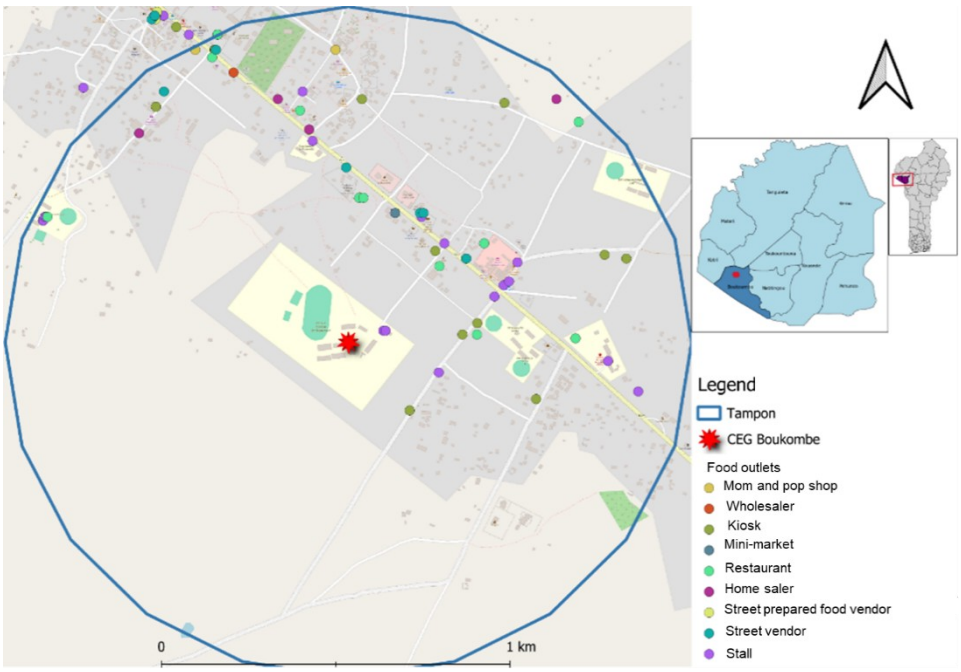


Figure 30: Distribution of food outlets in the food environment of General Education Colleges (CEG) in Boukombé

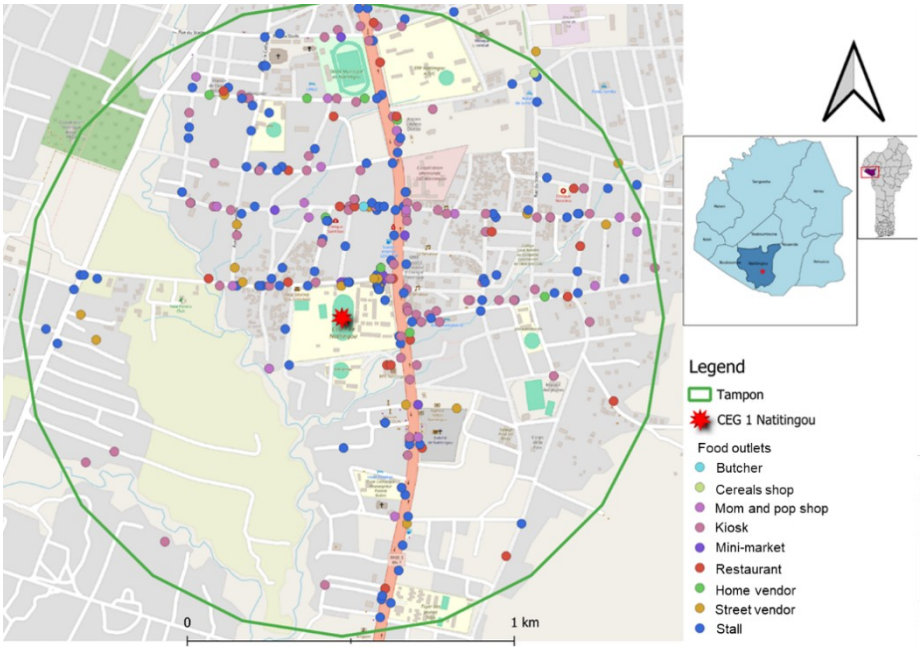


Figure 31: Distribution of food outlets in the food environment of General Education Colleges (CEG) in Natitingou

