Towards a participatory methodology for community data generation to analyse urban health inequalities: a multi-country case study

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Abstract

This paper presents results from the application of a methodological framework developed as part of an ongoing research project focused on understanding inequalities in the healthcare access of slum residents of cities in four countries: Bangladesh, Kenya, Pakistan and Nigeria. We employ a systematic approach to produce, curate and analyse volunteered geographic information (VGI) on urban communities, based on a combination of collaborative satellite-imagery digitization and participatory mapping, which relies upon geospatial open-source technologies and the collaborative mapping platform OpenStreetMap. Our approach builds upon and extends humanitarian mapping practices, in order to address the twofold challenge of achieving equitable community engagement whilst generating spatial data that adheres quality standards to produce rigorous and trusted evidence for policy and decision making. Findings show that our method generated promising results both in terms of community engagement and the production of high-quality data on communities to analyse urban inequalities.

1. Introduction

One of the big challenges for achieving the United Nations Sustainable Development Goal (SDG) of "ensuring healthy lives and promoting well-being for all at all ages" (SDG 6) is related to urban inequalities and people living in disadvantaged urban communities of the Global South, so-called slums [1]. The understanding of problems faced by people living in these communities is hampered by the fact that many of them are "invisible": national censuses and household surveys tend to focus on the formally recognised constituents of the city, and the corresponding neighbourhoods are frequently absent from official maps and socio-economic data. As a result, there is a high risk for official statistics and research on urban health to overlook these important structural intra-urban inequalities and thus fail to reflect the real progress towards one of the SDG's main goals of "leaving no one behind", which should start by "reaching the furthest behind first" [2].

Thus, there is a fundamental gap as regards to accurate and up-to-date socio-spatial data to the most vulnerable urban communities [3]. Moreover, it is important to go beyond a simple slum versus non-slum dichotomy and produce finer-grained assessments of urban environments to characterize urban spaces more granularly, e.g. through the use of features identifiable from space such as density of structures, footpaths etc. [4]. This detailed characterization of urban neighbourhoods would allow researchers and policy makers to identify existing inequalities across urban spaces, thus enabling differentiated and targeted approaches in analysis and policy making for urban health.

One way of filling this data gap is using citizen-generated data or volunteered geographic information (VGI) which involves harnessing specific tools to generate open-access geographic data through voluntary and participatory means [5]. OpenStreetMap is one of the most famous VGI platforms and is known as the "Wikipedia of maps", i.e. a crowdsourcing mapping platform with a worldwide community of more than 4 million

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registered users [6]. Other methods for generating geographic data such as those used by professional private companies or governmental mapping agencies tend to be more expensive, depend on political willingness, and usually exclude community residents from the mapping process. In contrast, using open source mapping tools and open-access data enables wider usage by other organisations (e.g. for advocacy and pro-poor policy making) and other researchers.

Following the paradigmatic examples of the use of OpenStreetMap (OSM) for crisis mapping, there have been sustained efforts to use participatory and collaborative mapping for generating data on vulnerable communities in the Global South [7], [8]. This includes, for instance, participatory mapping in the slums of sub-Saharan Africa [9] and the initiatives of the Humanitarian OpenStreetMap Team, such as the MissingMaps project [10]. Researchers have also started to study these mapping activities (e.g. [11] and [12]). These VGI-based initiatives are often aimed at producing detailed maps of human settlements at the building level, which can be useful to understand population distribution and urban health inequalities, for instance by providing insights into patterns of accessibility to basic services such as healthcare provision. However, although there is an ecosystem of several different open source mapping tools available used by a vibrant global humanitarian mapping community, there is still limited research that assesses the results of such initiatives, in particular as regards to their capacity to provide rigorous evidence to tackle urban inequalities, whilst also engaging and empowering communities. Furthermore, given the number of alternatives in tools and methods used in participatory and humanitarian mapping, another important knowledge gap is the lack of methodological guidelines for initiatives in this area.

In an attempt to contribute towards filling these knowledge gaps, this study presents the results from the application of a systematic and participatory methodology for generating urban community data to enable the analysis of urban health inequalities. We report here about promising results achieved in the context of an ongoing global project for improving healthcare access in slums in cities of Asia and Africa (Bangladesh, Kenya, Nigeria and Pakistan).

