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RESEARCH ARTICLE

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Participatory mapping and food-centred justice in informal settlements in Nairobi, Kenya

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Food vendors are pivotal in the local food system of most low-income informal settlements in Nairobi, Kenya, despite being seen as an obstruction and as agents of disease and filth by city authorities. This paper explores the geography of these foodscapes – defined as public sites of food production and consumption – in selected low-income settlements in Nairobi, focusing on the interaction of food vendors with their surrounding environment and infrastructure services. The research uses participatory geographic information system tools, including food mapping with mobile apps and high-resolution community aerial views with balloon mapping, to capture and contextualise local knowledge. The community mappers collected data on 660 vendors from 18 villages in Kibera, Mathare, and Mukuru, and situated them on multi-layered synoptic geographic overviews for each settlement. The resulting data on hazardous areas in relation to food spaces and infrastructure provision allowed local communities to prioritise areas for regular clean-up activities and assisted advocacy to improve these places in cooperation with local authorities. These multiple visual representations of foodscapes make local food vendors, and the risks they face, visible for the first time. Reframing their "right to safe food and environment" from a social and environmental justice perspective allows local communities to put their experiences, knowledge, and challenges faced at the forefront of urban development planning, policy, and practice.

KEYWORDS
environmental justice, foodscapes, Nairobi, participatory geographic information system (PGIS), participatory mapping, vendors

1 | INTRODUCTION

Urban low-income households in many sub-Saharan African cities, including Nairobi, Kenya, often rely on informal food vendors for their daily needs (Tacoli et al., 2013). Yet, these small-scale, but significantly numerous vendors are not perceived favourably in a planning and urban management system permeated by modernising ideals and shaped by the aspirations of a small elite. As their stalls contribute to congestion in the very limited public spaces of the informal settlements where they are located, they are often seen by local authorities as obstructing the adequate functioning of the city. They are also seen as agents of disease and filth due to their inadequate food safety measures, including poor storage facilities, and

often contaminated by their proximity to waste dumps and open sewers. These vendors frequently suffer removal or the forced closure of their stalls by city authorities during disease outbreaks, which not only puts their livelihoods at risk but also affects access to an important source of food for the poorest residents of low-income settlements who tend to be most dependent on them (Keck & Etzold, 2013; Tacoli et al., 2013).

Despite such adversities, food vendors continue to be crucial to food supply in most low-income informal settlements (Tacoli et al., 2013). Claims against food vendors in informal settlements are seldom grounded in evidence. Much scholarship on food vendors in cities of the global South focuses on central locations and official markets (Chukuezi, 2010; Muinde & Kuria, 2005; Muyanja et al., 2011; Omemu & Aderoju, 2008; da Silva et al., 2014). The challenges faced by food vendors in informal settlements to keep the food safe to eat in spaces characterised by multiple environmental hazards and inadequate basic infrastructure require further grounded exploration.

This article is based on primary research conducted in Nairobi and seeks to contribute towards filling this knowledge gap. We approached the research in three informal settlements from the angle of environmental justice with the premise that food vendors are important contributors to urban food security, while underlining the fact that they also represent a viable and sustainable source of livelihood. In the next section we introduce the notions of environmental justice and foodscapes that underpin the study. In the third section, within the broader context of scholarship on community or participatory mapping, we outline the community mapping efforts by members of the Kenyan Federation of the Urban Poor (*Muungano wa Wanavijiji*), without whose support this study would not have been possible. In the fourth section, we elaborate on the methods and tools used to co-produce local spatial knowledge on the networks of food vendors that operate in informal settlements and the environmental conditions in which they operate. Section 5 presents key findings from the aforementioned community mapping efforts, that is, food types, socio-demographics of vendors, and everyday risks faced by vendors. In the following sections we discuss how the community mapping process helped empower food vendors in their efforts for greater recognition, cooperation and more room for engagement across and beyond the settlements. This is followed by a final section with reflections on how locally produced knowledge can translate into meaningful action.

2 | MAPPING FOODSCAPES WITHIN AN ENVIRONMENTAL JUSTICE FRAMEWORK

The concept of environmental justice started its journey as a critical framework to explain the disproportionately higher concentrations of toxic sites in predominantly poor and black communities in the US in the late 1970s. A "conceptual transfer" has since taken place when the concept started to be adopted in global South contexts, too (Brulle & Pellow, 2006; Kubanza & Simatele, 2016; Myers, 2008; Schroeder et al., 2008; Walker & Bulkeley, 2006). The conceptual framing of environmental justice remains a "broad church," encompassing different notions and, as it continues to evolve (Walker & Bulkeley, 2006, p. 656), a more "rights and capability" based approach has been recently explored (Kubanza & Simatele, 2016; Myers, 2008). Building upon the work of social justice scholars such as Nancy Fraser and Iris Young, Schlosberg (2009), Allen and Apsan-Frediani (2013), and Allen et al. (2017), among others, consider procedural (in)justice and distributional (in)justice in the form of three inter-related processes: (un)fair distribution of resources affecting the disempowered, lack of recognition or lack of fair treatment of marginalised communities, and (un)fair democratic processes that lead to (in)adequate participation of all stakeholders in the environmental decision-making process, particularly without sufficient attention to marginalised and disempowered communities (Walker, 2009, p. 615).

As stressed by Myers (2008) and Kubanza and Simatele (2016), urban environmental justice is largely absent from development planning, policy and practice discourses in African cities: it is only found in planning policies in nine out of 53 countries, and Kenya is not one of them. In most African cities, scarce public resources for urban environmental management and infrastructure provision tend to cater to wealthier areas while ignoring poorer areas (Kubanza & Simatele, 2016, p. 873). As street vendors can both affect and be affected by unsafe and insufficient infrastructure and services, an important analytical step is to understand environmental injustice in the urban space where street vendors operate. As current debates on environmental justice appear to be limited to considering places in terms of where people live and work, we embrace Gottlieb's food-centred environmental justice that extends it to where, what, and how people eat (Gottlieb, 2009; Gottlieb & Fisher, 1996). Gottlieb also examines where, what, and how food is grown, produced, sold, and consumed with the aim "to introduce the concepts of community food security and justice as part of the organising framework and advocacy for a different kind of food system" (p. 7). Gottlieb's food-focused environmental justice is rooted in sustainable agriculture, localised production, and the dominant Northern discourses around sustainable food systems to tackle the globalised nature of food (in)security. We reframe this perspective to focus initially on what food is being eaten by the

community[1] in three low-income informal settlements in Nairobi, where many community members are actively engaged in food vending themselves. Food consumption practices can be illustrated by mapping the location of food vendors and positioning it in the "foodscape" of the settlement. Although the meaning of a "foodscape" can be wide and all-encompassing – to include different stages of food production, distribution, and consumption at a variety of scales that connect food, places, and people (Cummins & Macintyre, 2002; Trenouth & Tisenkopfs, 2015; Mikkelsen, 2011) – we adopt a narrower view to encompass the spatiality of food systems, the geography of sites of food production and consumption in public spaces. Such a view highlights certain modes of food access and practices in places of survival and provides us with a better understanding of the socio-spatial arrangements that interact with the lived realities of environment and infrastructure in these settlements. By taking into account the spatial knowledge of local residents, the concept gets rewarded by "being situated in a particular place and focused on the relationships that a particular community has with food" (Miewald & McCann, 2014, p. 540). Such hybridisation of knowledge through maps and narratives builds upon the work of Allen and Apsan-Frediani (2013) and Lambert and Allen (2016), and allows us to analyse whether food safety is compromised and whether the local environment has a role to play in it.

The study sought to explore foodscapes with local communities, more specifically how the range of food they buy, sell, and eat is connected with the places where they live, work, and walk. This highlighted the need for multiple layers of data to position "multiple ways of knowing" these foodscapes and their relationship with the environment. In the process, the local communities acquired access to innovative knowledge-producing tools which give them the potential to map their own realities.

3 | PARTICIPATORY GIS AND COMMUNITY-LED MAPPING

The use of geographic information systems (GIS) for data creation, analysis, and dissemination of information has become widespread in various disciplines because of their ability to bring more life to data. They do so by embedding data within a location, thus improving visualisation and aiding the decision-making process (Sieber, 2006). GIS proliferated in urban planning and management applications in the 1980s but was largely an elitist and positivist tool used for surveillance, control, and exercise of authority by a few (Cope & Elwood, 2009; Sieber, 2006). Public participation GIS (PPGIS) aimed to make spatial platforms more open to the public initially in more developed countries. By the late 1990s it had evolved into a tool to give voice to marginalised communities in the global South under the title participatory geographic information system (PGIS) – a fusion of participatory learning and action (PLA) and GIS – also called "community GIS/mapping" or "GIS-in-practice" (Corbett et al., 2006; Dunn, 2007; Forrester & Cinderby, 2005).

Participatory geographic information system involves a collaborative process offering the opportunity for diverse perceptions and realities of space and place to be represented by using geospatial technologies, including spatial and non-spatial qualitative data – for example, community narratives representing local knowledge initiated and directed by local actors (Elwood, 2006; McCall et al., 2015; Rambaldi et al., 2006).

Participatory geographic information system aims to represent local people's spatial knowledge by geographical information products – most commonly maps – that are flexible, adaptive to different socio-cultural environments, and by supporting communication and community advocacy, keep them informed and inclusive (Verplanke et al., 2016, p. 2).