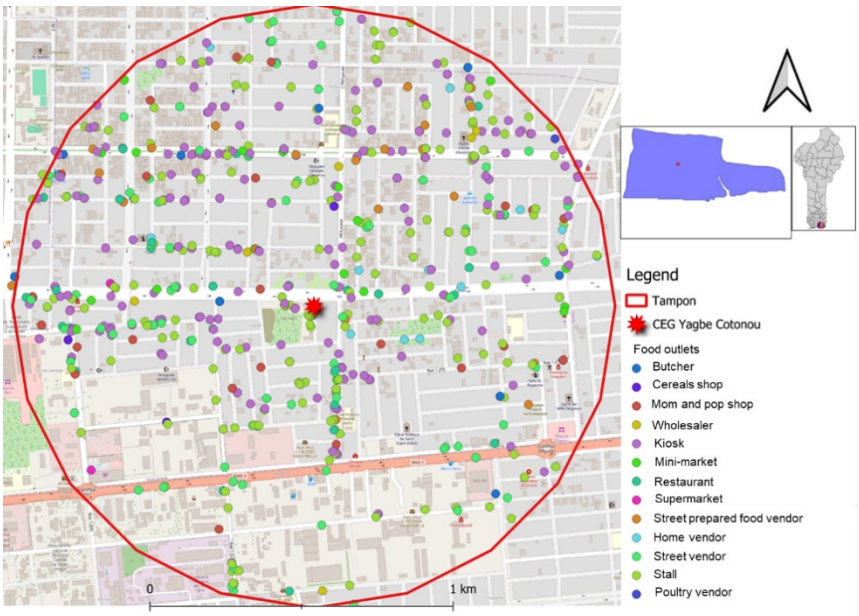


Figure 32: Distribution of food outlets in the food environment of General Education Colleges (CEG) Yagbé-Cotonou

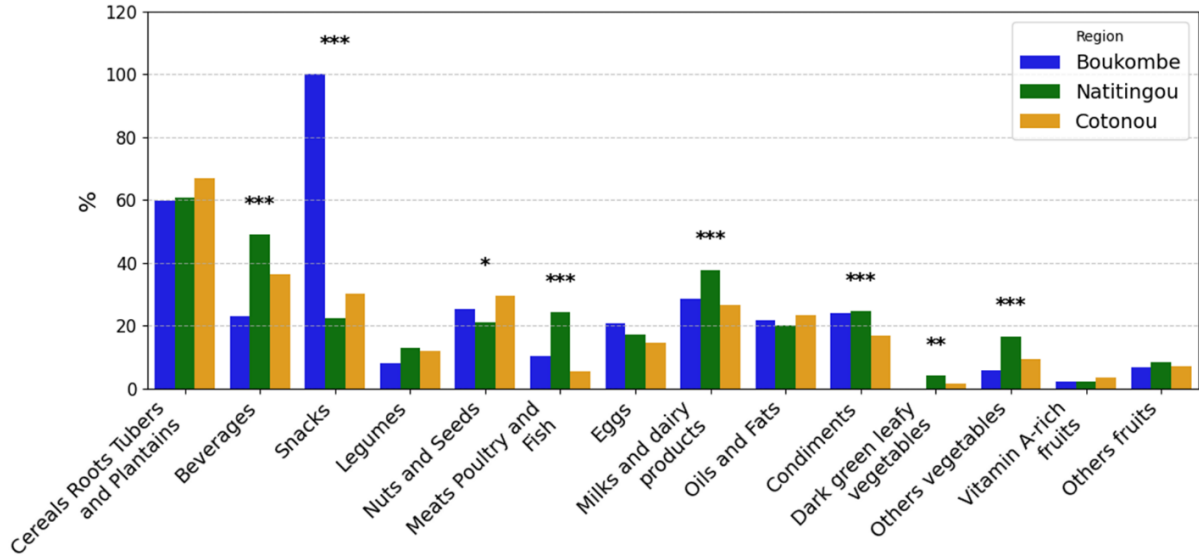


Figure 33: Food diversity in points of sale according to the MDD-W categorization, (FRESH Initiative, oneCGIAR, HD4A funded by EU); The *, ** and *** represent statistical significance at p<0.05, p<0.01 and p<0.001.

Across all the middle schools studied, the most frequently observed food groups in the school environment were cereals, plantain, roots and tubers (64.8%), followed by beverages (38.9%) and snacks (32.7%). Variations were noted depending on the geographical area. Eggs were more present in school environments in the North, while fruits rich in vitamin A were more represented around the CGE Yagbé-Cotonou school. Dairy products, vegetables, as well as

meat, poultry and fish were more frequently found around establishments located in Natitingou (North) (Figure 20-36).

The Nutrition-sensitive Food Environment Index (N-FEI)

An overview about the different approaches used for the various studies compiled in the course of the development of the nutrition-sensitive food environment index, its estimated population and land coverage is presented in Table 5 (Akingbemisilu et al. 2025). The overview excludes the two site assessed in the North of Benin, but includes two additional data sets compiled within the CGIAR SHiFT initiative which transitioned to Better Diets for Nutrition Program in 2025 (i.e. data from Ethiopia and Vietnam), and data sets from Makueni and Vihiga County, Kenya, funded by Biovision Switzerland and assessed under the leadership of Dr. Céline Termote, who is the team leader of the African FECB-research group at the Alliance Bioversity International and CIAT (IPGRI).

