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Messy maps: Qualitative GIS representations of resilience

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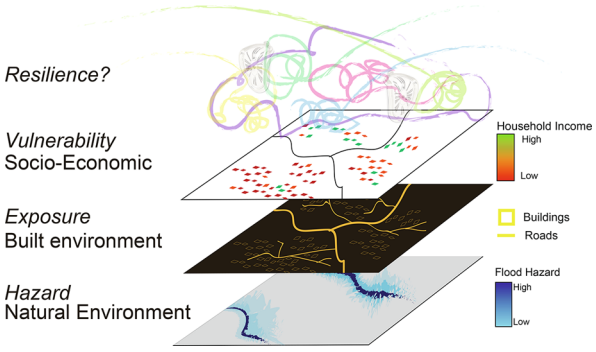
GRAPHICAL ABSTRACT



ABSTRACT

To include qualitative aspects of flood resilience, such as emotion, social connections and experience, into urban planning, we present a methodology incorporating innovative and experimental map visualisations of informal settlements. The concept of resilience in urban planning is often deployed in technocratic ways using quantitative tools such as geographic information systems (GIS). Yet in the urban Global South, where high proportions of the population live in informal settlements, the knowledge infrastructures used by public authorities leave little room for participation and consideration of local experience. We outline arts-based workshop activities and a qualitative GIS methodology to map resilience as defined by informal settlement residents in two case study cities, Nairobi (Kenya) and Cape Town (South Africa), with applicability across the urban Global South. For each city, four map layers were generated: (i) flood footprints showing resident's spatial knowledge of floods; (ii) georeferenced, narrated 360° photo spheres capturing different perspectives about a space; (iii) spatial social network maps showing residents connections to formal and informal actors before/during floods; (iv) multimedia pop-ups communicating contextual details missing from traditional GIS maps. We show how these prototype maps can be integrated within planning knowledge infrastructures. For spatially imprecise qualitative aspects of resilience in informal settlements, placing markers on a map makes them visible in ways that planners can begin to engage with. Although challenges remain, we found openness in Nairobi and Cape Town by city-level actors to use qualitative forms of evidence, and that the contextual detail aided their retention and understanding of resilience.

1. Introduction

This paper presents a methodology to better record and represent flood resilience of the urban poor and integrate these data within the existing knowledge infrastructures used for resilience planning. We demonstrate the potential for existing GIS tools used by planners to record and visualise more contextual information about resilience, with the aim of GIS being a more inclusive tool for policy.

2. Background

To set the context for this paper, we explain the context of urban

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flooding in the Global South, discussing how resilience building has become an important but problematic concept through vague definitions and deployment through technocratic tools. The background section finishes by discussing the potential for qualitative GIS techniques to more inclusively represent resilience.

2.1. Flooding and urbanisation in the Global South

In the urban Global South, flood hazards are driven by urbanisation and poor infrastructure (Douglas et al., 2008; Adelekan, 2010) and may be exacerbated by climate change (Winsemius et al., 2016). Exposure is increasing due to rapid urban growth (Angel, Parent, Civco, Blei, & Potere, 2011) and inequality resulting in settlement on marginalised land (Cohen, 2004; UN Habitat, 2016). Vulnerability is driven by unequal access to transparent governance, services and economic opportunity (Adelekan et al., 2015). As a result, the urban poor are disproportionately and increasingly at risk from flooding (Adelekan et al., 2015).

2.2. Building urban resilience

In light of increasing risk, *resilience to natural hazards* has become an important policy concept in planning for urban risk management and sustainable development. Originally deployed within disasters and hazards studies as the flipside of vulnerability (Blaikie, Cannon, Davis, & Wisner, 1994), the term has been invested with a growing range and messiness of meanings. Ecology, climate change adaptation, criminology, psychology and civil engineering have all contributed to this messiness (Pelling, 2011). An overarching critique has emerged on the political deployment of the term which has, at the meta-scale severed to deepen the self-responsibilisation of security so that those at risk and made to reduce their own risk (Evans & Reid, 2015). The more focussed use of resilience as a technical term in disaster studies and climate change adaptation is also contested and with a specific critique. Here we apply the definition of resilience offered by the IPCC (2014:127), that resilience is: “The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure, while also maintaining the capacity for adaptation, learning and transformation”.

Resilience has been explicitly included as an element of the Sustainable Development Goals (UNDP, 2015) and Sendai Framework for Disaster Risk Reduction (UNISDR, 2017). Yet at the same time as resilience is being widely adopted within policy, the concept as deployed technically within disaster risk management is critiqued (e.g., Harris et al., 2018; Winstanley, Hepi, & Wood, 2015). Concerns include: (i) a lack of clarity over the meaning of the term (Brown, 2014; Tiernan et al., 2019), (ii) a focus on retaining the status quo rather than bringing about transformative change (Pelling, 2011; Harris et al., 2018) (iii) an emphasis on engineering and technical aspects of resilience (Borie et al., 2019a) and (iv) the assumption that the systems in place to deliver resilience planning are equal and inclusive (Ziervogel et al., 2017). If resilience is considered a ‘boundary object’ (Borie & Hulme, 2015) where diverse actors are brought together around the consensus that “it is good to be resilient” (Davoudi, 2012), but deployed in a highly technocratic sense, it is possible that important conflicts and perspectives are silenced, particularly those of marginalised groups who do not speak in the technical language of planners and government (Ziervogel et al., 2017). Indeed, lack of meaningful consultation with the urban poor to build the social contract has been highlighted as a challenge for building socially just resilience to flooding (Mitra et al., 2017; Douglas et al., 2008).

Resilience in urban contexts is ultimately about change (Coaffee & Lee, 2016). This is a break from preceding risk management approaches that sought to engineer risk out of the city and in the process raised false expectations about individual and economic security. Urban resilience emphasises flexibility, redundancy, learning and adaptation over stability and robustness. This in turn raises challenges of transparency and accountability for decision-making and the potential for unanticipated outcomes in the redistribution of risk. If urban resilience is to respond to the critiques calling for greater emphasis on justice and for resilience itself to be a component of a transformation towards a more inclusive and sustainable future tools are needed to enable the full diversity of stakeholder views into urban planning.