Participatory geographic information system gave rise to a community of "grassroots GIS users and mappers,"[2] promoting GIS and mapping practices to navigate local initiatives while addressing priorities that are important to the local community (Corbett et al., 2006; Elwood, 2006; Haklay & Francis, 2018; McCall et al., 2015; Rambaldi et al., 2006; Sieber, 2006; Verplanke et al., 2016).

Inspired by many other examples of PGIS and community mapping elsewhere (e.g., Corbett et al., 2006; Livengood & Kunte, 2012), the Kenyan Federation of the Urban Poor (Muungano wa Wanavijiji) has been using PGIS for profiling, enumeration, and mapping of urban informal settlements (for examples, see Karanja, 201; Makau et al., 2012; and Weru, 2004). They have had long-term support in community profiling from Shack/Slum Dwellers International (SDI),[3] which also supports similar federations in 33 countries and 488 cities across Africa, Latin America, and Asia. The Muungano Alliance of the urban poor was formed in 1996 to give voice and legitimacy to the urban poor through enumeration and settlement profiling of those who usually remain invisible in city plans and are, therefore, largely excluded from accessing formal infrastructure services such as roads, electricity, water, and sanitation (Appadurai, 2001; Patel et al., 2012). While generating up-to-date data allows them to negotiate with local government to improve living conditions and fight evictions, such efforts also give them greater confidence as citizens and create self-awareness of their capacity as a community (Makau et al., 2012; Patel et al., 2012; Weru, 2004). In the last few years, Muungano has already profiled and mapped living conditions and concerns in over 150 settlements in Nairobi (Karanja, 2010). Innovative efforts like an upgrading plan

for the informal settlement of Mathare,[4] jointly done with scholars from the University of Nairobi and the University of California, Berkeley, helped attract pilot projects from the City Council (now called Nairobi City County), such as providing individual water taps and electricity connections to the neighbourhood of Kosovo (one of the villages in Mathare; Karanja, 2010). Community mappers were energised and given self-confidence by such successes.

4 | METHODS AND TOOLS FOR MULTI-LAYERED VISUAL REPRESENTATIONS

Despite its extensive work, Muungano had never examined how food is affected by living conditions in informal settlements. Food came to the top of its agenda when it became evident that there are risks to food arising from inadequate infrastructure provision. The Federation wanted to capture foodscape-related risks (i.e., food risks that are visible in the community around the space where the vendors usually operate from) in three informal settlements with grounded multiple visual representations showing how food can lead to poor environmental health. The research reported here sought to generate local spatial knowledge co-produced with Muungano and local residents about the food that is consumed. We restricted the study to identifying food-vending sites, as food vending is one of the predominant modes of consumption in Nairobi's informal settlements, as previously identified by Tacoli et al. (2013) and later confirmed by this study in discussions with residents. In cooperation with the Federation, community members conducted the study in 11 villages in Mathare, three in Kibera, and four in Mukuru (Figure 1). For a brief introduction to these settlements, see Ahmed et al. (2015a), p. 8 and supporting information Appendix S1 supplied with this paper.

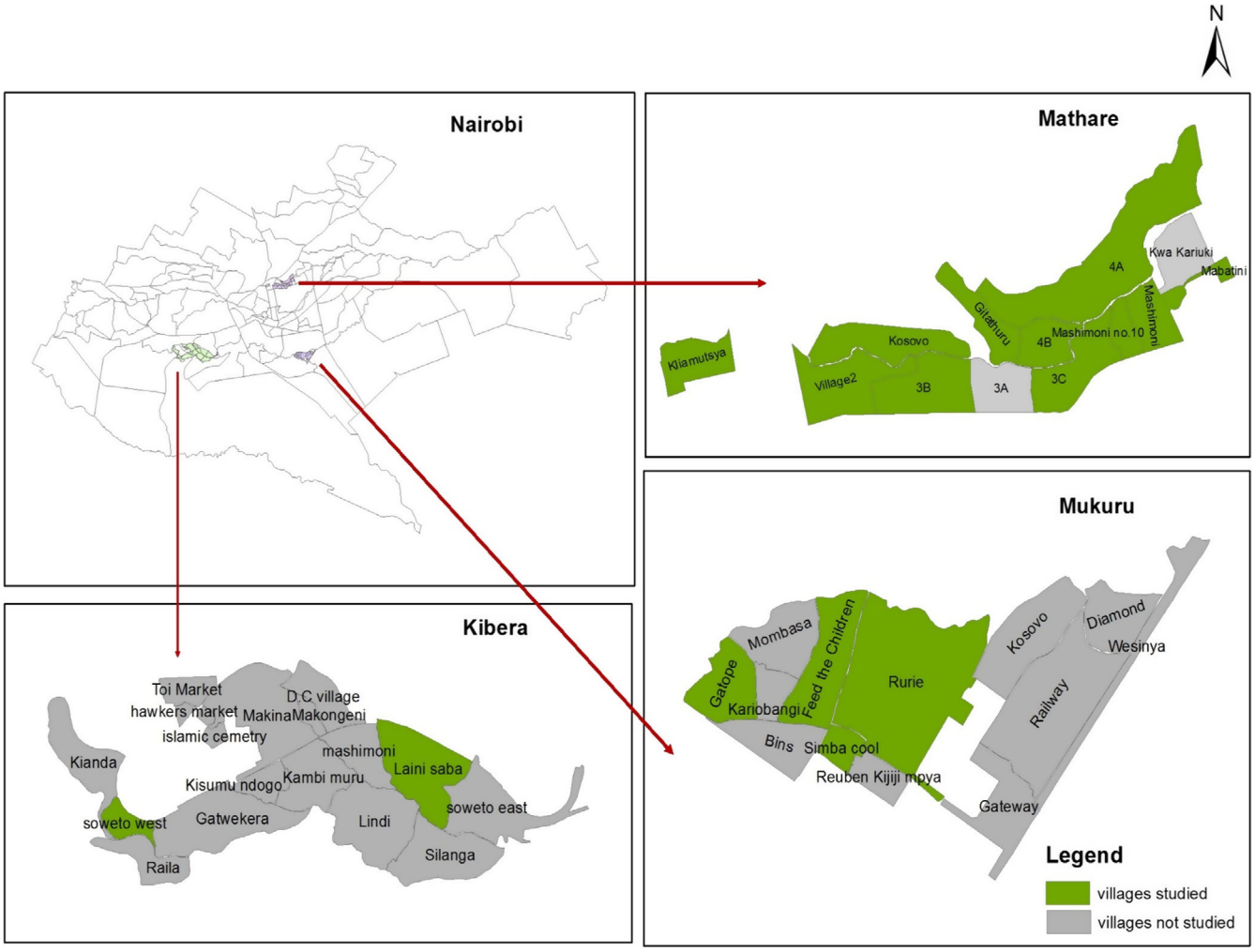

FIGURE 1 Location of case study areas.
(*Source*: Ahmed et al., 2015a; Ahmed, et al., 2015b, p. 8)

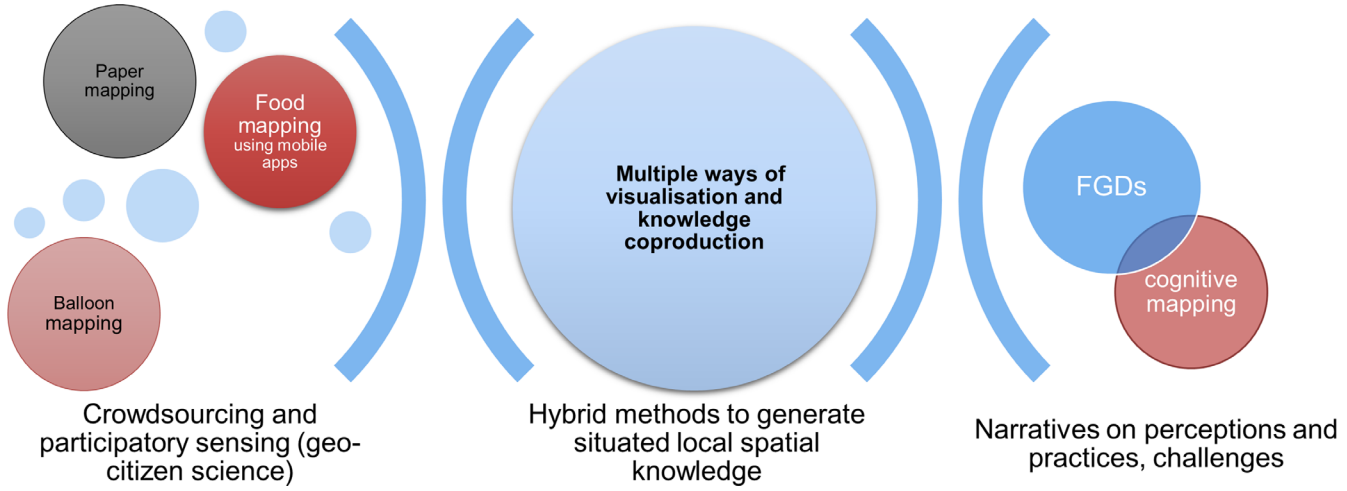

FIGURE 2 Hybrid methods to generate situated local spatial knowledge.

The process of mapping the issues identified by the community was supported by local and external analysts working in a collaborative way to collect and analyse the data. Using several PGIS tools, we adopted innovative ways for the multiple representation of places (as illustrated in Figure 2 and described below) by bridging citizen science[5] tools (mobile apps and balloon mapping) with conventional PGIS tools like paper maps[6] to create appropriate community data and knowledge platforms that assemble all partial and situated knowledge through multi-layered representations. Later on in Section 7 we examine how the mapping process adopted helped stir change and further empowered the participating communities.