Table 5: Overview of the approach used for each study site, its estimated population and land coverage used to develop the nutrition-sensitive food environment index (N-FEI)

Approach	Country[$]	Location level 1	Location level 2	Community units/Admin Areas	Population estimated	Land Area (km²)
Centered (1km)	Benin	Cotonou		Arrondissement 1	29366	3.14
Centered (1km)	Côte D'Ivoire	Bouaké		Air France; Kennedy; Sokoura	1098	3.14
Centered (500m)	Uganda	Kampala	Ndejje	Lweza; Sseguku	3364	0.79
Community	Kenya	Busia	Teso North	Kiriko; Koruruma; Onyunyur; Koteko; Okuleu	138034	261.00
			Teso South	Kotur; Okisimo; Kaliwa; Akobwait; Akiriamas	168116	303.00
		Kisumu	Kisumu central	Bandani	6077	8.20
				Obunga	18421	8.60
				Manyatta A	46705	2.40
			Kisumu east	Manyatta B	33183	2.60
		Turkana	Loima	Kaapus; Kablokor; Kawalathe; Lodwar Town; Lorugum; Napeikar	107795	9120.00
			Turkana South	Kalemngorok; Kamarese; Lochwa; Lokapel; Lokichar Town	153736	7045.20
		Vihiga	Emuhaya	Ebunangwe	5208	5.50

Approach	Country$	Location level 1	Location level 2	Community units/Admin Areas	Population estimated	Land Area (km²)
			Luanda	Emanda	6798	5.20
			Vihiga	Mwitubwi	5897	4.40
Administrative		Nairobi	Makadara	Viwandani	43070	5.00
		Makueni	Kilome	Kalonzoni	8770	32.60
	Ethiopia	Addis Ababa	Wereda 08	Kebele 08	37025	4.08
		SNPP	Butajira	Butajira 01; 02; 03; 04; 05	89824	16.13
	Vietnam	Sơn La	Huyện Mộc Châu	Thị trấn Nông trường	10020	11.15
				Xã Chiềng Sơn	7706	91.68
				Xã Tân Lập	9055	98.28
		Tp Hà Nội	Huyện Đông Anh	Xã Cổ Loa	16648	8.07
				Xã Vân Nội	10626	6.89
		Tp Hà Nội	Quận Đống Đa	Hàng Bột	18822	0.27
				Khương Thượng	14469	0.31
				Láng Hạ	28680	0.99
				Thịnh Quang	18058	0.42
				Ô Chợ Dừa	36318	1.10

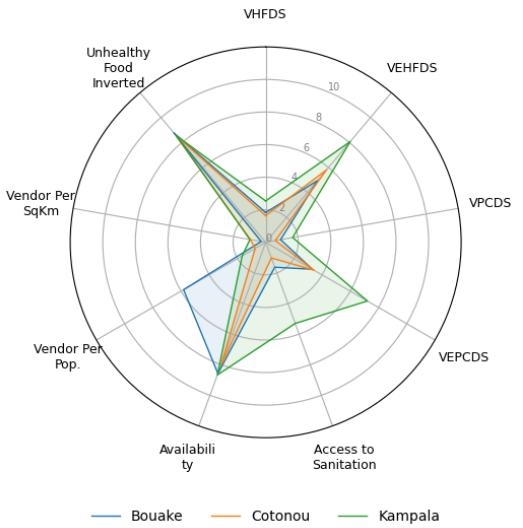
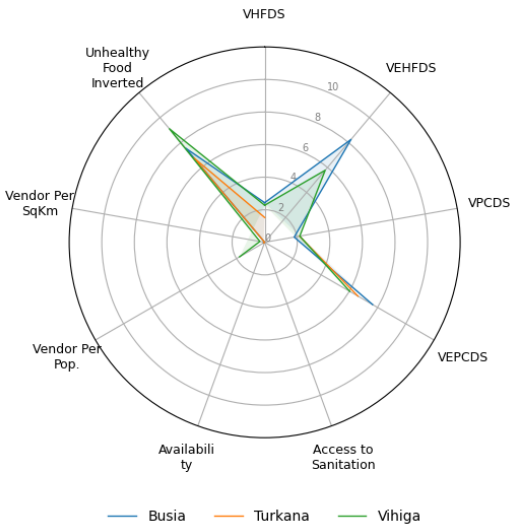
SNPP - Southern Nations, Nationalities, and Peoples' Region; $: Income categories of the countries are: Benin, Côte D'Ivoire, Kenya and Vietnam = Lower Middle Income; Ethiopia Low Income (The World Bank 2025)