2.3. GIS and resilience planning

The appeal of geographic information systems (GIS) for disaster planning and response is that a user can sit at a distant computer, receiving streams of integrated spatial data from multiple sources (Borie et al., 2019a) to see the city as a whole (Söderström, 1996) making data-driven decisions. Urban resilience has recently been incorporated into city masterplans (e.g., Barbarossa, Pappalardo, & Martinico, 2018; Moraci, Errigo, Fazia, Burgio, & Foresta, 2018), although primarily focuses on physical land use. Although it is possible to record qualitative media within a GIS (Cope & Elwood, 2009), GIS has historically been associated with the quantitative revolution in geography through the use of spatial models and statistics (Pavlovskaya, 2006). Indeed, ‘doing GIS’ has been the domain of experts with access to training, proprietary software and equipment (Pavlovskaya, 2009). Data within a GIS are stored and visualised as fixed locations in space and time, referred to as ‘the grid map’ Caquard (2013). These data formats lend themselves to information about the built environment (e.g., drainage channels) and physical processes (e.g., flood extent) rather than the social, political or economic relations of inhabitants. Heesen, Lorenz, Nagenborg, Wenzel, and Voss (2014) argue that forms of resilience other than infrastructure are inherently challenging to map as the processes are not singular isolated factors that are fixed in space or static in time, nor are they driven only by processes within the boundaries of the map. Thus, urban planning for resilience is arguably trapped in a self-validating loop of expert tools, technical knowledge, available data and established methods that focus on the built environment rather than the people that inhabit it.

There is a long history of critiques of maps as a socially constructed representation of a space (Pickles, 1999) and the authority conveyed by a map as a scientific object (Pavlovskaya, 2009). The body of work on participatory and crowdsourced mapping attempts to address some of these issues of representing marginalised voices or processes missing from the official map (Chambers, 2006; Neis & Zielstra, 2014), and there are successful examples of communities collecting and using spatial data to negotiate with the city (e.g., Dobson, 2017; IFRC, 2006; Mulligan, Harper, Kipkemboi, Ngobi, & Collins, 2017). However, we argue that ‘counter mapping’ is exactly that — maps that present an alternative construction of a space, which rarely become integrated within formal knowledge infrastructures. In practice, this may be an issue of participatory maps being in different formats (e.g., paper), fragmentation of heterogeneous maps held by different organisations (Borie et al., 2019b), or trust of crowdsourced data. More fundamentally, the lack of integration of participatory maps within ‘official’ ways of working may indicate that the potential of maps to open up a conversation around resilience is undervalued as opposed to acting as a confirmatory evidence basis with which to approve a decision (Borie et al., 2019b).

2.4. The potential for qualitative GIS

Although our work here does not go as far as creating a routinely used system for incorporating a more inclusive understanding of resilience within official knowledge infrastructures, we present a methodology for collecting and visualising spatial data that address some shortcomings of existing maps. We use existing GIS platforms and file formats to show the ease of integration within existing spatial data

portals used by the city. Using qualitative approaches to GIS, we attempt to spatially represent some of the components of resilience identified as important, but that are challenging to map within the 'grid' map (Heesen et al., 2014). These include: social networks (Aldrich & Sawada, 2015), local knowledge and experience (Ziervogel et al., 2017), informal infrastructures and actors (Mitra et al., 2017), and multiple interpretations of a single space (Blaschke et al., 2018) and more broadly, make the invisible visible in the planning process (Kwan, 2015; Kim, 2015). Recently, software and web developers have sought ways to overcome some of the grid map restrictions of traditional GIS approaches. For example, Story Map tools (ESRI, 2019; KnightLab, 2019) that enable a user to combine grid map data with narrative text, images, and multimedia content. Participatory approaches are beginning to emerge (e.g. Lung-Amam & Dawkins 2019), enabling communities to voice their shared narratives (Stokes, Villanueva, Bar, & Ball-Rokeach, 2015). These maps are visually different from 'traditional' GIS in which the rules of cartographic design push towards simplification and selection of layers to communicate a single, clear narrative (Monmonier, 2018). Qualitative GIS strives towards documenting the rich contextual detail of a space in a variety of formats (Cope & Elwood, 2009), and thus may be more visually 'messy'. In doing so, qualitative GIS can contribute to decision-making by adding experiential knowledge and providing immersive map layers that must be discussed rather than giving singular, objective answers, acting as conversation openers rather than closers. Such tools and approaches also seem appropriate for revealing, presenting and exploring the narratives and social networks that underlie perspectives on urban resilience that are alternative to the consensual views reinforced by traditional GIS approaches.

3. Study locations

Work was performed in two cities (Fig. 1): Nairobi (Kenya) and Cape Town (South Africa). Cities were selected for having active disaster risk reduction (DRR) agendas and high levels of informality (Borie et al., 2019a) and at the time of research were part of the Rockefeller 100 Resilient Cities programme, thus undergoing growth in resilience thinking (Rockefeller Foundation, 2019).

3.1. Andolo

Kibera is an informal settlement in the centre of the capital city Nairobi, Kenya. Kibera is thought to be the largest informal settlement in Africa, with an estimated population of approximately 300,000 in 2009 (although this number is contested) (Desgroppes & Taupin, 2011). Flash flooding is common during the short (October) and long (March – May) rainy seasons due to the proximity to the Ngong river (Mulligan et al., 2017). Flooding is compounded by informal drainage and poor solid waste management (Royo et al., 2018). In 2015, 50% of residents surveyed in Kibera reported household flooding (Mulligan et al., 2017). 'Andolo' is a recently developed settlement in Kibera, in close proximity/within the Ngong river channel. Andolo is one of the poorest, most at-risk and marginalised areas with low levels of literacy, high incidence of flooding and limited outside assistance (KDI, 2017).

At the household and community level in Kibera, there are examples of residents implementing structural (e.g., building waterproofing) and non-structural adaptations (e.g., drainage clearance) to flooding although these strategies tend to be reactive and sometimes ineffective (Mulligan et al., 2017). At the city scale, flood management has historically focused on relocating those who live within a given buffer zone of the river, although has been critiqued for the tens of thousands of people it would displace (Mulligan et al., 2017). Since 2013, the devolution of government in Kenya has advanced the impetus for a consultative and proactive approach to DRR. However, there is lack of clarity and coordination of responsibilities across government departments and fragmented access to data (Leck et al., 2018). Interviews with a range of actors involved in resilience planning across the city identified examples of innovative participatory mapping taking place (e.g., MapKibera, 2019; Safetipin, 2019), which contradicts narratives emerging from local government about a lack of access to data hampering resilience planning (Borie et al., 2019a, 2019b).