Furthermore, the raison d'être behind such multi-representations is to assist local communities to frame and reframe their own narratives and experiences as "representational practices" (Elwood, 2009, p. 61) and so arrive at new agreed priorities, while also challenging the existing meanings and identities embedded in those spaces. For example, the Federation had been working through mapping with other partner organisations (e.g., previously developed local base maps for the Mathare Zonal Plan[7]) to highlight inadequate infrastructure provision, thus showcasing and advocating the need to direct resources to areas requiring more attention. The use of hybrid methods outlined below and depicted in Figure 3 gives more room for community-led knowledge generation and advocacy as multiple ways of knowing. They offer "representational flexibility inherent in existing forms of the technology, creatively mixing and shifting representations, epistemologies, and signification strategies" (Elwood, 2009, p. 60).

In the initiative undertaken as part of the action research project that informs this article, the cognitive ability of community participants is used whenever possible to harness local knowledge about risk hotspots around food. Combined with conventional focus group discussions (FGDs), indoor mental/cognitive mapping exercises using printed satellite images, and other paper maps (see top right corner image in Figure 3) broadened the possibilities for gathering wider community views on foodscapes and the local environment. Such tools allowed the research team to glean preliminary local spatial knowledge from the communities involved and helped to collectively identify locations that require mapping. The communities also used "participatory sensing" techniques (Haklay, 2013a) now readily available in smartphones; the GPS and camera abilities of the mobile location-aware devices were used for mapping food-vending types (see bottom right corner of Figure 3). The data collection application EpiCollect[8] allowed them to collect vending locations as point data, offering a rapid scan of food consumption sites in public spaces. Information was also collected on basic demographic data about the vendors (age, gender), as well as the food safety measures used by vendors.

4.1 | Aerial images through community-led balloon mapping

In this era of crowdsourcing, when wiki-like knowledge production is flourishing, open-source mapping has gathered significant momentum, particularly for humanitarian purposes such as those following the earthquakes in Haiti and Nepal.[9] Open-source tools are also used to map marginalised communities (e.g., community-led mapping of Kibera, Mathare and Mukuru using the OSM platform; see MapKibera.org and Hagen, 2011). While building local map-making capacity and infrastructure, such platforms can be very effective when led and managed by local communities to map issues that are important to them (Warren, 2010, p. 39).

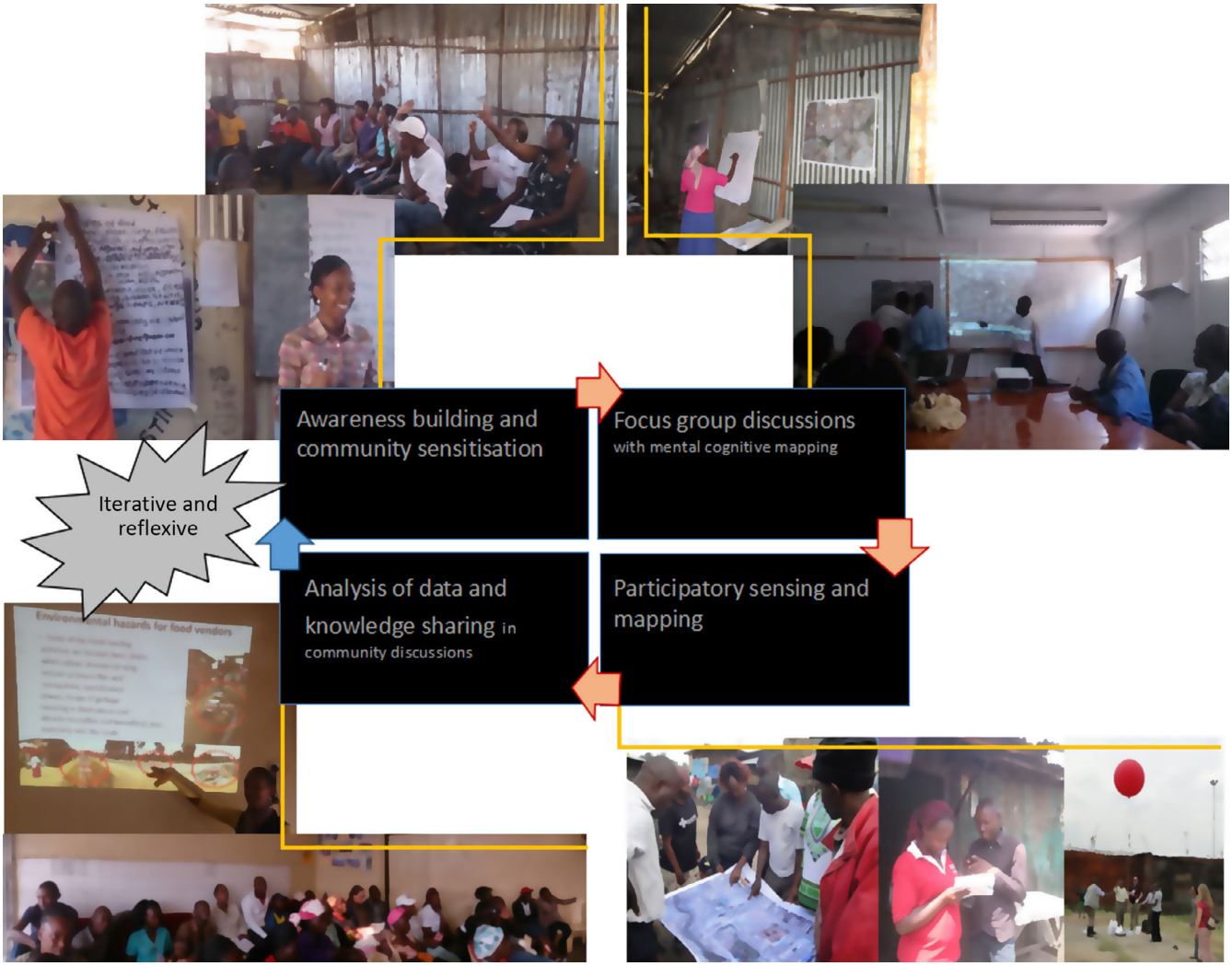

FIGURE 3 Key steps followed throughout the community-mapping process.

Nevertheless, open-source mapping tools still rely heavily on costly commercial aerial images from Digital Globe or Microsoft, which can be up to three years old or might suffer from cloud coverage in places with little commercial interest. Requiring a certain literacy level to know their source, cost, and appropriate resolution, many of these satellite images are not openly accessible to common citizens, unless purchased at high cost and with external technical support.

When, in 1885, French photographer and balloonist Gaspar Félix Tournachon (known also as "Nadar") used a tethered hot-air balloon 80 metres above the ground to successfully produce the first aerial photograph of the French village of Petit-Becetre, balloons, kites, and other forms or means (including pigeons) were used for capturing aerial photographs.[10]

The use of balloon mapping for environmental and other community/local concerns has recently proliferated (Barry, 2014; Shubert, 2014). The Public Laboratory for Open Technology and Science (Public Lab, see publiclab.org) developed and promoted balloon and kite mapping as a do-it-yourself (DIY) mapping technique to provide a cheap, accessible, up-to-date option for grassroots mapping. As a DIY technique, and part of a wider citizen science movement, balloon mapping is being constantly updated and improved by the Public Lab community. The balloon mapping kit consists of a helium balloon (similar to weather balloons used typically by meteorological departments across the world), an inexpensive digital camera (often second-hand), and other housing components that are inexpensive and can be locally found or made (Figure 4a). Upon reaching different heights, the balloon can give an on-demand bird's-eye view as high-resolution aerial photographs (see Public Lab's website, and the paper by Cravero (2015) for a brief overview of how the Kenyan Federation used it in this project).

We also looked at other means of taking aerial photographs. Kite mapping, for example, is often considered as complementary by Public Lab or, where possible, as an alternative to the balloon, as it is cheaper and readily available. It can be made locally (even from cement bags) and does not need the relatively expensive helium gas. But it has its limitations, too,

FIGURE 4 Balloon mapping process in pictures: (a) balloon mapping kit, (b) assembling the kit for flight preparation, (c) testing the inflated balloon, and (d) balloon flight in one settlement.
(*Source*: Sohel Ahmed, Grace Githiri)

as it requires certain wind conditions as well as some open space to start its flight that, unlike the balloon, are challenging in crowded settlements. We found this a critical issue for Nairobi's informal settlements where congested places often lack wire-free open space. Although drones are becoming increasingly affordable and easily available, the community rejected their use, fearing that local residents might not welcome the use of drones, while authorities might perceive them as potential threats to national or local security. For Mathare, this might have been the case due to the close proximity of the settlement to a police station and an air force base.