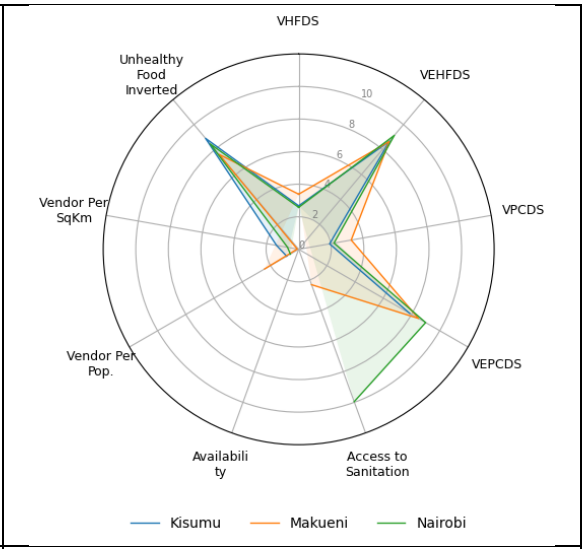
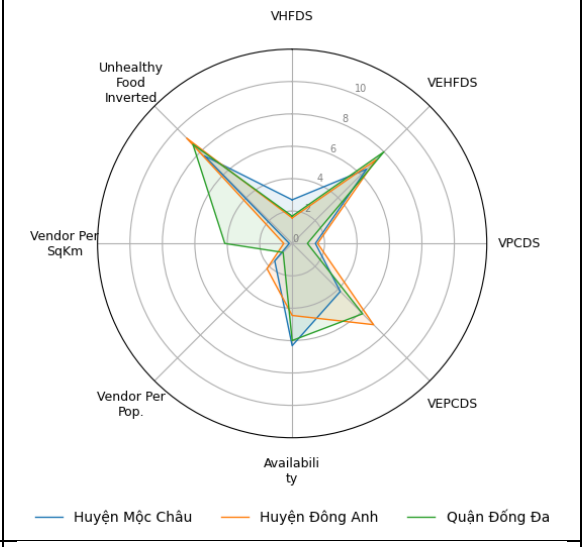
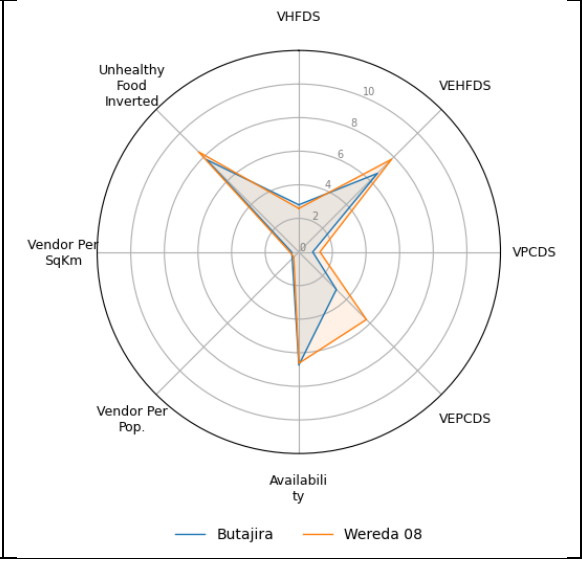
The mapping results were visualized in spider webs (Table 6). If all indicators performed as it best the index would score a maximum of ten. Turkana scored lowest with 2.2. The highest score was achieved in Viwandani, an informal settlement in Nairobi. However, the score of 5.3 indicates still room for improvement. The visualization in the spider web indicates that the access to public water and sanitation facilities in the food environment may have improved the score. However, the area is also known for limited water and sanitation facilities at private level.

The regression analysis (Table 7) showed statistically significant IRRs of 0.86 and 1.24 for Cotonou (Benin) and Kampala (Uganda), respectively, with Bouaké (Côte d'Ivoire) as a reference (p-values <0.001). Compared to Bouaké (reference category), Kampala is associated with a 24% increase in the likelihood of a higher N-FEI score, while Cotonou shows a decrease of 14%. Turkana South (Kenya), which has a drastically lower IRR of 0.22, showed significant lower N-FEI scores compared to Bouaké. On the contrary, areas like Viwandani in Nairobi had a substantial higher IRR=1.32, indicating a more favorable food environment. Locations such as Wereda 08 and Huyện Đông Anh display IRRs close to 1, suggesting no significant difference from Bouaké in terms of-N-FEI scores. Among the various types of vendors, Stalls/Tabletops (IRR of 1.22), showed i.e. 22% increase in achieving higher N-FEI scores compared to the reference categories of ambulant/street hawkers/mobile vendors. Similarly, Specialized-D vendors (cooperative/non-convenience food vendors) and

Street/Roadside Catering showed positive associations with the N-FEI (IRRs of 1.11 and 1.09, respectively). Specialized-C vendors (drink-based vendors) had a lower IRR of 0.85, indicating a negative association with a higher N-FEI.

Table 6: Overview of indicator performance across survey sites and the resulting Nutrition-sensitive Food Environment Index

Approach	Indicator Performance per study site	Food Environment Index			
		Location	No. of vendors	Index (min-max = 0-10)	SD
Centered — urban		Bouaké, Côte d'Ivoire	396	4.01	± 0.89
		Cotonou, Benin	1011	3.42	± 0.91
		Kampala, Uganda	331	4.96	± 1.17
Community —rural		Busia, Kenya	716	3.97	± 1.25
		Turkana, Kenya	387	**2.29**	± 1.38
		Vihiga, Kenya	822	3.92	± 1.10
Community and/or Administrative— rural /		Kisumu, Kenya (community, vulnerable urban)	2506	4.61	± 1.19

vulnerable urban		Makueni, Kenya (admin, rural)	889	4.53	± 1.09
		Nairobi, Kenya (Admin, vulnerable urban)	1197	**5.33**	± 0.83
Administrative — urban; peri-urban; rural		Huyện Mộc Châu Vietnam (rural)	1155	3.81	± 1.18
		Huyện Đông Anh, Vietnam (peri-urban)	1228	4.24	± 1.00
		Quận Đống Đa, Vietnam (urban)	3811	4.55	± 1.20
Administrative – urban-peri-urban		Butajira, Ethiopia (peri-urban)	1892	3.62	± 0.86
		Wereda 08, Ethiopia (urban)	953	4.17	± 0.92