The remainder of the paper is organized as follows. Section 2 reviews previous studies and identify the research gap addressed by our study. Section 3 describes our approach and outlines the main components of our methodology, whilst Section 4 presents our results and findings. Section 5 concludes the paper and presents suggestions for future work.

2. VGI in Humanitarian Mapping

The use of VGI and crowdsourcing for humanitarian mapping in addressing disaster risk response has exponentially increased during the last decade [13], [14]. Current humanitarian mapping practices commonly use OpenStreetMap (OSM) together with a number of open source mapping tools to manage the mapping tasks. Through the help of volunteers, a new map is created, usually based on satellite imagery, through a remote mapping process. Some regional groups host social events (so-called 'mapathons') to come together and map, but most contributors participate online [15]. Volunteers undertake different types of tasks for the production of geographic data, for instance by interpreting satellite imagery and drawing buildings and roads seen on the imagery to produce data that is uploaded to an online database [14].

One of the most active organisations in this area is the Humanitarian OpenStreetMap Team (HOT), a non-profit charitable organization created in 2010 in the aftermath of the Haiti Earthquake, which aims at providing humanitarian aid in the most under-developed areas of the world [16]. Many HOT projects are exclusively based on digital imagery of the mapped areas, but this type of remote mapping may produce an uncertain data quality [17], since the mappers may not have the tacit knowledge on the local spatial context.

However, several humanitarian mapping projects have also included participatory mapping, which consists of methods that could be largely situated within the tradition of Public Participation Geographic Information Systems (PPGIS) [18] and engage local residents for producing geographic data on the ground. The work of Map Kibera in 2009 in Nairobi is one of the early and most significative examples in this area [9], [19], [20]. Within a three-week period, local residents were taught to use the OpenStreetMap toolbox and upload their data in the platform producing the densest map available of Nairobi's largest slum, Kibera [9], which was previously largely invisible. Another example includes the work of Kathmandu Living Labs in Nepal, which conducted participatory mapping preventively and ended up being one of the key sources of information for relief efforts after the

Nepal Earthquake in 2015 [16], [21], [22]. The Missing Maps project [10] launched by HOT in partnership with the humanitarian organisations *Médicin san Frontiére/*Doctors without Borders (MSF), British Red Cross and American Red Cross focuses on preventive mapping of vulnerable communities and also includes participatory mapping practices in some initiatives.

Notwithstanding the importance and vibrancy of the humanitarian mapping community, there are two important obstacles that hinder the wider utilisation of humanitarian mapping based on VGI to generate evidence for research and policy making. The first consists of uncertainties related to the quality of the spatial data generated by participatory mapping and other similar methods for community data generation. This is a common issue in the PPGIS literature as well [18], and a frequent concern voiced by stakeholders. Second, although several quality assurance mechanisms are generally in place and volunteers have been shown to be able to produce high-quality data [14], most of the existing literature on digital humanitarian projects still consists of single case studies, not always conducted using a rigorous evaluation methodology.

3. Approach and Methodology

Based on the analysis of existing methods and practices in the humanitarian mapping community, we would like to frame the production of urban community data as an interdisciplinary methodological challenge as illustrated in Figure 1. The methodological challenge consists of designing a process that can provide rigorous evidence for policy and decision-making, whilst at the same time effectively promoting inclusive and empowering relations with the communities involved. This involves a dialogue with two different perspectives on mapping. Traditional mapping techniques (e.g. such as those used by geomatics companies and national mapping agencies) can produce spatial data with a high degree of adherence to spatial data quality standards. They follow strict guidelines and aim at a well-defined set of dimensions of spatial data quality [23] (e.g. completeness, logical consistency, positional temporal and thematic accuracy). However, the application of these methods is costly and the technical expertise required excludes inhabitants from the poor urban communities from the process. In contrast, participatory mapping techniques (as the ones used in the humanitarian mapping community) are a good way to engage residents and local stakeholders in thinking differently about their relationship with the environment and the urban space; but as previously seen the extent to which the resulting data matches quality requirements is often uncertain.