In this case, balloon mapping seemed to fit well into the ethos of the community-led mapping process. As can be seen in Figures 7 and 8, the local communities engaged used balloon mapping tools to generate cheaper DIY high-resolution community aerial photos that offer different and unique bird's-eye visual representations of environmental hazards (such as open sewerage lines and waste dumping sites) at a community scale. This tool also helps to update local base mapping and helps with enumeration activities. Even though it is not a scalable technology and is ideally for small-scale use (Warren, 2010, p. 24), for this study, the community took the extraordinary leap to a scale often not tried with this tool elsewhere – extending beyond an individual village or community – and entirely for the aims prioritised by local communities. The cognitive abilities of community participants were also used to stitch these images together to create settlement-wide images and offer an overview of the scale of environmental problems they face. Figures 7 and 8 also show attempts by community mappers to use the images to generate community data in a GIS environment. Thus, the "expert power" of GIS, complemented with other visual representations taken from the ground and from the air and linked to maps, provided a powerful set of tools for representing "objective" local realities that local authorities might be more inclined to accept than oral or written accounts.[11]

5 | FINDINGS FROM THE COMMUNITY MAPPING EXERCISES

5.1 | Food types and location of vending

Although vegetables, fruits, and cooked food account for the majority of the food sold by informal vendors in the three settlements,[12] demand varies by settlement (Figure 5). For example, in Mathare most of the food sold is cooked compared with the other two settlements. Knowing the location of food vendors is useful to understand the potential environmental risks involved in selling food. The maps in Figure 6 identify the locations of 660 vendors who were mapped by community mappers in the 18 villages of Kibera, Mathare, and Mukuru. A Kernel density estimation tool[13] was run on the data set for the vendors' locations to identify clustering patterns, as well as the short distances between some of the vendors. The locations, depicted as red dots and clustering patterns for each settlement (shown in gradual shades of blue, light for low-density and dark for high-density), were overlaid on roads and boundary data for the villages. In Kibera, where 106 vendors were mapped, there is a higher concentration of vendors in particular road segments in two villages: Laini Saba and Soweto East. In Mukuru (where 117 vendors were mapped), it is interesting to see that certain road segments shared between the villages – like Feed the Children, Simba Cool, and Rurie – have much higher concentrations of vendors. Similar trends are found in Mathare, between Village 2, Mathare 3B, and Mathare 3A.

Most vendors in Mukuru concentrate in the street between Rurie and Simba Cool, and are relatively busy catering for employees from neighbouring industries. Due to the presence of vendors selling chapatis[14] 24 hours a day,

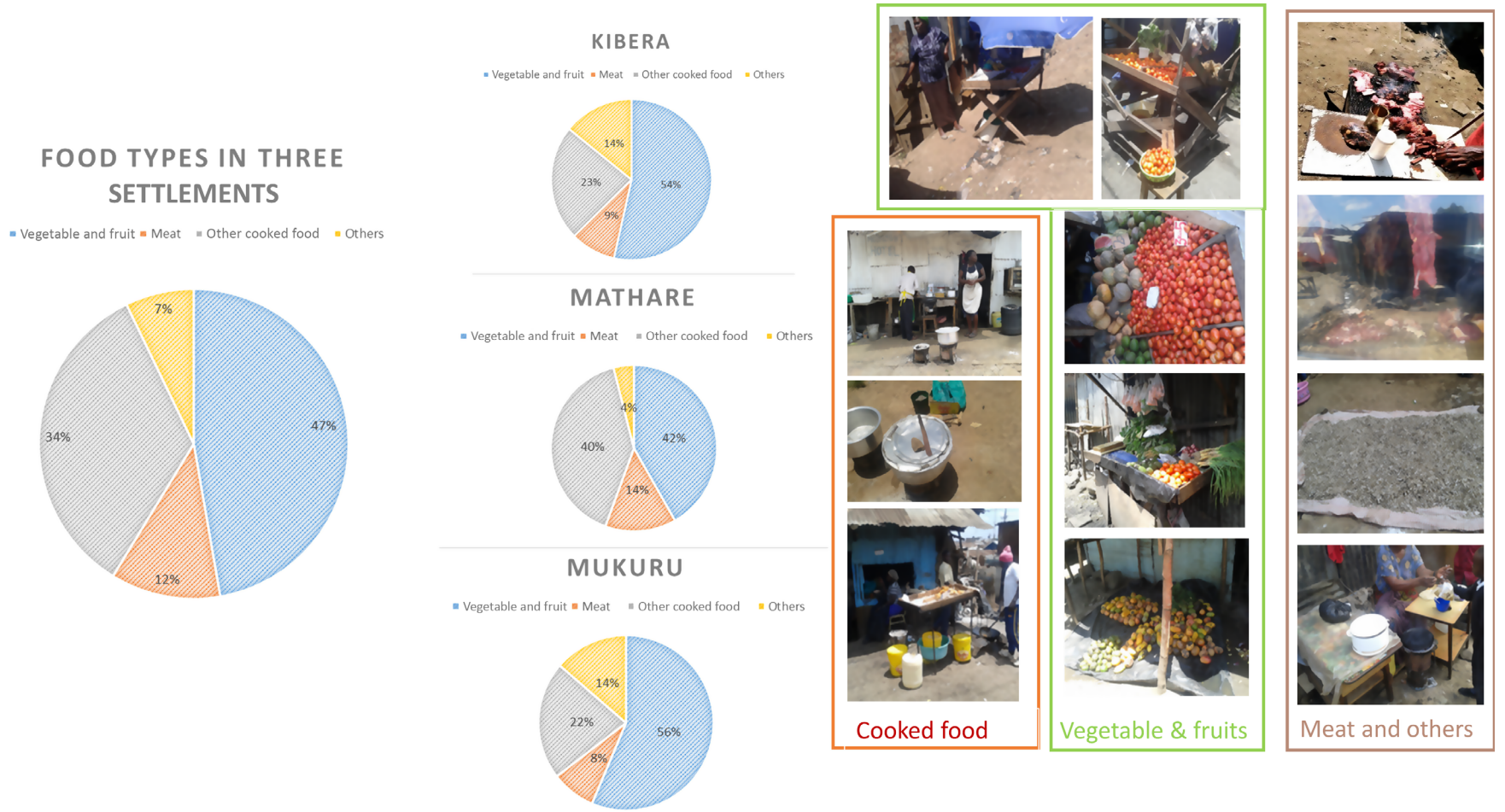

FIGURE 5 Food types sold in the three settlements combined, in individual settlements (pie charts), and examples of food types captured through mobile app survey.

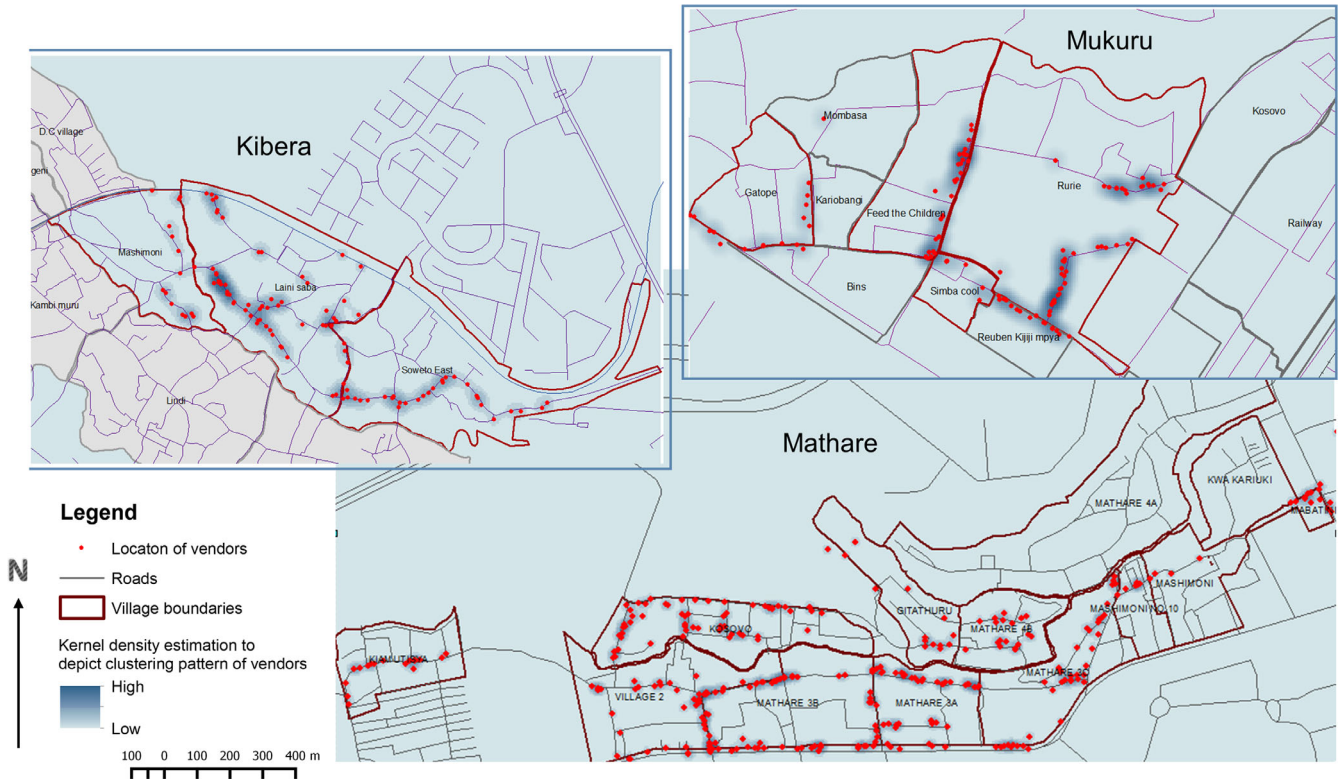

FIGURE 6 Spatial distribution of vendors (as red dots) in the 18 selected villages across the three settlements.

the route cutting through Rurie village is known informally as "chapati road." As we found from our observations during several transect walks, due to the scarcity of open space, streets ("including paths, alleyways and all the fine capillary connections that allow movement between the buildings of the slum, as well as major thoroughfares, busy routes and vehicular roads"; Ashkenazi, 2015, p. 28) are the most dominant form of public space accommodating multiple social and economic functions like shopping, hawking, social interaction, child playing, and livestock roaming.