3.2. Philippi

Philippi is an official suburb of the city of Cape Town, South Africa. Philippi is approximately 47 km^2 with a population of 200,600 in 2011 (Statistics South Africa, 2011), comprised of informal settlements, low-income housing, farms and industry. There are numerous informal settlements in Philippi. Settlers have arrived at different times for differing reasons (e.g., evictions, economic opportunity), creating a complex mix of cultures, settlements and governance structures (Brown-Luthango, 2013). Due to the high water table, low topography and poor formal and informal drainage, Philippi experiences regular and prolonged winter (June-August) flooding (Drivdal, 2016).

A number of actors are involved in flood management across a variety of scales, with examples including (i) individual households raising their home's entrance, (ii) residents and NGOs working together to reblock settlements to improve drainage, (iii) local government structural measures such as drainage channel maintenance and (iv) local government non-structural measures such as risk awareness campaigns (Drivdal, 2016; Ziervogel, Waddell, Smit, & Taylor, 2016). There are implementation challenges such as obscure and heterogeneous power dynamics within settlements lead by informal local leaders (Drivdal, 2016) and lack of consultation and qualitative engagement with communities from the city (Joubert & Martindale, 2013). In terms of mapping, the city of Cape Town has an open online platform housing many of the datasets owned and maintained by the city (CTMV, 2019) although their primary focus is the built environment and tends to lack detail in informal settlements (Borie et al., 2019b).

4. Methods

Maps were generated by (i) (Section 4.1) an arts-based workshop with local actors in informal settlements and guided walk of the settlements; (ii) (Section 4.2) production of GIS layers by the authors. Arts based facilitation (e.g., storytelling, performance) has been shown to be a fruitful means of data generation by creating a safe space for discussing complex issues and not requiring consensus (Borie et al., 2019b). The process of generating spatial data used here is somewhat different to classic cartographic techniques in that there was minimal prescribed structure to the data; data were collected in a variety of qualitative formats (e.g., transcripts, photographs) and some of the aspects of resilience emerging from the workshop do not have fixed spatial locations. The production of the final output maps involves less classic GIS techniques such as spatial analysis and visualisation and was more concerned with documenting the rich, sometimes conflicting information. Therefore, the maps presented in our results (Section 5) could be considered 'messy' in that they do not present one single, clean narrative about a space, but instead require exploration.

4.1. Workshops

One-day workshops in each city were organised by local partners in April–June 2017. Workshops were led by arts-based facilitators communicating in the local language, hosted within the settlements and attended by 15–20 people in each city. Sampling was undertaken at the organisational level to ensure participation from grassroots organisations and local government. Participants were identified by their host organisations. Workshop design included experienced local facilitators to create methods enabling all participants to contribute. Participants were informed of the nature of the research and that outputs would be from the group not individuals, with permission given though verbal

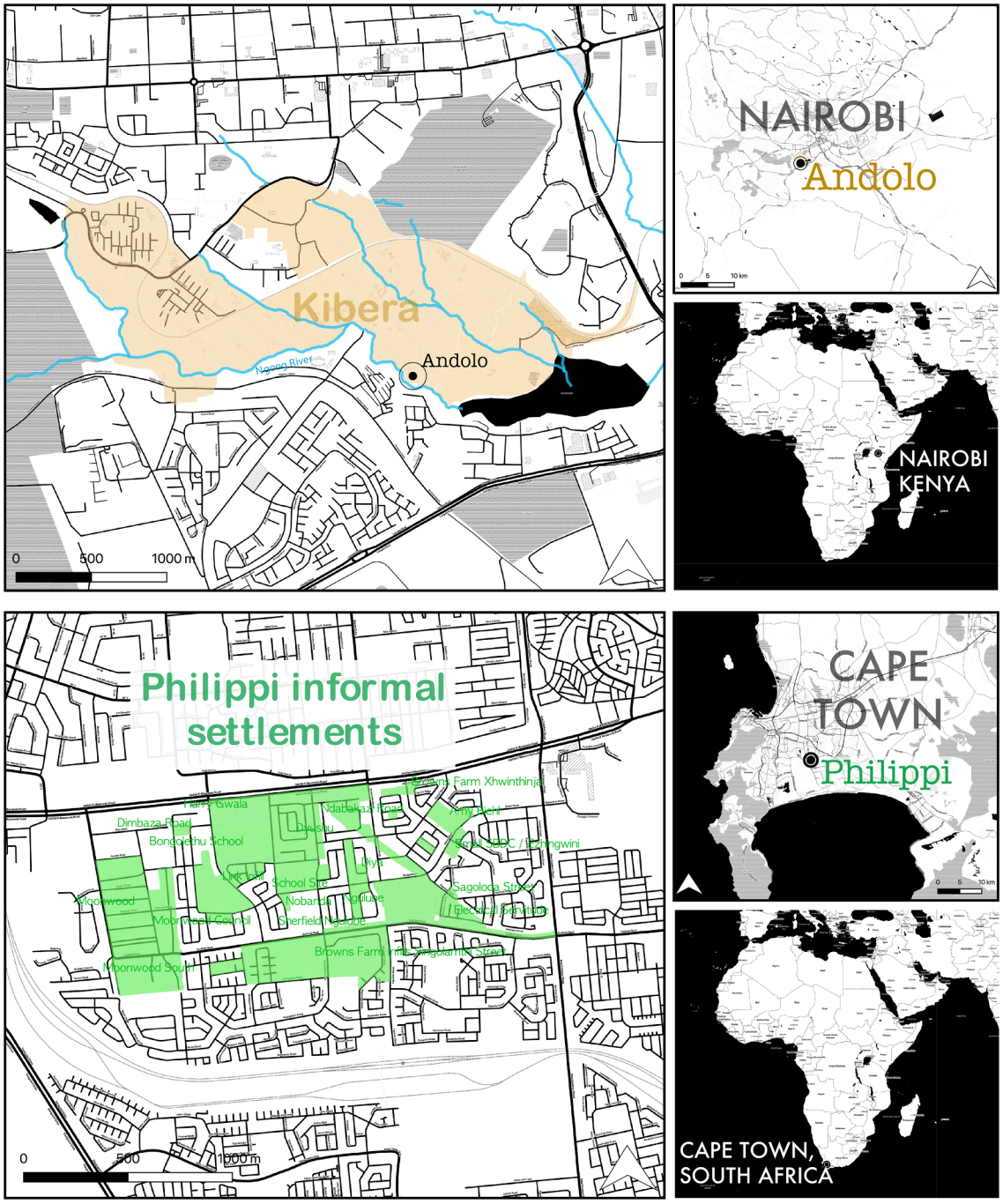

Fig. 1. Overview maps of study locations. (A) Andolo, in Kibera, Nairobi (Kenya). Andolo does not have a formal boundary so is mapped as a point. (B) Informal settlements in the Philippi area, Cape Town (South Africa). Other informal settlements are located in Philippi, but only those included as part of this study are shown. Data: OpenStreetMap (2019), MapKibera (2019), City of Cape Town (2019).

consent. Following map production, two participants from each city viewed the maps and provided feedback. Formal ethical approval of this process was received from King's College London. Methods presented here (and Section 5 results) should be interpreted in terms of their ability to be scaled and applied further, rather than a sample of each community's resilience.