Operating at the intersection of these two mapping traditions, we see an interdisciplinary problem space that is associated with a twofold methodological challenge: (a) promote effective engagement and participation of local stakeholders and residents of urban communities, with the goals of building capacity, empowering them for creating local ownership and ensuring the sustainability of the geographic data generated; (b) assess and improve spatial data quality, in order to ensure that the resulting data is able to capture intra-urban inequalities and be used as trusted evidence for scientific research and policy making.

To tackle this challenge, our methodological approach is based on participatory and collaborative mapping, but in addition to the methods adopted to by similar initiatives [22][24], the present approach introduces further steps of data production and validation to maximise spatial accuracy, whilst simultaneously engaging community members. Given the high density of poor urban neighbourhoods such as slums and their morphological variety across countries [25], using a methodology which is sensitive to the contextual characteristics is of crucial importance to creating a base for representative urban policies. The ultimate scope of this research is to propose a roadmap for systematic but context-aware participatory mapping of disadvantaged communities.

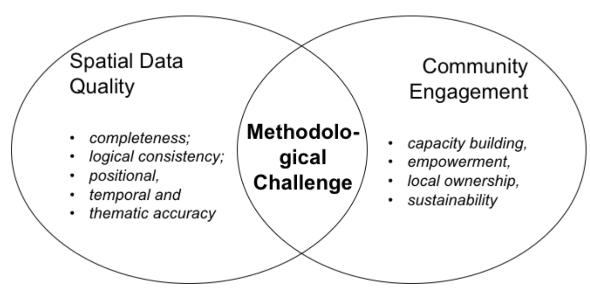

Figure 1. Our approach: an interdisciplinary methodological challenge

3.1. Project background: Slum health in Asia and Africa

The context of the present study is an ongoing project funded by the UK National Institute for Health Research (NIHR) Global Health Unit on Improving Health in Slums at the University of

Warwick in partnership with academic institutions of five four different countries to study slums in five cities: Dhaka (Independent University of Bangladesh), Karachi (Aga Kahn University, Pakistan), Nairobi (African Population and Health Centre, Kenya), Ibadan and Lagos (University of Ibadan, Nigeria) [26]. These countries were selected to have representatives from two continents where slums are an important phenomenon (Africa and Asia). Together with the local partners, seven slum neighbourhoods were selected for the study, based on existing relationships with the communities, namely: Korogocho and Viwandani in Nairobi; Korail in Dhaka; Bariga in Lagos; Idikan and Sasa in Ibadan; and Azam Basti in Pakistan. The largest area, in terms of physical area, from among our study sites is Sasa (1.22 sq. km), followed by Viwandani (0.54 sq. km), Korogocho (0.48 sq. km), Idikan (0.39 sq. km), Azam Basti (0.37 sq. km), Korail (0.34 sq. km), and the smallest is Bariga (0.33 sq. km).

The main objective of this research project overall is to understand problems faced by slum residents in accessing healthcare. This will be researched from different disciplinary perspectives including health sciences, social sciences and geographic information. This paper presents initial results from the latter component which is aimed at producing accurate maps of slums through the combination of digitization of Earth Observation satellite imagery and participatory mapping, following our interdisciplinary approach previously outlined. The results of this component will serve as a baseline to establish a sampling frame for the household surveys on healthcare access in the other components of the project, thus enabling us to capture spatial urban health inequalities in a granular and precise way.

3.2. Overview of the methodology

The main steps of our methodology are briefly described in Table 1. Similar to previous initiatives in this area, it consists on the combination of collaborative mapping (i.e. based on satellite imagery digitization) with participatory mapping (described in Section 2). However, to our knowledge, this is the first project to combine these tools with the requirements of scientific research in a multi-country, large-scale project. We thus correspondingly extended and adapted the methods and practices of humanitarian mapping to fulfil the twofold requirements our approach described earlier: producing rigorous evidence that adheres spatial data quality standards and generating effective community engagement towards empowerment. A detailed explanation of all activities involved in this process is beyond the scope of the current paper due to size restrictions. Instead, the next sections present main activities performed in each of the steps.