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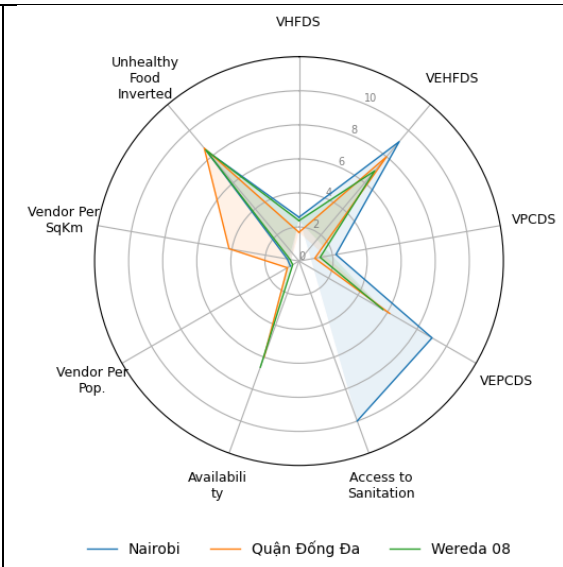
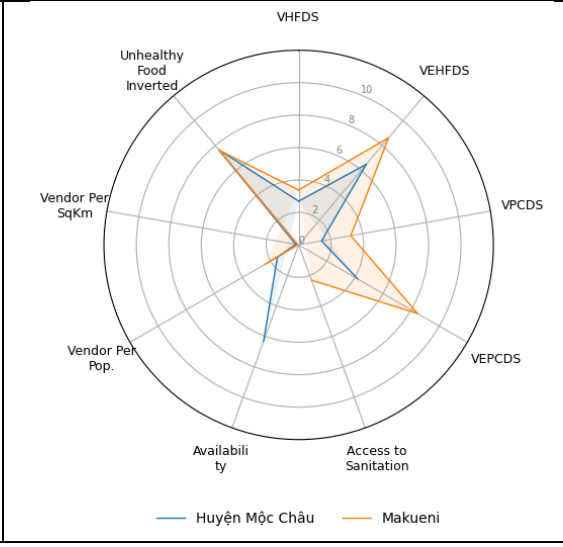
Admin urban		Nairobi, Kenya (Admin, vulnerable urban)	1197	**5.33**	± 0.83
		Quận Đống Đa, Vietnam (urban)	3811	4.55	± 1.20
		Wereda 08, Ethiopia (urban)	953	4.17	± 0.92
Admin Rural		Huyện Mộc Châu Vietnam (rural)	1155	3.81	± 1.18
		Makueni, Kenya (admin, rural)	889	4.53	± 1.09

Note: The number of indicators visualized in the radar chart depends on data assessed in each study; VHFDS = Vendor Healthy Food Diversity Score; VEHFDS = Vendor Environment Healthy Food Diversity Score (within 50m); VPCDS = Vendor ProColor Diversity Score; VEPCDS = Vendor Environment ProColor Diversity Score; Nairobi=Viwandani; Makueni=Kilome; Kisumu=Kisumu central (Bandani; Manyatta A; Obunga) and Kisumu East (Manyatta B); Kampala=Ndejje; Busia=Teso North and Teso South; Turkana=Loima and Turkana South; Vihiga=Ebunange-Emuhaya, Mwitubwi-Luanda and Emanda-Vihiga; Wereda 08=Kebele 08; Butajira=Butajira 01, 02, 03, 04 and 05; sqkm=km²

The variance decomposition analysis conducted measured the contribution of each indicator to the variance in the N-FEI, which can be directly compared to the insights gained from the sensitivity analysis through simple exclusion and Monte Carlo simulations.

Table 7: Incidence Rate Ratios (IRRs) showing the association between sublevels, vendor types, and N-FEI scores