Our interdisciplinary workshop activities were co-designed between the paper authors (including GIS and resilience experts), local partners and experts in arts-based facilitation. Techniques included performance, storytelling, role play and multimedia art. Sitas (2017) outline more detail of all activities. Workshop outputs were recorded through: videos, photography, translated transcripts and annotated paper maps.

The workshop aimed to first define what the term 'resilience' means to participants and then based on this definition:

- Identify key formal/informal actors who play a role in resilience and understand their characteristics;
- Understand the nature of flooding and coping strategies;
- Explain local context.

We now outline five activities used to inform our maps.

4.1.1. Activity A: Material metaphors

This activity defines aspects of resilience relevant to the group. A

series of household objects were selected as having metaphorical associations with resilience through their flexibility. As resilience did not have a direct translation into any of the languages we worked in, we used the concept of 'living a decent and dignified life in the face of flooding' to ask participants how aspects of the objects represented this concept to them. This output was not used directly in the map production but formed the basis for themes in subsequent activities. Table 1 summarises the key resilience definitions emerging from this activity, highlighting both physical (e.g., buildings) and social aspects (e.g., equality) of resilience.

Table 1
Definitions of resilience generated from workshop activity A: material metaphors.

Object	Definitions of Resilience
Ruler	Equality, Building structures, Measuring boundaries (to avoid conflict), Flood depth, Livelihoods
Bottle	Unity, Transparency, Security/Unity, Float during a flood
Broom	Working together, Supporting the weak, Cleanliness

4.1.2. Activity B: Storytelling

This activity generates spatial information about the location of flooding and coping strategies. Groups were split into ~10 and A0 maps of the area laid on the floor. Maps were produced using OpenStreetMap data (OSM, 2019) with local partner input to ensure maps were locally specific. Participants were given time to familiarise and orient themselves with the map (e.g., placing stickers to represent landmarks). Participants were asked to talk about a previous event and tell stories of what happened without marking the map. Finally, three transparencies were placed over the map, and participants were asked to mark on the map:

- Flooding location(s) during the previous event.
- Flooding impacts on the participant.
- How the participant coped with the flooding.

4.1.3. Activity C: Trust transects

This activity identifies key formal/informal actors involved in flood resilience within the informal settlement and gauges the strength of their connections.

Stage 1 consisted of short, impromptu roleplays where one local actor asks the other for help with a hypothetical task. The other person roleplays various actors, such as a neighbour or police officer. This allowed participants to explore power relations between various groups, in a hypothetical, often comedic way, thus diffusing tension.

Stage 2 consisted of smaller groups of ~5 people, laying out a transect on a roll of paper and asking individuals to place people/organisations on the transect to indicate a level of trust/reliance. Transect extremes were labelled as 'definitely would help' and 'would not help'. A wastepaper bin was placed nearby to represent those who might hinder. Groups were presented with three scenarios that were locally specific, representing different stages of the disaster life cycle. In Nairobi these were:

[Before Disaster] *Who would help you raise your doorstep to protect your house from flooding before the rains?*
[During disaster] *Who would help you recover your possessions if your house was damaged during the rains?*
[After disaster] *If you could not work for a month due to injury/illness from the floods, who would help you financially?*

Participants then marked along the transect (or in the wastepaper bin) different types of people or groups they felt were less or more likely to help.

4.1.4. Activity D: Social networks

This activity aimed to identify connections between the individuals/community and various actors who have a role in resilience at a range of spatial scales. The maps from Activity B (storytelling) were used in addition to maps of the broader city, the country, the world and a blank sheet of paper to represent 'non-spatial places' (e.g., heaven). Using string and stickers, participants were invited to mark individuals or groups on the maps (particularly those listed in Activity C, trust transects) and connect them with string to identify how they are linked to the community. Notes were taken on the nature of the connections by facilitators.

4.1.5. Activity E: Guided Walks

In the days following the workshop and assisted by local partners/participants, in each settlement we collected supplementary data and clarified or expanded on workshop discussion topics. Data included:

- Georeferenced photographs, video and audio clips collected with a smartphone using the iPhone camera app (with geolocation services enabled) and VoiceRecordPro for audio.
- Georeferenced 360° photographs of key locations collected with a smartphone using the free Google StreetView App.

4.2. Map production

Following workshop Activities A–E and guided walks, we synthesised outputs for each city into a geographic information system (GIS). Cape Town already has national or city level webGIS services available (CTMV, 2019) and Kenya an open data portal which is not fully operational although gaining traction (Williams, Marcello, & Klopp, 2014). A webGIS is an online portal where users can visualise, query and download spatial data through a web browser on a computer or phone without specialist software (Kemp, 2008). Due to the growing presence of webGIS in our study cities, we chose to visualise generated data as online map layers using GoogleMyMaps (Google, 2019). We now describe generation of the four data layers for each city.

4.2.1. Flood footprints

Activity B (storytelling) resulted in paper maps indicating the extent of previous floods. Although these are somewhat quantitative and 'traditional' in terms of the data they depict, they were digitized as polygons and included as an additional data layer to emphasise the detailed spatial knowledge of local actors.