Table 1. Main steps of the method

Main steps	Brief description
1. Preparation	Preparing of materials, engaging stakeholders and defining responsibilities for the subsequent steps. This involves clarifying who are the persons that will fulfil the roles for each local partner team, as well as preparing materials for the digitization and mapping phases.
2. Digitization	To produce detailed base maps of the slum locations by tracing all streets and building structures from high-resolution optical satellite imagery. It involves digitization by remote and local teams and validation by experts.
3. Participatory mapping	To validate and enrich the digital maps obtained in the previous steps with the local communities ("ground-truthing") by correcting potential inaccuracies and, most importantly, conflating the map with local knowledge of residents.
4. Analysis	To consolidate the geospatial data obtained in the previous steps into data products and visualizations that will be useful for end-users and researchers.

3.3. Preparation

The preparation phase consisted of the following activities: secure slum access via community leaders and government permits; prepare training materials for the field mapping coordinators, the local digitization team and the local field mappers; procure high-resolution satellite imagery to be used for setting up the technical infrastructure; define responsibilities for the subsequent phases together with local partners, and collaboratively prepare an initial workflow protocol (procedure) with local partners. The training material comprises steps for creating OpenStreetMap user accounts, how to use the account to access the mapping platform setup using open-source mapping tools, and an online tutorial session on how to use point-line-polygon geometries to create features seen on provided satellite imagery. Additionally, a "data collection and management" manual has been created with detailed instructions on how to complete each of the outlined activities in the workflow protocol as well as manage data at both the local level and server side.

Key stakeholders were engaged, through our local project partners, including slum residents, which facilitated access to the communities. An expert mapping team was constituted including local mappers of the OpenStreetMap community who had previous experience with the mapping tools we used. Expert mappers from Pakistan, Ghana, and Bangladesh responded to our call and helped to correct topological errors created during the online mapping by less experienced mappers. Slum residents were recruited by our local partners via community leaders identified during the initial stakeholder engagement. Interested slum residents were invited to the first mapathon (mapping event) for training.

The base data in our project comprised high-resolution optical satellite imagery (Pleiades 50cm Colour Archive Data) acquired from Airbus. The procurement of satellite imagery became necessary because of the need for high-resolution, cloud free, and recent data for the chosen study sites.

3.4. Digitization

The digitization phase consists of tasks such as: the configuration of digitization tasks using the Humanitarian OpenStreetMap Tasking Manager; conducting training sessions with the local digitization team of each slum site about mapping and validating using open mapping tools; conducting mapping sessions with remote mappers and the local digitization team for the tracing of the building structure as well as the street network of each slum site from satellite imagery; and, conducting validation sessions with experts to assess the quality of the digital maps produced.

In this project, the Humanitarian OpenStreetMap Team (HOT) Tasking Manager, a free online infrastructure for coordinating remote crowdsourced mapping [27], [28], was used for managing the digitization of the satellite imagery by editing the areas on OSM. The Tasking Manager provides a graphical user interface which allows a user to define a specific geographic area and divide it into smaller squares ("tasks") which are allocated to whoever volunteers to contribute to the digitization. Once a user has decided to work on a task, this area is "locked" to preventing duplication while the user is working on the task.

We first trained our local project teams by "training the trainers" via skype using the training materials we had prepared. The sessions covered training on digitization using the Tasking Manager and organizing a mapathon (a coordinated mapping event with volunteers from the slum community as well as the local or global OSM community). Local project teams subsequently organized the mapathons with and invited volunteers from the slum community, the local and global OSM community, and in some cases students to update the OSM database using the base data and technical infrastructure.

Online validation of the data immediately follows the tasks that have been mapped. The online validation was done by experienced mappers on the platform identified during the recruitment of participants. Project team who are experienced mappers also took part in the validation activity. While mappers used the iD editor via the Tasking Manager to do the actual mapping, the validator used another editor, JOSM (josm.openstreetmap.de) which provides more functionalities to ensure data quality. However, the process for accessing the data, using OpenStreetMap account, is used by experienced with the only different being the change in type of editor used. For example, overlapping features could easily be detected and removed in JOSM than in iD editor. Although validation is another form of mapping, the emphasis is more on checking potential errors (e.g. topological errors) to enhance data quality. Validated data is available, on OpenStreetMap, to all stakeholders anytime throughout the mapping and validation process.