5.2 | Socio-demographics of vendors and perceived exposure to environmental hazards

In all three settlements, about two-thirds of vendors are female (67%). The age of vendors varies by settlement, with two-thirds in the 26–35 and 36–45 age brackets. In Mathare, more vendors are aged 36–45 years (40%), while in Mukuru and Kibera they are on average younger, with the majority in the 26–35 age bracket (53% and 55%, respectively).

During the rapid scanning of vendors using EpiCollect, community mappers also collected data based on their perceived notion of proximity of food locations to roads, waste dump sites, open sewers, and drains (Table 1).[15]

As mentioned earlier, vendors are often found in and around places of high circulation of people. Some 90% of vendors in Kibera and Mukuru operate near main roads. When vending activities happen away from this public space,

TABLE 1 Perceived proximity of exposure of food-vending locations to environmental hazards by community mappers

Criterion		Three settlements count (%)	Kibera count (%)	Mathare count (%)	Mukuru count (%)
Proximity to main roads	Near	511 (80.2)	95 (89.6)	232 (72.95)	109 (93.16)
	Not near	126 (19.7)	11 (10.37)	86 (27.04)	8 (6.84)
Proximity to dump sites	Near	95 (14.91)	21 (19.81)	61 (19.18)	2 (1.7)
	Not near	542 (85.08)	85 (80.18)	257 (80.81)	115 (98.29)
Proximity to open sewers/drains	Near	418 (65.62)	74 (69.18)	235 (73.89)	51 (43.58)
	Not near	219 (34.37)	32 (30.18)	83 (26.10)	66 (56.41)

Source: Fieldwork.

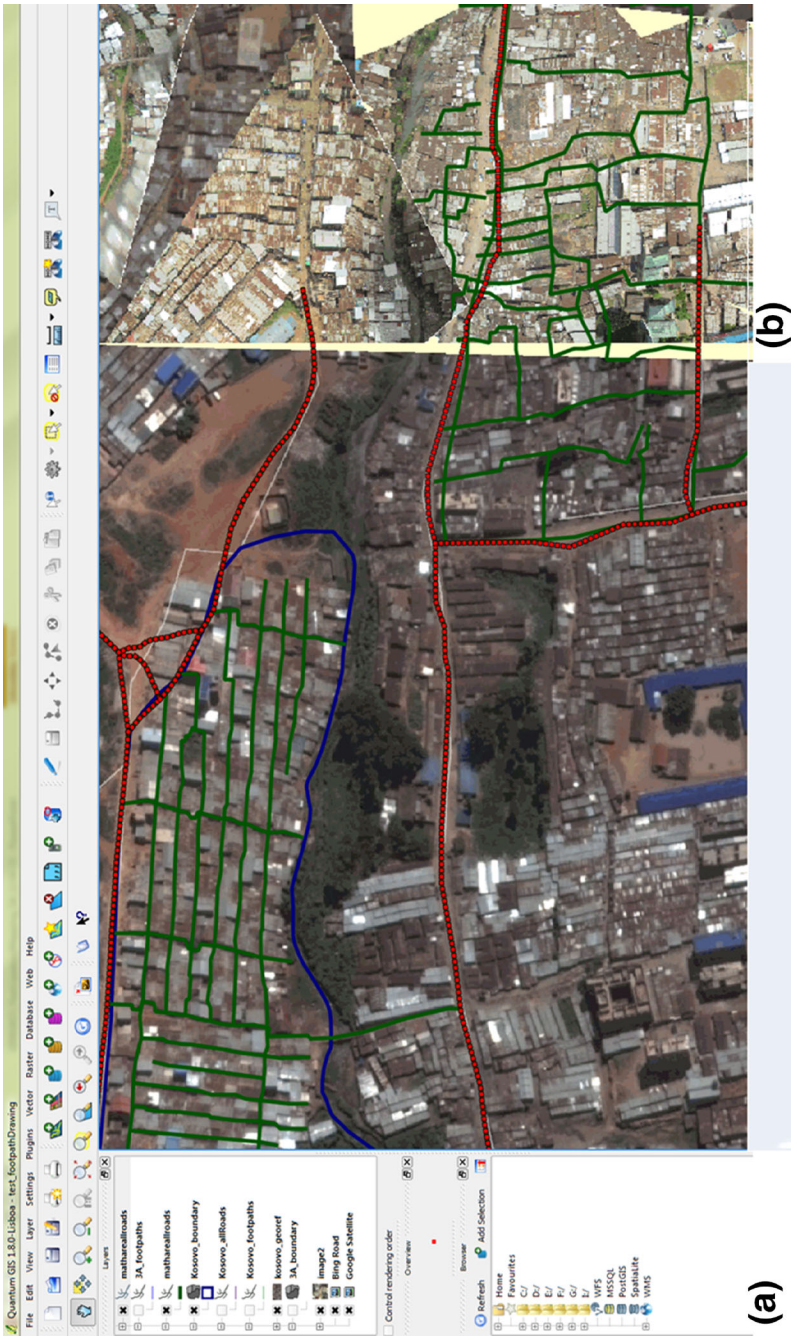

FIGURE 7 Balloon-derived high-resolution community aerial images used for updating footpaths (green lines), roads (red lines) (a), and waste dumping sites (b).

FIGURE 8 Visual representation of the village Bondeni/3A captured from the balloon on the air (a), Village 3A at street level (b), and use of balloon-derived images for dumping ground identification (c).

they are considered isolated or not near. For example, 27% of vendors in Mathare operate away from the main roads arising from specific individual or social constraints (e.g., mothers operating from their front doors so they can look after their children).

Most vendors are found away from waste dumping sites (85% of them, on average, across all settlements) due to the generalised perception that food sold near such sites is unsafe. And yet, there are still a good number of food vendors near dumping sites in Kibera (19.8%) and Mathare (19.2%), who are either unlikely to find other suitable locations or have limited choice due to care responsibilities as mentioned before. However, nearness of some of these dumping sites to pathways and other conduits of movement still allows them to tap into steady customer flows (see Figure 10). Besides, the near lack of public investment in sewerage and solid waste management options means that sewerage lines and dumping grounds are closely aligned with the spatial configuration of roads, either within a foot or two, or on top of, these public spaces. As residents tend to dump waste on the sides of the roads, railway lines, and into the river stream, and over two-thirds of vendors are located near open sewers in Mathare and Kibera, inevitably most vendors and their food are likely to be exposed to poor environmental conditions.

5.3 | Use of balloon-derived images to generate community data

With the help of balloons, community mappers managed to capture a good number of high-resolution aerial images in all 11 villages in Mathare, with the best images screened and stitched together to create high-resolution images for particular villages. Residents identified and updated data on footpaths, waste dumping sites, and open sewers/drains, and explored further spaces for economic activities. Figure 7 shows attempts to draw footpaths and dumping sites in a GIS (QGIS) and Figure 8 offers an example of how the same location can be represented and visualised in multiple ways. In Kibera and Mukuru, by contrast, balloon mapping proved difficult, primarily due to security issues and the lack of sufficiently long corridors free of electric wires that criss-cross the roads.

6 | ENVIRONMENTAL HEALTH AND THE SPATIAL DISTRIBUTION OF VENDORS AND INFRASTRUCTURE SERVICES

6.1 | Operating times and location of vendors

Although we learned that food vendors usually operate between 5 a.m. and 10 p.m., through more in-depth discussions we found that these times vary notably depending on issues like the physical setting, coverage of electricity

lines, proximity to main roads, the gender of vendors, and security concerns. Location decisions are not always straightforward as we understand from our conversations with women vendors who prefer selling near their homes so that they can look after their children and do the household chores at the same time. Women vendors also avoid secluded sites due to security concerns, which can come up even during the day. As said earlier, in general, vendors prefer to operate near main roads because these have street lighting and higher customer flows. And yet, some interesting narratives emerged from our conversations with them. For example, we heard of cases of vendors forging partnerships with other vendors to take turns and operate in two or three mutually agreed time slots spanning the whole day, so that, between them, they retain strategically located spots, a practice that offers greater security and better chances of tapping into the constant flow of customers irrespective of the time of the day. By aligning vendors' operating locations with those of electricity lines, decisions on many of the different locations shown in Figures 7 and 8 start to make sense (Figure 9). Vendors in Kosovo enjoy better reticulation of electricity connections compared with other places due to recent municipal interventions arising from the Mathare Zonal Plan and other advocacy efforts. Similarly, we found that Village 4B, which lacks the physical infrastructure advantages of Kosovo, enjoys similar security advantages arising from its relatively strong social cohesion due to the common cultural, ethnic, and social background of vendors and residents, especially local youth. Being from the same tribe provides the vendors operating within their own village better security from local youth gangs both during day and night times. Vendors in Kosovo and Village 4B are thus able to operate until late at night, even after 11 p.m., while in other places vendors take the precaution of finishing earlier. In Village 4B, in particular, tighter social ties allow vendors to operate without any hindrance away from the main roads, even in internal narrow alleys, while experiencing enough customer flow compared with vendors operating during the day in comparable locations in other villages.