4.2.2. Mapping social networks

Activity C (trust transects) aimed to capture a record of the strength of social bonds (aspatially). Activity D (social networks) resulted in large paper maps connected with stickers to represent individuals/organisations and pieces of string to represent connections. Following the workshop, the locations of individuals/organisations were digitised as points in QGIS and imported to Gephi, a free network analysis software (Bastian, Heymann, & Jacomy, 2009). In Gephi, connections between individuals/organisations were digitised as links between each point, resulting in a table containing the location, individuals/organisation and connections to other individuals/organisations. Where possible, the table of points and links was cross referenced with the 'trust transects' output (Activity C) to give a numeric value strength of connection and at what time the connection was active (before/during disaster). Connection strength was ranked from 1 (weak) to 10 (strong) based on where an individual placed a name along the transect of trust. Connection strength was visualised using line width. Time at which the link was active was visualised using colour.

The resulting visualisations of the social network were exported from Gephi as a KMZ file which can be visualised in GoogleMyMaps.

Where possible, multimedia files generated from the workshop or guided walk such as videos and narratives were embedded to points or link so that when the viewer clicks on a point/link, they observe additional information to qualitatively further explain the social network.

4.2.3. Generation of Storyspheres

The Storyspheres website (https://storyspheres.com/) is a free platform combining 360° photographs with audio. The generated Storyspheres can be viewed in a web browser or as an immersive experience using a smartphone and Google Cardboard low-cost virtual reality headset (https://vr.google.com/cardboard/). The Storyspheres were generated by uploading and combining 360° photographs collected from Activity E (guided walks) and audio snippets recorded throughout the workshop and/or on the guided walks to the Storyspheres website. The directional audio function was used to associate multiple audio with one 360° photograph so the viewer can pan around the scene to hear different perspectives about the same point in space. To spatialize Storyspheres, point locations were created for each Storysphere in GoogleMyMaps. When a user clicks a point, a pop-up containing a hyperlink appears, opening the Storysphere in a new page.

4.2.4. Mapping multi-media layers

Throughout the workshop and walks, videos, photographs, stories and sketches were generated. Some had specific spatial references through capture in-situ (e.g., geotagged smartphone photos). Other media could be associated to locations (e.g., verbally describing a location in a video). Other media pop-ups were given indicative locations based on consultation with local partners (e.g., comments made by multiple local actors applying to the whole settlement). Although siting of some points is somewhat subjective, it allows for aspects of resilience that do not have fixed spatial locations to be placed upon the map. Multimedia 'snippets' are presented as a GIS layer, primarily comprised of clickable features which open a pop-up box containing images/videos/text/etc.

5. Results

Open interactive web maps containing all layers and interactive pop-ups for Nairobi and Cape Town are online at https://whydarproject.wordpress.com/maps/, with map interfaces shown in Fig. 2 (Nairobi) and Fig. 3 (Cape Town). We describe the initial impression of the maps as 'messy' in that they do not visually convey one clear message, but instead a multiplicity of views and local experiences and require exploration to understand. In this section we outline results of individual layers shown in Figs. 2 and 3 and emphasise stories that emerge from each layer.

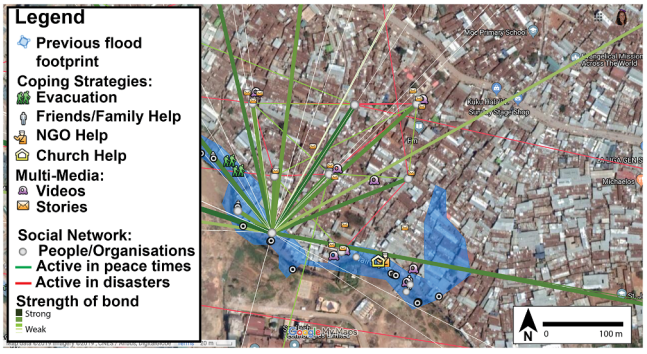

Fig. 2. Overview of map of Kibera (Nairobi) generated from Section 4 methods. Interactive map at: https://whydarproject.wordpress.com/maps/. Basemap: Google (2019).

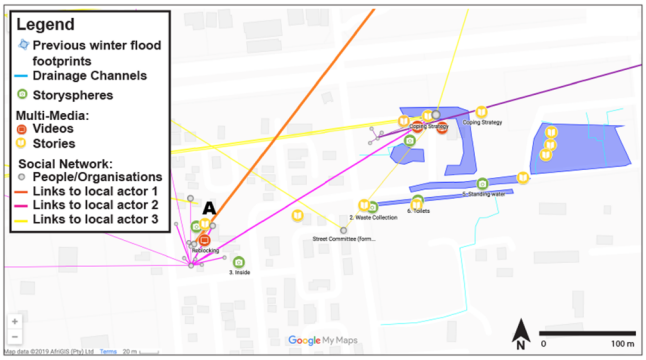

Fig. 3. Overview of map of Philippi (Cape Town) generated from Section 4 methods. Letter A indicates Storysphere location in Fig. 7. Interactive map at: https://whydarproject.wordpress.com/maps/. Basemap: Google (2019).

5.1. Flood footprints

Fig. 4 shows a flood footprint generated by local actors in Kibera, Nairobi overlaid with a 1-in-100 year flood hazard map generated by an engineering consultancy (BurroHappold, 2017). From visual comparison, there is significant overlap between the two flood extents (although the workshop flood footprint has no defined return period). There is an additional area identified as flooding by local actors which does not appear in the consultancy map (southeast corner, Fig. 4). From discussions with local partners, it appears that this area floods due to blocked informal drainage channels which would not be included in the consultancy map.

In Philippi, flooding maps by locals indicated specific zones flooded within the settlement, at a considerably higher resolution than would be shown in flood model outputs. These examples highlight the complexity and challenges of high resolution urban flood modelling in informal settlements with informal landscape and drainage modifications, and the value local actor observations can add (Msilanga, 2018; Mulligan et al., 2019).

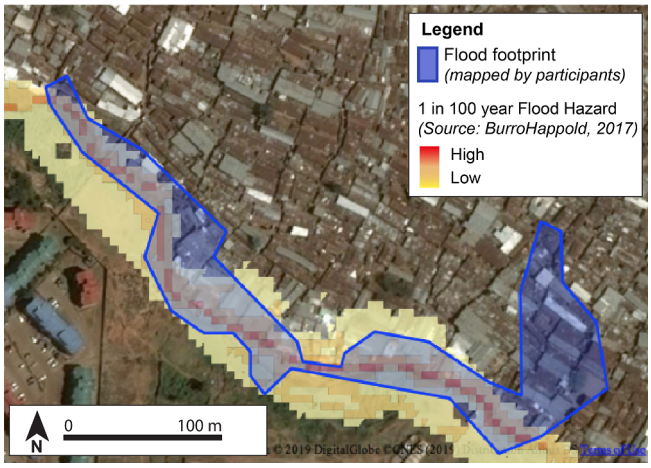

Fig. 4. Kibera (Nairobi) flood footprint map generated by participants using Section 4.1 methods overlaid with a flood hazard map generated by BurroHappold (2017) for a 1-in-100 year flood.