3.5. Participatory Mapping

The goal of the third phase is to validate the digital maps obtained in the previous phase with the local communities ("ground-truthing") by correcting potential inaccuracies and, most importantly, conflating the map with local knowledge of residents. As a preparatory step, GPS handheld devices are used to track all roads in the area. The resulting data is digitized into OpenStreetMap to establish a more complete road network and thus serve as a reference for the mapping on the ground.

Afterwards, the participatory mapping is conducted with a twofold method illustrated in Figure 2: (a) paper maps generated with the Fieldpapers tool [29] were used to annotate required changes, i.e. each built structure on the ground was verified against the map, and potential corrections (e.g. geometry inaccuracies, missing structures) were drawn on the paper maps; (b) an electronic from using OpenDataKit [30] was filled for each structure with some basic information needed for identification and its approximate position in the map pinpointed with the app OpenMapKit [31].

In many of the research communities, the building structures did not have unique identifiers, so we generated a unique identification code so that each structure could be traced, and double checked in the ground truthing phase. Furthermore, the slum residents involved were also able to map additional concerns of the community.

Figure 2. Participatory mapping using paper maps and electronic form.

3.6. Analysis

The first stage of analysis of generated data is through the monitoring of the HOT Tasking Manager dashboard which provides descriptive statistics of activities and contributions. The second stage is to download the vector data from OSM database and produce detailed maps using the open source software QGIS to assess the achieved results. To understand the completeness of the data, before-and-after mapping estimates covering total number of structures, roads and their total length were generated for each slum site.

Due to the use of the OSM platform, this data is available online for everyone to access. Furthermore, the Tasking Manager platform also openly provides metadata and process statistics of what has been mapped and validated.

4. Findings

This project involved a diverse set of stakeholders comprising the slum communities, academic researchers, OSM volunteers, humanitarian organization practitioners, government and non-governmental organizations. Harnessing the information generated by stakeholders to generate highly granular data on the spatial distributions of urban communities revealed two main findings: one, the completeness of the spatial data improved significantly adding new layer of spatial knowledge towards improving and understanding the spatial distribution of physical structures in the communities; and, two, there was successful engagement of community members. We thus frame our presentation of the findings in this section using the components of the twofold challenges highlighted in Figure 1 (spatial data quality and community engagement) to provide an initial assessment of our methodology across the four countries.

4.1. Data quality

Spatial mapping estimates have been suggested as one of the indicators that could help "deepen [the] understanding of how slum upgrading can influence the multiple drivers of human health in cities" [32]. Our study details the diversity of existing data on the communities, showing that the previous state of OpenStreetMap data on the examined slums is highly heterogeneous not only comparing the slums in different cities/countries/continents, but also amongst different areas within a single slum site. Table 2 shows pre-mapping estimates of features from the OSM data base showing the limited number of roads and structures in many of the research sites.

Table 2. Pre-mapping estimates of slum features from OpenStreetMap.org (30th November 2017)

Slum name	Structures (No.)	Roads (No.)	Total road length (Km)
Korail	5,152	28	6.26562
Sasa	1,842	89	15.68946
Bariga	0	18	2.58195
Idikan	2	14	3.72105
Korogocho	6,405	56	9.16841
Viwandani	1,415	11	4.00137
Azam Basti	0	29	4.19563

Table 3 presents some interesting information regarding the quality of spatial data, which emerged from our mapping and validation process. It is noticeable that the spatial data, namely structures and roads, within examined slum areas have increased significantly as a result of our project. Even in communities such as Korogocho (Nairobi), where there was previous data and the number and length of roads seem to have been reduced, the overall accuracy and precision of the spatial data has been largely enhanced. The numbers in Table 3, with the exception of Korail, are the result of online mapping and validation processes, as ground-truthing activities have not been performed so far. Figures 3, 4, 5 and 6 show the previous data (small inlet map) and current status (larger map) of some of the mapped communities. The most extreme cases in improvement of data completeness are Bariga in Lagos and Azam Basti in Karachi, where no structures at all had been mapped prior to the application of our method; thus, the entirety of spatial information presented is an outcome of our approach. On the other hand, in Korail and Korogocho, although some features had already been mapped before our intervention (based only on satellite imagery), most of them needed further mapping and validation, as their accuracy has proven to be variable after verification on the ground.