Location			N	Mean Index	IRR[1]	95% CI[1]	p-value
Côte D'Ivoire		Bouake	396	4.01	—	—	
Benin		Cotonou	1011	3.42	0.86	0.81, 0.91	**<0.001**
Uganda		Kampala	331	4.96	1.24	1.16, 1.33	**<0.001**
Kenya	Busia	Teso North	397	4.05	0.95	0.89, 1.02	0.2
		Teso South	319	3.88	0.94	0.87, 1.01	**0.081**
	Turkana	Loima	326	2.55	0.66	0.60, 0.72	**<0.001**
		Turkana South	61	0.91	0.22	0.17, 0.29	**<0.001**
	Vihiga	Emuhaya	250	3.87	0.91	0.84, 0.99	**0.026**
		Luanda	323	3.92	0.92	0.85, 0.99	**0.019**
		Vihiga	249	3.97	0.96	0.89, 1.04	0.3
	Kisumu	Kisumu Central	1752	4.60	1.10	1.04, 1.16	**<0.001**
		Kisumu East	754	4.63	1.11	1.04, 1.18	**<0.001**
	Makueni	Kilome	894	4.52	1.12	1.06, 1.19	**<0.001**
	Nairobi	Makadara	1192	5.34	**1.32**	1.25, 1.40	**<0.001**
Ethiopia		Butajira	1892	3.62	0.95	0.90, 1.01	**0.086**
		Wereda 08	953	4.17	1.08	1.02, 1.15	**0.009**
Vietnam		Huyện Đông Anh	1228	4.24	0.98	0.93, 1.04	0.6
		Huyện Mộc Châu	1155	3.81	0.95	0.90, 1.01	0.1
		Quận Đống Đa	3811	4.55	1.12	1.06, 1.18	**<0.001**
Vendor type							
Ambulant/street hawkers/mobile			1393	3.91	—	—	
Kiosk			3928	3.87	1.01	0.98, 1.04	0.5
Modern restaurant/ Fast food outlet			1681	3.89	0.99	0.96, 1.03	0.7
Specialized - A			219	3.83	0.96	0.90, 1.04	0.3
Specialized - B			188	3.97	0.96	0.89, 1.04	0.3
Specialized - C			1038	3.37	0.85	0.81, 0.88	**<0.001**
Specialized - D			398	4.37	1.11	1.05, 1.17	**<0.001**
Stalls/Tabletop			6592	4.81	1.22	1.19, 1.26	**<0.001**
Street/Roadside Catering			663	4.93	1.09	1.04, 1.14	**<0.001**
Supermarket/Convenience Stores			1041	3.75	0.98	0.93, 1.02	0.3
Wholesalers			153	3.29	0.95	0.87, 1.04	0.3

[1]IRR = Incidence Rate Ratio; CI = Confidence Interval ; N-FEI: Nutrition-sensitive Food Environment Index; Ambulant/street hawkers = mobile vendors with no fixed locations; Kiosks = over-the-counter service with minimal varieties of brands and small packaging with credit options; Modern restaurant/ Fast food outlet = permanent or semi-permanent structures that offer a diversity of cooked food and are individually owned and a serviced by operator to customers who enter the structure and sit to eat; Specialized-A = specialized in cereal-based products (ready to eat and uncooked); Specialized-B = specialized in animal-source foods and include butchers, poultry, dairy and egg shops, which may operate in small, fixed structures; Specialized-C = specialize in drinks (hot or cold) include cafés, coffee shops, coffee and juice houses; Specialized-D= group of vendors selling non-convenience foods of no particular food group (this group was created for Ethiopia and Vietnam as the specialization was not identified); Wholesalers = groups of vendors who sell food products in bulk to retailers, restaurants, and other food service providers, often at lower prices. Kisumu central=Bandani, Manyatta A and Obunga; Kisumu East=Manyatta B; Kampala=Ndejje; Vihiga=Ebunange-Emuhaya, Mwitubwi-Luanda and Emanda-Vihiga; Wereda 08=Kebele 08; Butajira=Butajira 01, 02, 03, 04 and 05

Modeling predictions for population health risks related to food environments

Figure 34 presents the SHAP analysis of the different models predicting the population risks in relation to the different food environment indicators. Akingbemisilu et al. (2025) reported, "the XGBoost model was used to predict the severity of health risk among populations of

women and children residing within the specified food environments using default hyperparameters."