5.2. Social networks

In Figs. 2 and 3, social networks are represented as grey spheres ('nodes' representing individuals/organisations) and straight coloured lines ('links' representing connections between individuals/

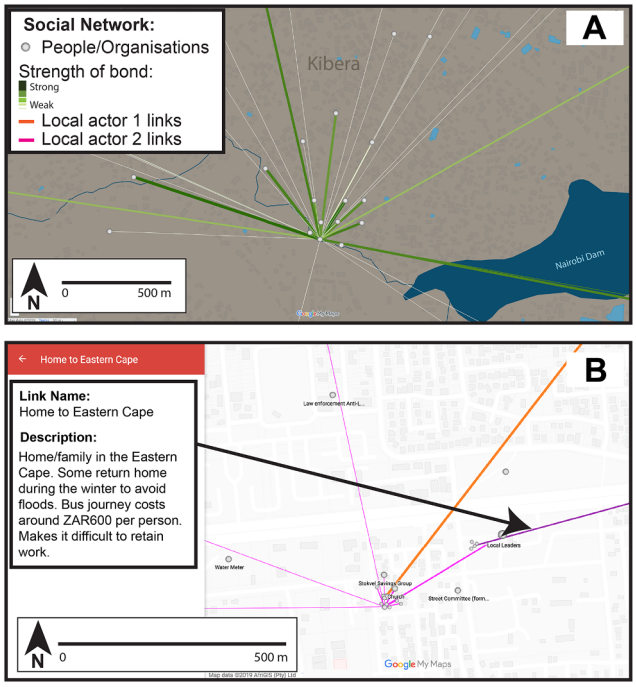

Fig. 5. Social network maps of (A) Andolo, Nairobi and (B) Philippi, Cape Town generated from Section 4 methods. Basemap: Google (2019).

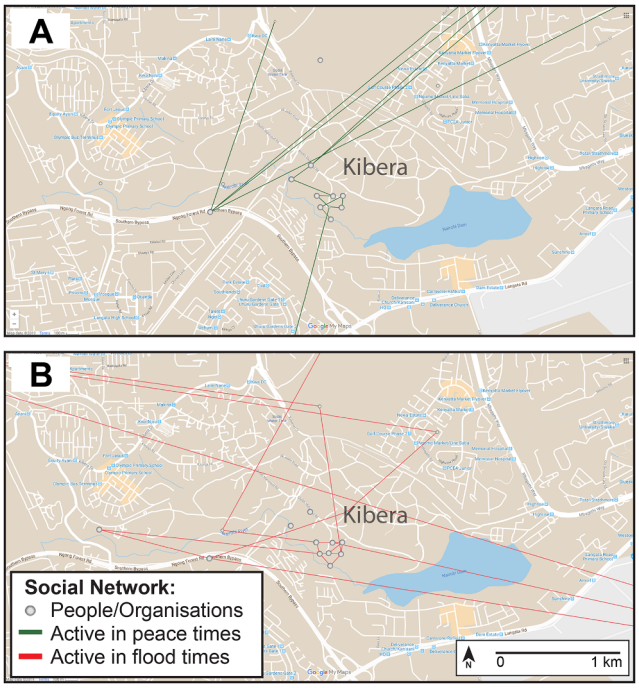

Fig. 6. Social network maps of Kibera, Nairobi (A) during 'peace' times and (B) during flood event. Basemap: Google (2019).

organisations. The links in the social network vary in terms of spatial distance, strength and specificity, and are not fully representative of the entire settlement, as they are based on what was mapped by ~20 workshop participants in each city. We now experiment with different ways of visualising these networks.

5.2.1. *Community versus individual networks*

In Nairobi, we observed workshop participants working collaboratively on the social network mapping and thus we consider the network to be more representative of the community as a whole (acknowledging the term 'community' is reductive, e.g. Allen, 2006). By comparison, in Cape Town, we observed stronger power dynamics and heterogeneities within the group in terms of connection, resources and influence, and participants were less open to sharing their social connections. These workshop differences led us to visualize the network at two different social scales:

- Fig. 5a shows an example social network map for Nairobi where the hypothetical 'community' is at the map centre as one node, and the line width and colour depth indicates strength of connection to other actors.
- Fig. 5b illustrates using different colours to visualise hypothetical social connections of different types of individuals (e.g., a single mother, a community leader, etc.) to highlight the heterogeneity of the internal social network in Cape Town.

Fig. 5a indicates strong connections to informal actors (e.g., family) and NGOs (e.g., Red Cross) and relatively weak connections to official bodies (e.g., city office), and additionally a few relatively weak international connections (e.g., family abroad, donors). Fig. 5b highlights differences between individuals in Cape Town such as a local leader with numerous local connections they could rely on to help during a flood, as opposed to a recent migrant to the area with only one strong connection to home.

In the Cape Town example, to add more contextual detail, many links have text pop-up boxes which explain the nature of the connection, thus moving beyond standard methods of social network analysis which aim to quantify the network (Wasserman & Faust, 1994), to a more qualitative tool that can be explored to add context. In further work, it would be useful to look at both the (i) individual and (ii) community social networks together for each city to reveal how information and resources flow both between individuals in the community, and between the community and wider actors across the city.

5.2.2. *Network changes over time*

Fig. 6 shows two examples of social networks in Kibera, Nairobi. Fig. 6a shows the social network before the rainy season ('peace times'). Fig. 6b shows the social network during a flood event. This reveals the different social networks before and during an event, which may help identify where weak links could be improved. For example, 27 nodes (representing people/organisations) are present during 'peace' times, but only 18 of these nodes are active during flood times, and the three connections to administrative organisations become inactive during a flood. Additionally, participants indicated that many NGOs are connected to the community during peace times for activities such as healthcare. Whereas, during floods many of these NGO connections disappear and active connections are less formal, for instance, a reliance on 'Chaamas' (savings groups). Local actors indicated that many NGOs do not feel equipped to deal with flood response and/or there is a long delay before help arrives.