Table 3. Mapping progress, completeness and changes in OSM database features

Site	Additions and enhanced data quality			
	# structures added	# roads added	added road length (km)	Structure density (per km^2)
Korail*	**+2,562**	**+127**	**+14.63**	**2,449**
Sasa	**+221**	**+63**	**+4.72**	**169**
Bariga	**+2,352**	**+10**	**+0.8**	**687**
Idikan	**+2,637**	**+95**	**+8.21**	**675**
Korogocho	**+3,824**	**-4**	**-0.53**	**2,122**
Viwandani	**+6,344**	**+14**	**+2.45**	**1,423**
Azam Basti	**+3,126**	**+36**	**+8.37**	**934**

* Participatory mapping phase completed.

Table 3 also presents the normalized structure density estimates per site, so as to demonstrate not only the high densities of structures encountered in some of the communities, but also how variable they are. With more than 2,400 structures per square kilometre, Korail (Dhaka) has the highest density of structures followed by Korogocho (Nairobi). Interestingly, the other sites have much smaller densities, showing that great variations exist among the different neighbourhoods that are called “slums”.

Figure 7 presents a density map of the most densely built community of our project. The small inlet map in Figure 7 shows the points generated based on the centroid of building structures which will be used as a baseline for the sampling frame. The large heatmap illustrates how the density of slums vary by applying a kernel density estimation. It can be observed that the density of structures varies considerably within the slum area. Clearly, only after the analysis of the household surveys on healthcare access (planned to be executed on the basis of this data) we will be able to verify how and to what extent inequalities in the spatial distribution of structures are related to intra-community urban health inequalities. However, it is already evident that the method we used was able to capture in high detail the spatial variation of the morphological structure and thus lends itself to compose a spatially-aware sampling frame to analyse inequalities in terms of the social and environmental determinants of health.

Figure 3. Before (small) and after (large) maps for Bariga, Lagos, Nigeria.

Figure 4. Before (small) and after (large) maps for Korogocho, Nairobi, Kenya.

Figure 5. Before (small) and after (large) maps for Azam Basti, Karachi, Pakistan.

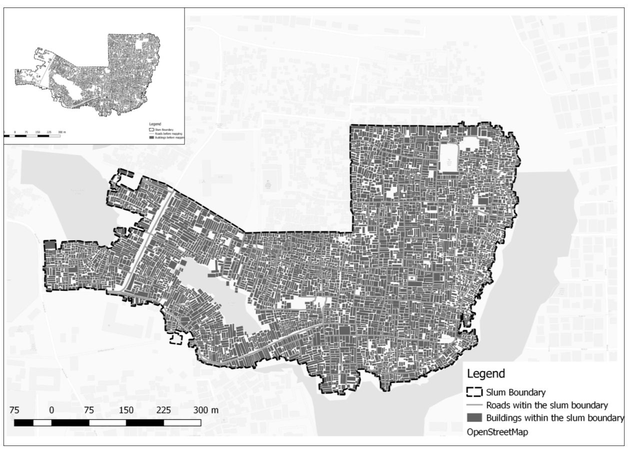

Figure 6. Before (small) and after (large) maps for Korail, Dhaka, Bangladesh.

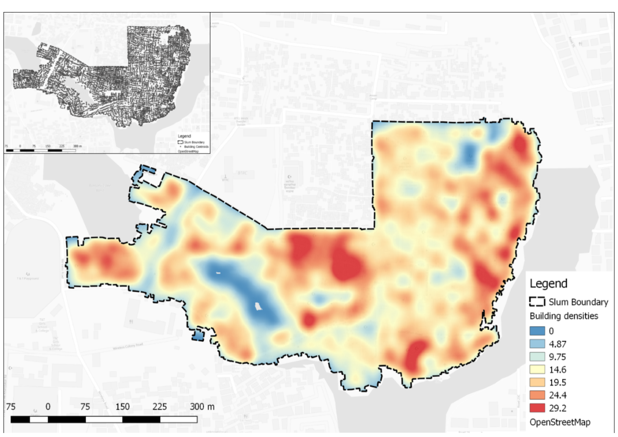

Figure 7. Density map of Korail structures, after ground truthing (large) and map of the structure polygon centroids (small).