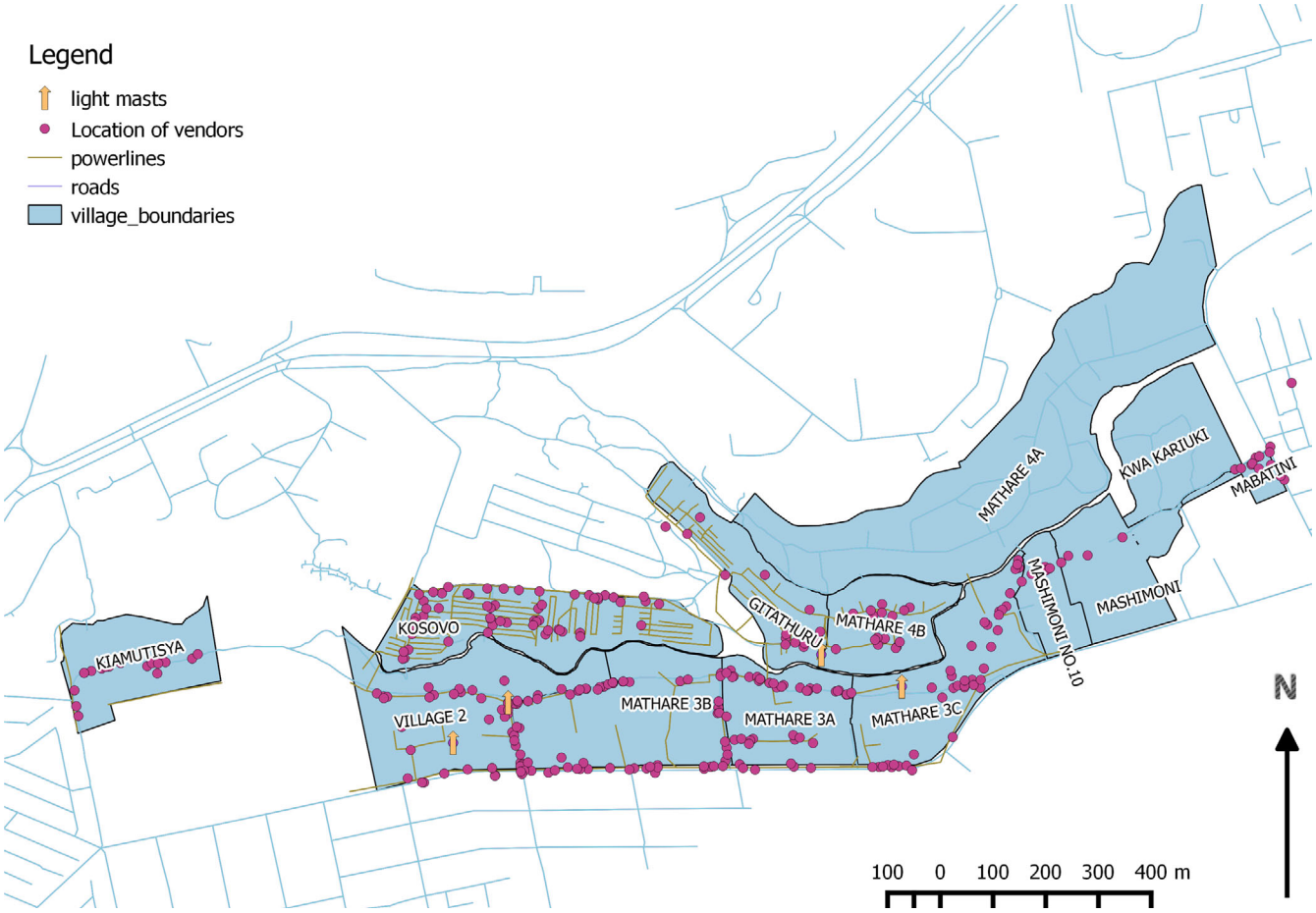

FIGURE 9 Intersection of vending locations and electricity lines in Mathare.

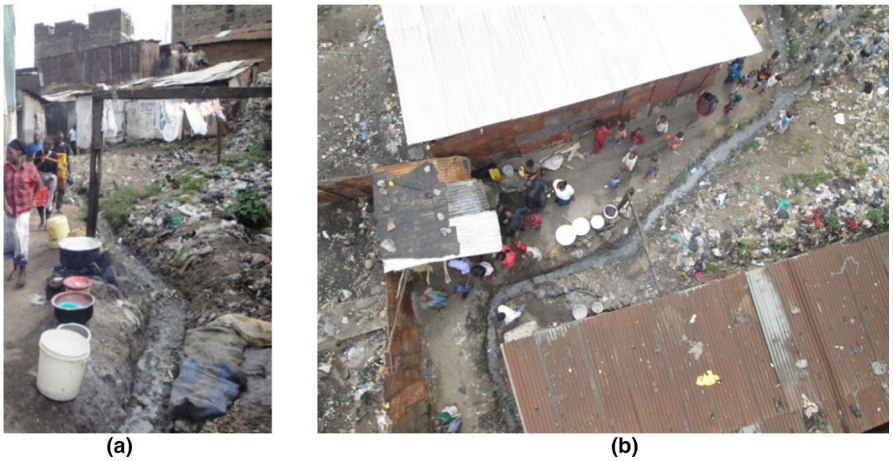

FIGURE 10 Dining with risk (from left to right) – pictures from transect walk (a), balloon-generated community aerial view of manifestations of food and environmental health intersections (b) in Bondeni/Village 3A.

6.2 | Exposure to everyday environmental risks

Food sold by vendors is not only likely to get soiled when the stalls are located close to main roads but is also likely to be exposed to contaminated water and sludge from open drains and open sewage. This is the case of Village 3A/Bondeni, Village 4B, and Kosovo in Mathare, where many vendors operate next to open drains. From the balloon-generated image in Figure 10, one can easily picture the hazards that the surveyed communities live with when heavy rain causes the drains and river to overflow and affect food-vending activities.

Around a quarter of the 161 vendors surveyed in the three settlements did not use sheds to sell their produce. These vendors run additional daily risks to their health from exposure to heat from the scorching sun and to heavy rains. Without adequate storage facilities, the food they sell is more likely to suffer from spoilage.

6.3 | Inadequate infrastructure and food safety

The majority of vendors access water either from communal taps or water kiosks. The price of water is quite high in these settlements and varies widely between them. According to Corburn (2013), Mathare residents pay 43.5% and 48.5% more for a litre of water than residents in Kibera and Mukuru, respectively. Mathare residents either have to rely more on long queues to water kiosks, or travel long distances when public water points close by malfunction (Figure 11). In many cases, when they cannot leave their vending places, they have to rely on water vendors. This is often the case for Village 3A/Bondeni and Village 4B, which lack sufficient public water taps. According to Edwin (2014, p. 55), vegetable and fruit sellers in Mathare are limited to two to three jerry cans per day. The cost of carrying water can add 25–75 Kenyan Shillings (KSh) per day, which is much higher than the retail price of water.

Given the fact that people in these informal settlements spend, on average, 11% of their income on water alone (about 40 times more than high-income groups elsewhere in the city; Corburn, 2013), it is no wonder food vendors use water sparingly, which means food quality and food safety are often compromised as washing produce and cooking pans, and even personal hygiene, including hand-washing, involve the additional cost of water.

Figure 11 also shows the everyday sanitary challenges vendors face. Given the high cost of accessing toilets (about 3%–7% of monthly household expenditure), and with 83% of residents in Mathare relying on public toilets, this constitutes another heavy economic burden (Corburn & Karanja, 2014, p. 263). In Bondeni village in Mathare, for example, there is only one public toilet available to vendors, which means that they have to negotiate daily with unsafe practices. Compounded with water scarcity, such practices make the task of keeping food safe more daunting.

7 | PARTICIPATORY MAPPING AND SAFE FOOD

As discussed in Section 3, settlement mapping, saving schemes/groups and community to community exchanges are core activities of SDI/Muungano to ensure that community members remain "at the centre of planning and managing initiatives