5.3. *Storyspheres*

Six Storysphere scenes were created for Philippi, Cape Town. The Storyspheres are shown on the overall maps (Fig. 3) as clickable green points with a hyperlink to the scene (example in Fig. 7). An example Storysphere can be viewed in 360° with directional audio at https://storyspheres.com/scene/hVAFmzTP. This Storysphere shows a drainage pond where water is held during the winter season and contains three different audio narrations focused on the drainage outlet and two houses:

(a) *Drainage outlet.* Residents describe a conflict with the city about clearance of the drainage outlet which becomes blocked by trash.

Residents describe being blamed for garbage accumulation, although municipal waste collection in this area is poor. Residents describe a continuous process of calling the city to ask them to visit.

(b) *House 1.* Description of a resident who moved here in the summer dry season when the drainage pond is empty. The resident was unaware that the area flooded during the winter season.

(c) *House 2.* Description of a resident who had lived at the site for a long time. The resident was aware of flooding but had nowhere else to go.

Fig. 7. Screenshot of Storysphere of a drainage pond in Philippi, Cape Town. Storysphere location marked with 'A' in Fig. 3.

Some Storyspheres (e.g., Fig. 7) represent differing experiences/perspectives of different individuals, whereas others illustrate different components of a problem. For example, another Storysphere describes how the houses flood during heavy rains, the lack of help experienced, and community-derived solutions to move houses to higher ground to reduce the risk of flooding.

5.4. Multi-media pop-ups

The final layer in Figs. 2 and 3 is a series of interactive points and polygons which when clicked show a pop-up containing contextual text, videos and photos (e.g. a video of a resident describing building modifications). These pop-ups add further context to other layers such as the social network (e.g., a resident with limited social ties) and flood footprints (showing nearby flooding and an informal drainage channel). For example, informal modification of a building may affect the drainage downstream and would unlikely be included in any formal maps of the area's drainage topography; whereas, a pop-up can provide content to explicitly highlight this issue.

6. Discussion

In Section 6 we recap challenges of current approaches to mapping resilience in order to highlight four areas where we believe qualitative GIS shows potential. This was informed by presenting the maps in Section 5 to city-level actors in both cities.

6.1. Challenging current GIS approaches

The outcome of typical approaches to GIS is a map that is both partial and a social construction of space, but conveys a veneer of objective scientific authority through being both statistical and eye-catching (Heesen et al., 2014). The prototype map layers we have generated here in Nairobi and Cape Town attempt to retain an authoritative visual evidence basis by integration with 'the masterplan' but contain more inclusive information and be used in different ways. In other components of our research project, Borie et al. (2019a, 2019b) reviewed approaches to resilience planning in both cities, showing that although a range of innovative, crowdsourced and participatory approaches exist, a technocratic 'God's eye' view approach to city-wide GIS systems dominated. There has been growing uptake of GIS systems for urban planning in the Global South with a belief that these can facilitate data storage and sharing, help solve 'wicked' city wide problems and support decision making (Baud, Scott, Pfeffer, Sydenstricker-Neto, & Denis, 2014). For some components of DRR (e.g., evacuation routing) this works well, but as Heesen et al. (2014) and others argue, there are many aspects of resilience that do not obey the typical data architecture of being static in space and time that a GIS demands. Moreover, the unique context of rapid and informal growth in the urban Global South is arguably not a system that can be rationally managed through an approach of collection, analysis and visualisation of systematic data layers, and indeed retaining 'equilibrium' may not be a good thing (Gotham & Campanella, 2010). There is also the issue of cartographic design. Cartographers are trained in careful selection of layers, symbology, scale to create clean maps that succinctly visually communicate a concept (Monmonier, 2018) which silences the messy, contradictory components of resilience.

Arts-facilitated workshops create a space for engaging diverse communities and soliciting a range of perspectives, often lacking consensus (Borie et al., 2019b). Indeed, both within and across Kibera (Nairobi) and Philippi (Cape Town), the same workshop activities revealed different themes and narratives. For example, social networks mapping (activity C and D) revealed disparities between individuals in Cape Town, whereas in Nairobi there was more consensus amongst participants, allowing us to investigate relationships between the 'community' and 'the city' at a different spatial scale. Nonetheless, although themes and narratives differ, the menu of potential GIS visualisations we present appears to be flexible enough to represent different spatial scales and narratives around resilience in a consistent format.

6.2. Making the invisible visible within existing GIS systems

The map layers we created attempt to evidence components of resilience such as informal social connections that have long been emphasised as important (Cook & Bickman, 1990; Richardson, 2002; Wisner, 2003), but which have few metrics for recording and visualising (Aldrich & Meyer, 2015). For some data layers, we used formats familiar to urban planners, for example networks (Section 5.2) are typically used to quantitatively characterise networked structures such as roads/power (Jenelius, 2010). Within classic geographic theory, social networks are rarely represented on the grid map, as they represent a different cartographic space, where the connections and relations between points are more important than locations and distances (Wasserman & Faust, 1994). However, by mapping informal social connections and utilising often overlooked components of GIS, such as ability to store and retrieve multimedia formats (Pavlovskaya, 2009) to add contextual detail, we make invisible and informal processes visible and integratable within existing GIS architectures. For example, in Nairobi, local partners and community members expressed that it was rare for city officials to visit informal settlements, indicating that traditional GIS approaches may create a disconnect from planners seeing and experiencing a location (Borie et al., 2019a). The Storyspheres attempt to fill this gap by creating an immersive and engaging experience and switching the view from bird's eye to street level. For Cape Town, the social network mapping emphasised disparities within the informal settlement, underlining that even the 'community' may be too coarse a scale for planning (Allen, 2006). In Nairobi, city-level actors commented on how the network emphasised the disconnect between the community and the city and evidenced existing internal coping strategies. In both study areas, the social network layer supports calls for providing socially and spatially disaggregated data on urban risk to better understand disparities in risk (Adelekan et al., 2015).