4.2. Community engagement

In the digitisation phase, user accounts were created and authorised in the task management platform, so that the number of registered users provides us with an indicator of the reach of the engagement activities. Overall, total numbers of authorized contributors for each site were as follows: 55 for Bariga, 37 for Korail, 55 for Sasa, 56 for Idikan, 58 Korogocho, 61 for Viwandani, and 46 for Azam Basti. We interacted with OpenStreetMap communities in Kenya and Bangladesh (usually residents outside the slum communities) who actively participated in both the mapathons and subsequent mapping and validation activities.

In the cities where there was no active OSM community, capacity building and training of local teams was a viable alternative. In Nigeria (with no active OSM community) and Bangladesh (with a very active OSM community) there were also interesting contrasts from the fact that the majority of mapping has been carried out by postgraduate students on the one case (Nigeria) and experienced mappers on the other (Bangladesh). Although the experienced mappers' participation in Bangladesh enabled the mapping process to be completed faster than in the other sites, the trained students in Nigeria could achieve comparable results in a slightly longer time. In contrast, during the mapathons in Karachi, some community members registered email accounts for the very first time, and received initial ICT training, with effects on digital inclusion. Some of the photographs taken during the mapathon events in Bangladesh and Nigeria are shown in Figure 8.

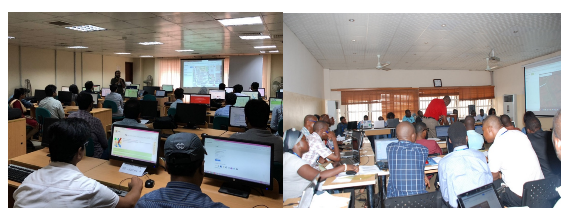

Figure 8. Photographs taken during mapathons in Bangladesh (left) and Nigeria (right).

As an interestingly particular case, most of the participants in the mapping of Viwandani (Kenya) were slum residents (Table 4). The active participation and enthusiasm from the residents were also connected to the fact that all data collectors were recruited from the slum community. The local partner organisation in Kenya had built trust relationships with the slum residents and community leaders through previous projects and this facilitated the process of recruitment, training, and data collection.

Table 4. Participants during mapping in Kenya

Community (Type)	Participants (No.)
Slum community residents	35
Local OSM community	8
Remote OSM community	5
Project team	13

5. Conclusion

In this paper, we presented results from a multi-country study that applied a consistent participatory methodology to map urban poor communities (slums) in five cities of four different countries (Bangladesh, Kenya, Nigeria, Pakistan). The results and findings provide evidence that the project has been effective in creating a reliable baseline for the analysis of urban health inequalities whilst at the same time achieving an important level of community engagement. The geographic data achieved so far will be used in the continuation of the project as a baseline for surveys that will map geo-spatially health care service provision and household surveys with residents. Due to the high granularity of the basemap generated, further analyses will be able to investigate the existence of inequalities in an intra-urban, neighbourhood scale, being in this manner better able to account for social and environmental determinants of health and spatial inequalities.

The collaboration with local institutional partners trained in data validation and with links to the community enhanced accuracy and completeness by combining mapping methods with context-specific knowledge. The creation of links between residents, the local partners and the volunteers of the global humanitarian mapping community is a particularly interesting outcome, which could improve the sustainability of the mapping efforts.

By applying a consistent methodological framework across the different sites, we are able to draw preliminary conclusions from comparisons. These relate to the process (e.g. proportion of different types of participants during mapping) as well as the outcome (e.g. differences in housing densities). Main process-related differences in the cases can be traced back to the degree of previous technical skills and knowledge of tools, existing links and collaboration with the community, and perceived need for participatory methods for obtaining a basis for a sampling frame. However, in the present study these factors were identified in an exploratory way and further analysis is due to define more precisely the role of these contextual factors and derive lessons about which other factors should be observed in the conduction of participatory humanitarian mapping. Similarly, even if the open source mapping tools were capable of effectively generating significant results, there are still important further development needed to make them more integrated and accessible to stakeholders. Nevertheless, we see the present study as a step towards establishing a systematic methodology that will support and empower researchers and communities to generate urban community data and thus provide solid evidence to analyse and change urban inequalities.

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