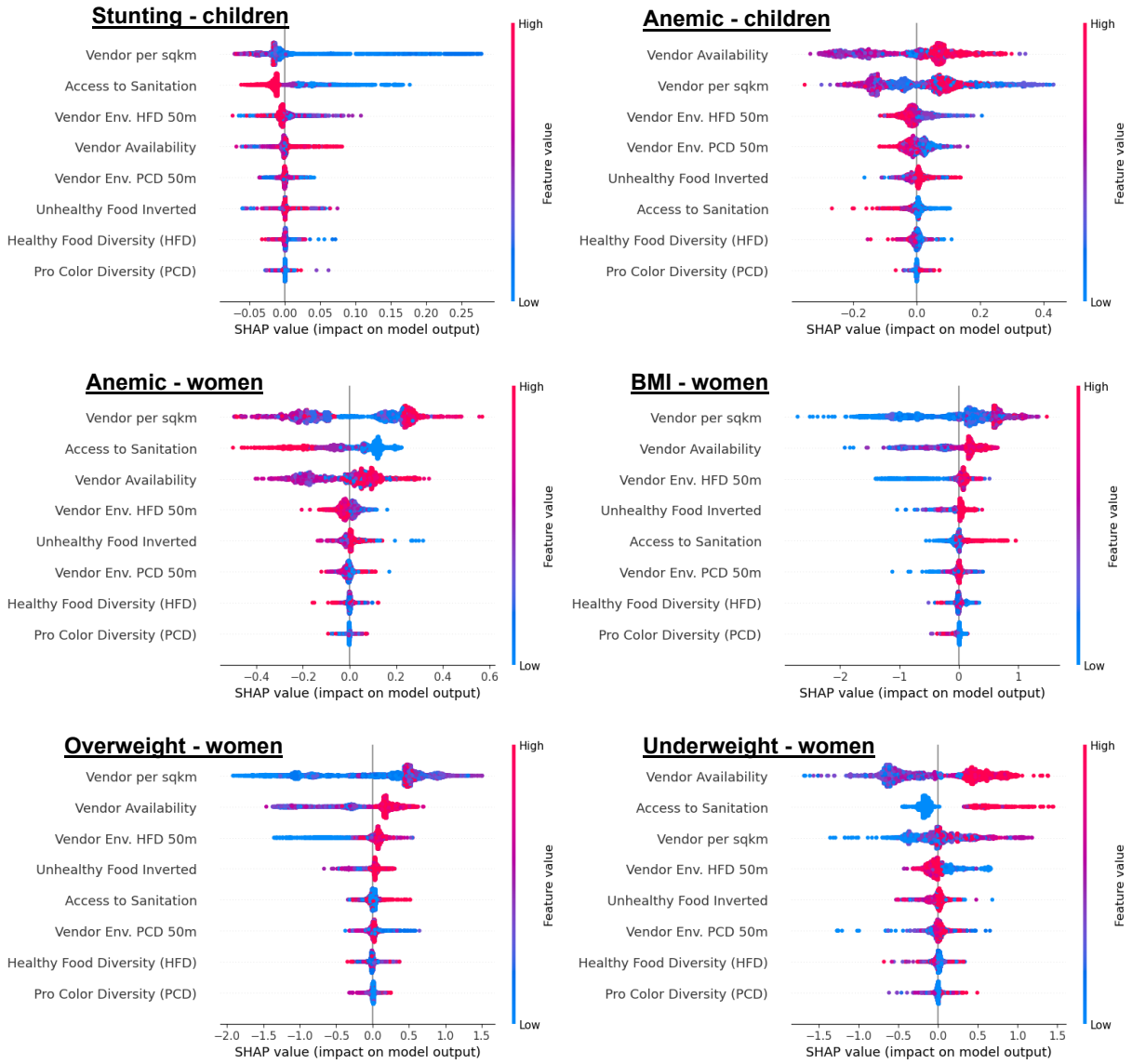


Figure 34: SHAP Analysis of the food environment variable impact on model health risk prediction; HFD=healthy food diversity; PCD=ProColor Diversity; sqkm=km²

According to Akingbemisilu (2025), "the food environment indicators explained approximately 89.3% and 87.1% of the variation in stunting risk. The low RMSE values (0.028 and 0.030) further confirm the precision of the model, highlighting the strong association between food environments and stunting prevalence. The models for anemia, particularly among women, showed exceptional predictive power. The children's anemia model achieved R-squared values of 0.849 (standard) and 0.856 (cross-validated), suggesting that food environment

indicators accounted for approximately 85% of the variation in anemia risk among children. The women anemia model performed even better, with R-squared values of 0.934 (standard) and 0.948 (cross-validated), paired with low RMSE values (0.118 and 0.103). This indicates a strong link between food environments and anemia prevalence within each food environment population, particularly for women.

Summary

Food environments were mapped across different agro-ecological zones and in both urban and rural areas, with a focus on the urban poor. Apart from these places a hospital or a School was selected as a potential hub for different vendor types (Table 9). The density of vendors in informal settlements and urban areas is higher than in rural areas. However, this does not necessarily translate into better access to safe and nutritious foods. Usually, less than 50% of all food and beverage vendors sell fresh fruits and vegetables. The diversity of these foods is quite low. More analysis is needed to better understand diversity within food groups. There is limited knowledge about the origin and safety of foods. More information on this will be gathered during the project in food value chain analysis (another deliverable of the HD4A project). A more in-depth analysis of the diversity available and comparisons between selected sites to evaluate the tools was done, to further simplify the tools for usage as surveillance instruments. The infrastructure for access to safe drinking water and sanitation in areas where food is sold is often poor. Fruit trees are available in public places, but little is known about their usage and whether the fruit trees are harvested systematically and consumed.

Radar charts provide a visual comparison of the average of each indicator per region used to compute the N-FEI. They visualize the differences in the findings across the different regions, disaggregated by the approach (centered, community, or administrative) used during data collection and location of the study, the number of vendors assessed in each area, and the summary statistics of the N-FEI. In cases where all indicators perform at their best, the index would reach a maximum of 10. However, only one site included in the N-FEI study reached a score of 5 out of 10, most sites reached a score of around 4, while one site (Turkana) performed very low with a score of 2.29 out of 10.