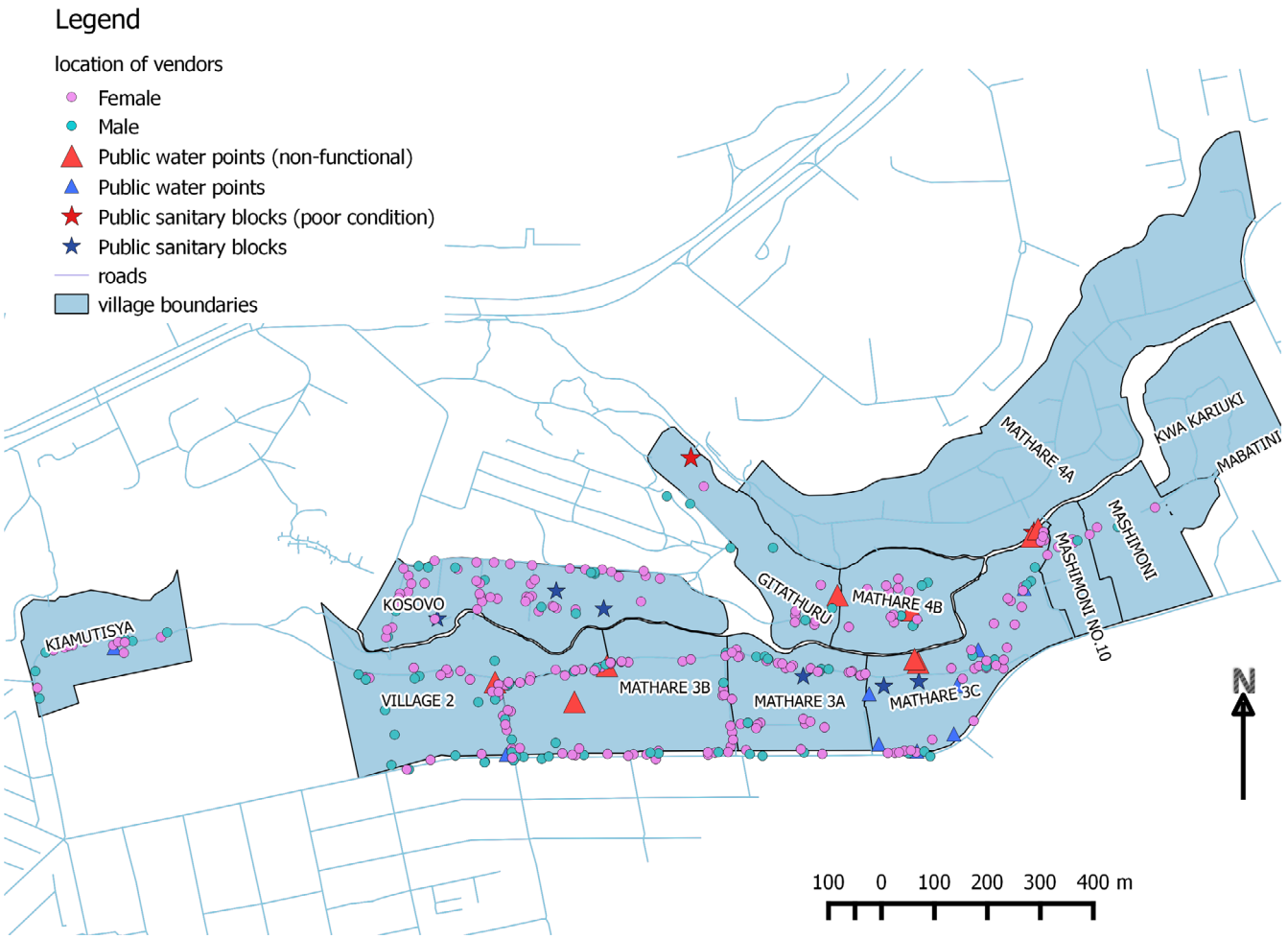

FIGURE 11 Intersections of vendor locations and distribution of (non)operational public water points and toilets in these settlements.

(including conceiving how participation should be done) and of the negotiations with all external agencies, including local governments" (Patel, 2004, p. 117). In other words, enumeration and mapping have been central in gaining ground in places where most community members are considered to be "illegal" (Karanja, 2010; Makau et al., 2012; Patel, 2004; Patel et al., 2012). Instead of going by the conventional consultation route with local governments for settlement improvement projects, SDI and its Federation members are always looking for opportunities to set precedents after trials through the learning cycle that embed tested methods of organisation, mobilisation, teaching, and learning (Livengood & Kunte, 2012), developing more cost-effective and sustainable solutions to housing, infrastructure, services, and livelihoods (Patel, 2004, p. 118).

The innovative participatory mapping process discussed in this paper was not set in isolation but was brought into a community discussion dating back to 2012, when Muungano members started thinking of ways to improve residents' access to safe food and, at the same time, support food vendors, most of whom live in the settlements they serve (Ahmed, et al., 2015a, 2015b; Cravero, 2015; Tacoli et al., 2013). Mapping remained part of a social learning cycle that includes several stages:

> Identifying priority concerns; trying out solutions; learning from each other as these solutions develop; refining solutions and supporting more groups to try them; and using solutions as precedents to encourage change in government policies, programmes or regulations. (Patel, 2004, p. 119)

Consequently, multiple and innovative ways of gaining knowledge through mapping have injected empowerment in a number of ways in this social learning process.

7.1 | Learning through iteration and making mistakes

With a deep mistrust towards residents of low-income settlements, many public/local government-led community programmes leave little room for mistakes. As Patel has noted, this

> … does not allow the learning and training capital produced by mistakes to be reinvested in new processes. It stops participation at the first sign of error … [so] poor communities are unable to experiment because they have no margin within their limited resources to absorb mistakes. (Patel, 2004, p. 126)

The social learning cycle that the SDI Federation members/Muungano members follow gives them the flexibility to make mistakes and learn from them and share the experiments and experiences through community exchanges. We followed a similar approach during the mapping process. When we started the pilot run in the Bondeni village/settlement 3A, Mathare, the community struggled initially to fly the balloon high enough as they did not put enough gas in the balloon fearing it would burst. This resulted in a balloon not inflated or big enough to fly on higher ground, yet they saw its potential for high community acceptance and engagement at that very first trial. With trial and error, they managed to work out how to do it properly and came up with innovative solutions on how to cover ground seemingly inaccessible initially.

7.2 | Community-led knowledge, legitimacy, voice, and capacity-building

The research project we report here was largely led by the community. Food vendors were central to all discussions but livestock keepers, consumers of street food, and others all took part in the learning cycle (Ahmed, et al., 2015a, 2015b; Cravero, 2015). Once the mapping and data analysis were completed, the results and aerial photographs were shared and discussed with the communities engaged by Muungano. In those meetings, the communities identified primary concerns and ranked them according to their priorities, while acknowledging how crucial food vendors are to community health and well-being. For instance, community members recognised that food vendors need more food safety training to improve their hygiene practices. At the same time, they also acknowledged that they had to do more in terms of instigating initiatives and cover more ground towards strategic partnerships with the Nairobi County government (formerly City Council) to organise frequent clean-up exercises around disposal sites and sewerage lines, and to arrange community awareness campaigns themselves to designate waste disposal sites, improved water provision, sanitation and lighting, as well as communal storage and refrigeration facilities.

At this stage of the conversation, food vendors who were traditionally stigmatised for selling unsafe food, found a clear "voice" and a sense of legitimacy after being mapped for the first time by their own people. The scale of their operation, made visible through figures, aerial images, and maps, helped give recognition to their service to the community, thus nurturing a sense of pride among them. New-found legitimacy fostered greater levels of cooperation among vendors within and across settlements, leading eventually to the formation and expansion of the Food Vendors' Association (FVA), which operates in low-income settlements. To enhance their capacity-building and access to more resources (previously largely limited to informal reciprocity between some vendors), they launched a new saving scheme to help each other with Federation support. The FVA subsequently ran several food safety training sessions for food vendors with the help of one of the partner organisations in the research project, the International Livestock Research Institute (ILRI), which trained the first vendors, who then acted as trainers to train other vendors across the settlements in Nairobi with the help of the FVA. More clean-up operations were arranged with Nairobi County, who also handed over resources to the communities so that they could conduct additional clean-up operations themselves.

7.3 | Mapping that feeds into deep democratisation

Adopting new state-of-the art technologies and mapping tools (e.g., using maps in FGDs and aerial photography through balloon-mapping kits) has helped community members acquire new skills and organisational abilities while strengthening their capacity for engaging with actors such as local authorities. Lessons learned allowed them to use the tools in other settlements with different local needs, realities, degrees of official support, and community dynamics requiring different negotiating strategies (see Githiri et al., 2016). Information, knowledge, and data assimilation from our project allowed trust to be built among citizens across different settlements as community mappers continued to train residents in other settlements to help map problems they consider to be priorities, and more specifically to help make food safer. Similar to what has

been documented in the Map Kibera project, we also witnessed "enhanced social, occupational (and indeed, geographic) mobility, and a level of technical facility indicating deep democratisation" (Hagen, 2017, p. 24; Haklay, 2013b).

We found that the community started with fewer questions to kick-start the discussions in Bondeni/3A (Mathare) during the trial run of the project than they ended up with in the settlements of Korogocho and Viwendani, where women, who make up the majority of food vendors, helped articulate more gender-centred approaches (Githiri et al., 2016). The role and contribution of women vendors thus became more recognised in community discussions.

In summary, the study identified a number of emerging opportunities for empowerment and deep democratisation (see Hagen, 2017, p. 24). For instance, the mapping process and its products led to a new awareness on food safety, greater knowledge of the constraints in which food vendors operate, how health can be improved through greater food security and better food vending practices, as well as identifying inflection points or triggers for directing attention to target immediate and near-future interventions. The mapping process itself allowed new technology to be learnt and generated specific context-aware data and a sense of legitimacy and voice. Food-centred mapping has encouraged new ways of experimenting and precedent-setting within the existing template of the social learning cycle of the Federation and has helped FVA advocate for pro-poor urban policies to support and expand livelihood options for the poor. As Rashid Mutua, National Chairperson of Muungano wa Wanavijiji, said:

> This [process] has helped the community understand the issues of health, safety, and wellbeing. The collection of data, the trainings, the awareness, the mobilization, have helped the community … to understand their issues so that they can push the bigger agenda of the Federation and of the community (Cravero, 2015).

8 | CONCLUSION: KNOWLEDGE LEADING TO ACTION

This project shows that bridging new PGIS tools (such as food mapping with mobile apps and high-resolution aerial images through balloon mapping) with conventional GIS functionalities can respond better to local realities and give local communities greater control than simple digital cartography. The processes and products arising from the co-production of spatial knowledge led to several actions. First, community members have used the narratives built on the maps, images, and other data in further community discussions and advocacy, eventually translated into planning for immediate and future location-specific and settlement-wide interventions: for example, settlement-wide awareness-building by showcasing these multiple forms of visual representations. With such multi-layered synoptic geographic overviews, communities identified hazardous areas in relation to food spaces and infrastructure provision (for example, pinpointing accumulated solid waste that might be sources of food contamination) while allowing them to prioritise areas for clean-up. These tools gave them objective representations and helped to establish priorities that could be put forward to the government of Nairobi County, leading to public-community-based solid waste collection efforts. They also led to a rare opportunity to present findings in a Parliamentary Committee.