6.3. Representing aspects of resilience resistant to mapping

GIS has historically struggled to adequately represent concepts of

time, emotion, multiple epistemologies and concepts that do not have fixed geographic locations (Elwood, 2009). This is problematic for studies of resilience which is multi-faceted and multi-scalar (Meerow, Newell, & Stults, 2016). In our work, individual and physical coping strategies emerging from workshops (e.g., household structural improvements) were easier to map using traditional GIS approaches, while collective social coping strategies (e.g., moving children to higher ground) resisted mapping. We have attempted to address these GIS limitations in three ways: (i) using Storyspheres (Section 5.3) to associate multiple explanations and narratives about a single point in space; (ii) exploring multiple visualisations of social networks throughout the disaster life cycle (Section 5.2.2) and (iii) attempting to give abstract and complex concepts a place on the grid map through incorporating multimedia (Sections 5.1 and 5.4). An example from Nairobi is a text pop-up explaining the importance of informal savings groups ('Chaamas') of which there are many without fixed geographic locations, for longer term recovery. In this example, the Chaamas location is placed within the settlement, conveying the importance that this is part of the overall settlement, although the exact map location is meaningless.

Many features (particularly in informal settlements) have imprecise or vague geographic locations (Fisher, Wood, & Cheng, 2004) and regardless of precision, simply placing markers representing these coping strategies on a map makes them visible in ways that planners can begin to engage with and helps to add context to understanding the issues. For example, in discussing our maps with urban planners, they stated that adding personal experiences to the map helped them to better absorb and memorise information. This finding aligns with psychology literature that shows more intense emotional states are linked with better ability to encode, consolidate and recall information (Clore et al., 2001).

6.4. Messy maps

Although we have outlined some ways our approaches to mapping have potential to integrate local experience into existing knowledge infrastructures for urban planning, one criticism emerging from consultation with city-level actors is that map layers look 'messy'. Indeed, our map layers do not lend themselves well to traditional forms of spatial analysis nor do the output maps slickly communicate one interpretation of reality. Instead, the maps demand time to explore and interpret. The viewer of the map might not interpret the map in the way intended or in the same way as others, and the viewer might miss some of the map narratives. However, feedback from city-level actors in both cities was positive, and there was an openness to accepting more qualitative forms of evidence and integrating this with existing data and approaches to DRR to add context. It is possible that in future work, ESRI's new Storymap format could provide a more structured platform to introduce and explain data layers in a sequence that helps to overcome initial confusion and ensure possible narratives are presented. However, we argue that 'messy' is in fact more representative of the realities of informal settlements, resilience and complex environmental and social processes. As our activity results show, resilience is characterised by networks of actors and relationships whose spatial locations cannot be precisely specified and are not fixed in time. As Brundson (2015) states, when creating any map we should "draw crisp lines with caution" and recognise that even the most precisely collected data are subject to uncertainties, whether distortion due to projection, rounding of decimal places, smoothing of lines, sampling frameworks, or many limits of representation inherent in GIS (Monmonier, 2018). Forcing chaotic characteristics of resilience through traditional data formatting processes to produce clean, objective-looking maps may not only introduce an unjustified sense of certainty but also omit important, subjective perspectives.

6.5. Maps as conversation openers

In both Nairobi and Cape Town, there is desire and political will for more participatory approaches to DRR (Borie et al., 2019a). Messy maps do not reveal obvious and simple (physical) solutions to enable resilience, but the challenges of interpreting them may provide opportunities to open up conversations about different elements of resilience to identify appropriate and just solutions. The more technocratic, infrastructure-based approaches tend to provide an evidence basis to shut down conversations rather than open them up. Borie et al. (2019b) gave examples from city-level actors in Cape Town and Nairobi where the iterative process of mapping and conversing helped to better understand the evolving context of informal settlements. Yet, these conversations are difficult both practically and also regarding the value placed on lay knowledge. By integrating narratives into grid maps, richer contextual detail is added to the map (Elwood & Cope, 2009). In Cape Town, city officials expressed a desire to be able to contribute to the maps we generated, so that the map could act as a repository for perspectives from both themselves and 'the community'. In Nairobi, city officials indicated that some pop-ups contained information they already knew from experience but placing these within the map made it easier to share this inherent knowledge with others. As a result, local partners in Nairobi have continued to produce Storyspheres as part of their work.

6.6. Resilience in the era of big data

Our maps are prototypes, and there are naturally limitations and challenges for longer term uptake, such as ownership (Chambers, 2006), privacy (Li & Goodchild, 2013), legacy and maintenance (Msungu & Jacobs 2015), and level of community participation versus 'expert' mapping (Karanja, 2010). However, we are now in an era of 'data rich' approaches where geocomputational techniques to handle big spatial data are flourishing (Miller & Goodchild, 2015) and multiple global frameworks promote data-driven approaches to managing risk. Graham and Shelton (2013) warn that a focus on data intensive and computational approaches might result in a new era of positivist geography with less space for critical and qualitative understanding of social processes. The 'messy' maps we present here illustrate that there is a space for qualitative understanding of resilience, and that existing knowledge and spatial data infrastructures have potential to be more inclusive and holistic. Future development of such maps may aim to include yet wider sources of information that give voice to those outside the types of workshop activities used here, for example sourcing content from social media.

7. Conclusions

To capture qualitative aspects of resilience, such as emotion, social connections and experience, we have developed a methodology for generating a series of map layers in exisiting free GIS software. We have shown the application to two cities (Nairobi, Cape Town) with differing contexts in terms of flooding, level of GIS capability and approaches to urban resilience, indicating that although the narratives differ between the cities, the qualitative GIS map formats presented are flexible and adaptable to the local setting. We believe this methodology of generating and visualising an inclusive version of resilience will supplement other DRR methods being used by Global South urban planners and local governments. We show that these qualitative map layers have the potential to go beyond traditional approaches to GIS by: (i) making invisible social processes such as social connections visible at a range of spatial scales, (ii) incorporating concepts that do not have a fixed location such as time, emotion and collective action into the map, (iii) opening up conversations about the local context in which resilience is deployed and (iv) more truthfully and inclusively representing the complexity of the vaguely defined concept of resilience.

CRediT authorship contribution statement

Faith E. Taylor: Conceptualization, Methodology, Software, Formal analysis, Writing - original draft, Investigation. **James D.A. Millington:** Conceptualization, Methodology, Writing - original draft, Funding acquisition. **Ezekiel Jacob:** Software, Formal analysis, Data curation. **Bruce D. Malamud:** Conceptualization, Methodology, Writing - review & editing, Funding acquisition. **Mark Pelling:** Conceptualization, Writing - review & editing, Funding acquisition.

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Conflicts of Interest and Ethics

There are no conflicts of interest. The work undertaken was approved by the King's College London Ethics committee. Work in Kenya was performed under a National Commission for Science, Technology and Innovation (NACOSTI) research permit.

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