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Table 8: Overview about food environment mapping sites

Country	Location	Geographics	Vendors assessed	Date of assessment	Project	Funded by
Kenya	Kisumu Town	Urban-poor	2927	2022	HFA	EU
	Busia County	Rural, border area to Uganda	676	2021	ImproDiet-Co	BMZ
	Turkana County	Rural poor – (agro-) pastoralists, semi-arid zone, and county capital	384	2020	ImproDiet-Co	BMZ
	Nairobi Town	Urban-poor, capital city	1189	2023	OrganicFood	Biovision Switzerland
	Makueni County	Rural	889	2023	OrganicFood	Biovision Switzerland
	Vihiga County	Peri-urban, rural	822	2023	Vihiga	Biovision Switzerland
Uganda	Kampala Town	Urban, Private Hospital, capital city	337	2023	HD4A	EU
Ivory Coast	Bouaké Town	Urban, Primary School	396	2023	HD4A	EU
Benin	Atacora Department	Urban (remote), Secondary School	149	2022	HD4A, FRESH/BDN	EU, CGIAR Trust Fund https://www.cgiar.org/funders/
	Cotonou	Urban, Secondary School	1011	2024	HD4A	EU
Ethiopia	Addis Abeba	Urban	37025	2023	SHiFT/ BDN	CGIAR Trust Fund https://www.cgiar.org/funders/
	Southern Nations,	Peri-urban	89824	2023	SHiFT/ BDN	CGIAR Trust Fund

	Nationalities, and Peoples' Region (SNPP)					https://www.cgiar.org/funders/
Vietnam	Quận Đống Đa	Urban	3811	2023	SHiFT/ BDN	CGIAR Trust Fund https://www.cgiar.org/funders/
	Huyện Đông Anh	Peri-urban	1228	2023	SHiFT/ BDN	CGIAR Trust Fund https://www.cgiar.org/funders
	Huyện Mộc Châu	Rural	1155	2023	SHiFT/ BDN	CGIAR Trust Fund https://www.cgiar.org/funders

Conclusion

- Opportunities to purchase different fruits and vegetables are very limited compared to staples (carbohydrates) and beverages.
- Diversity of vegetables and fruits sold in different places differ based on seasonality and the economic status of the residence.
- Vegetable and fruit production is highly seasonal, affected by precipitation pattern and/or depends on groundwater availability (case Turkana). In Uganda, a diverse array of vegetables and fruits is available on the markets all year. However, precipitation patterns affect the types of vegetables and fruits available at a given time (affecting preferences). In addition, precipitation patterns affect the prices such that vegetables (especially indigenous leafy green vegetables, cabbages, and kales) are cheaper in the wet season and get more expensive in the dry season – this will be followed up in upcoming work.
- All year-round access to vegetables and fruits and thus a diverse diet is very difficult to achieve which increases the risk for malnutrition.
- There is no traceability of the foods sold by the vendor. This this may expose consumers to unsafe foods.
- There is no or low regard to food safety by most vendors.
- Affordability is given prominence over food safety and nutrition.
- In the informal settlements and around markets infrastructure improvements especially clean water, proper disposal of waste, and drainage systems around markets are needed to enhance food safety. Access to clean water for washing fruits and vegetables (especially those consumed raw) remains a challenge in the study areas.
- In Uganda, almost all vegetables and fruits on the market are sold in unprocessed form. Fresh vegetables must be sold within 24 hours from the time of harvest due to unavailability of proper storage space. While fresh fruits (mangoes, oranges, jackfruits, pineapples) can stay longer, the storage facilities (non-cold facilities) used expose the produce to damage. Heaps of spoilt fruits could be seen in the marketplaces.
- Income opportunities, especially in informal settlements, are needed to enhance access to fruits and vegetables, which become too expensive at certain periods of the year and to increase access to safe drinking water and proper sanitation.

- The type of food environment mapping presented in this report can be used to compare food environments across regions and countries (N-FEI study).
- However, the mapping tool is not meant to trace back the food offered in the built food environment to its place of origin. It is an observational tool without using personal interaction with traders and vendors which would be needed to describe the complete value chain. Apart from this, tracing back products from the number of vendor places and products assessed in the mapping may be very costly.
- The N-FEI study reveals significant variations in food environment quality across different regions, emphasising how local food availability, vendor diversity, and sanitation facilities influence public health. The study's outcomes highlight the dire need for tailored, location-specific interventions to enhance food security and nutritional health, particularly in underserved or high-risk areas.
- The selection of different mapping approaches can influence the outcomes and applications of food environment studies. For example, the centred approach, while less costly and simpler to implement, may not provide the full picture needed for comprehensive public health planning. In contrast, the administrative approach, despite its higher costs, offers detailed insights that can better inform targeted interventions and policy decisions.
- Overall, observational food environmental mapping assessments as presented here which includes infrastructure assessments can be used to estimate malnutrition risks among populations.
- The substantial impact of vendor environment variables on health outcomes signals the need for comprehensive food policies that encompass both the economic aspects of food markets and the socio-economic contexts of the communities they serve.
- The N-FEI offers opportunities to identify entry points to improve built food environments to reduce malnutrition in all its forms.

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