Second, mapping expertise continues to be disseminated widely by training individual mappers and assisting with technology transfer to other settlements in Nairobi and beyond. The enumeration prototype and profiling of food vending are also being replicated in other settlements (for preliminary findings on the two large informal settlements of Korogocho and Viwendani, see Githiri et al., 2016). Similarly, a visual working paper[16] (Cravero, 2015) was launched for wider dissemination of the benefits arising from the mapping efforts so that federations in other countries can learn and benefit from this study.

Third, from a food-centred environmental justice angle, such uses of GIS and data collection tools were not mere knowledge-building tools, but also provided a solid platform to help empower local communities. The quick survey of 660 vendors made them visible for the first time to residents in their own informal settlements. Furthermore, through the physicality of food vendors, their typology and magnitude, the survey provided valuable insights into what residents eat and how critical food-vending activities are to community health, functioning and well-being. The mapping process gave food vendors (traditionally stigmatised for serving unsafe food) a new sense of legitimacy and a clear voice after being mapped for the first time by their own people. The FVA has made a difference in terms of raising concerns and creating solidarity among vendors across informal settlements, enabling them to act as change agents who can work together to support local livelihoods. The initiative has brought the right to safe food and environment to the forefront of development, planning, policy, and practice for recognition.

In Ahmed, et al. (2015a, 2015b), we argue how inequality in water access in low-income settlements is not the result of scarcity but is rather due to historically and socially reproduced, deeply entrenched socio-spatial segregation that leaves these marginal communities not only with inadequate access to water but forces them to pay at least 40% more for it than the elite does. Most residents are forced into unsafe practices without meeting their daily needs. Consequently, community food safety is systematically compromised due to deeply rooted structural factors, while vendors from these settlements suffer from the same unequal and inadequate access to water and sanitation. As shown in this article, many are persistently drawn to selling food near hazardous sites and, like others in these settlements, suffer from poor environmental health.

Although vendors are central to the food security of these settlements, they are often criminalised, even by local authorities, for selling unsafe food. To overcome unfair practices while promoting greater food security requires more inclusive, supportive interventions. The FVA has helped give vendors recognition, and allowed them to participate in decisions that affect community food policies, environment-related programmes and other interventions that are fairer to them. That there is a vibrant community social capital is evident in examples of reciprocity. For example, green-grocers give away leftovers to goat keepers – a practice that allows for hidden yet innovative waste or nutrient recycling. In order to enhance capabilities, recognising such practices and making procedural changes that accommodate locally innovative coping strategies is crucial. Another example is the FVA's unique savings scheme to help members share and exchange knowledge on practices and ideas across settlements and outside Nairobi too (with federations in Tanzania and Ghana).

This project has in some ways helped the community gain a voice. At a policy level, the FVA has shared the results with international policy actors like FAO and UN Habitat at regional food security workshops (Tacoli, 2015, 2016).[17] This study also leads to the conclusion that urban upgrading efforts in informal settlements that focus solely on physical upgrading of infrastructure miss a large part of the picture. No physical improvements are likely to be successful where safe food is unaffordable and inaccessible to local residents. Much can be learned from local authorities in Latin America (e.g., Rosario in Argentina, Belo Horizonte, Brazil, or Bogotá and Medellin in Colombia) that have taken an explicit pro-poor orientation towards food as a citizen right, redefining governance issues around food access, regulations and subsidies, as well as education (Haysom, 2015). Although much has been gained from using technology creatively to raise awareness of the realities of Nairobi's poor, there is still much that local authorities can do to improve the lives of residents in the city's informal settlements.

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ENDNOTES

[1] Here we adopt the definition of community in a similar vein to that proposed by MacQueen et al., 2001 (p. 1929) as "a group of people with diverse characteristics who are linked by social ties, share common perspectives, and engage in joint action in geographical locations or settings." This is in line with other definitions of community by Nutbeam (1998), and Fettes (1999), found in Allman (2015). In this study "community" refers primarily to residents of particular villages in Nairobi's low-income settlements. One feature they share is that they engage in several core activities of the Kenyan federation of the urban poor with the aim of finding more cost-effective and sustainable solutions to housing, infrastructure, services, and livelihoods in these settlements. For additional information on their activities, see section 7 and Karanja (2010), Makau et al. (2012), and Weru (2004).

[2] Individuals and organisations involved in PGIS initiatives: smaller NGOs, activist groups, community organisations (Elwood, 2009, p. 59).

[3] For more information, see sdinet.org.

[4] For more information, see http://ced.berkeley.edu/collaborate/collaboration-in-action/mathare-zonal-plan

[5] "Scientific activities in which non-professional scientists voluntarily participate in data collection, analysis and dissemination of a scientific project" (Silvertown, 2009, in Haklay, 2013a).

[6] The community mappers prepared and printed both satellite and hard copy maps for all of the 18 villages. The hard copy maps usually included prior mapped information on the villages' basic infrastructural facilities and boundaries, captured through prior community mapping processes

by Muungano. When available, satellite imagery (purchased, or downloaded from free platforms such as Google Maps) helped the community mappers to orient themselves and allow for smoother navigation along the desired transect walks (Ahmed, et al., 2015a, 2015b).

[7] https://www.muungano.net/publicationslibrary/2017/4/6/mathare-zonal-plan-collaborative-plan-for-informal-settlement-upgrading

[8] EpiCollect is a free, open-source application developed by Imperial College London for data collection purposes (with funding from the Wellcome Trust). It provides a web and mobile application to generate forms (questionnaires) and freely hosted project websites for data collection. Data are collected (including GPS and media) using multiple phones and all data can be viewed centrally using Google Maps, tables, or charts (Aanensen et al., 2009). For more information on using EpiCollect, see http://www.epicollect.net/.

[9] For more on this, see OpenStreetMapping (OSM) and its efforts in base-mapping in disaster, disease, or conflict-affected areas for humanitarian reasons at https://hot.osm.org, or https://missingmaps.org – now supported by the British and American Red Cross and Médecins Sans Frontières (MSF).

[10] For a short history of aerial photography, see https://papa.clubexpress.com/content.aspx?page_id=22&club_id=808138&module_id=158950.

[11] Other actors, particularly public and local government actors, usually treat "GIS-based data and maps as accurate representation of local conditions" and so take it more seriously as an "expert or legitimate portrayal on the ground" (Elwood, 2009, p. 70).

[12] Cooked food usually includes *Githeri* (a stew made of maize and beans), *Ugali* (a staple starch made of maize flour, rice, roasted meat, and other cooked meat products such as "Mutuura," "Sambusa," "Mushugi," and cooked chicken parts), beans, porridge, chips (French fries), *Chapati* (flat round fried bread), *Mandazi* (fried sweetened triangular doughnut), and hot beverages like coffee and tea; uncooked food typically comprises raw meat and fish products (fish, "Omena"), sweet potatoes, arrowroot, Irish potatoes, and bananas; vegetables include "Sukuma Wiki," cabbages, carrots, tomatoes, onions, "Kunde" (cowpea leaves), and other traditional vegetables such as amaranth ("Terere"), spider plant ("Saget"), pumpkin leaves ("Malenge"), and African nightshade ("Managu"); fruits typically include oranges, watermelon, mangoes, bananas, pawpaw, and avocado (Ahmed, et al., 2015a; Ahmed, et al., 2015b, p. 17; Edwin, 2014, pp. 43–44).

[13] As part of a suite of classic spatial data exploration tools set to visualise clustering patterns in point data sets, "Kernel density estimation provides an informative (exploratory) tool for hot-spot and cool-spot identification and analysis" (De Smith et al., 2007, p. 220).

[14] Flat round bread (baked or fried) made with wheat flour, water, and salt – a traditional Kenyan food thought to have been brought in the nineteenth century by Indians who came to work in Kenya for the Kenya–Uganda railway.

[15] The importance of embedding the notion of perceived proximity (i.e., how the community mappers viewed the distance of vending locations to other spatial features affecting their operations and food safety) surfaced during the design and initial phase of the research, as well as during the focus group discussions and cognitive/mental mapping exercises. Validated during the pilot mobile app survey and associated paper mapping exercise, we found that mappers had perceived proximity to roads and associated hazards ("subjective measure") more accurately than GPS ("objective measure") could locate them. Most community mappers are vendors themselves and have substantial spatial cognition of risk. Their eyes (and noses) seem better than GPS at identifying potential exposure of their food/produce (in terms of nearness or not nearness) to everyday risks from roads, waste dumping grounds, or sewer lines. We continued to tap into mappers' perceptions of subjective proximity in the mobile app surveys by keeping questions on the simple dichotomous scale of proximity to hazards, complemented by GPS capture of the location (with over 1 metre error margin) with mobile phones. Given the nature of our study, we believe that people's mental representation of distance is more relevant than device-generated measurement of distance. Hence, we have not reported the objective measure here (see Arias et al., 2017; Giordano et al., 2010; Kato et al., 2015; O'Neill et al., 2016).

[16] https://www.iied.org/mapping-for-food-safety

[17] Led by IIED with funding from the International Fund for Agricultural Development (IFAD). For more on the policy discussions, see the blogs, policy briefs and reports at https://www.iied.org/urbanisation-rural-urban-transformations-food-systems.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix S1. Brief profile of Mathare, Kibera and Mukuru.

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