Mapping (for) resilience across city scales: An opportunity to open-up conversations for more inclusive resilience policy?

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ABSTRACT

There are growing calls, across a continuum from international agreements to social movements, for strengthening urban resilience alongside reductions in inequality and poverty. Although there is broad agreement on what the term resilience means in general, different perspectives exist on how the concept should be implemented locally and controversies around its transformative potential continue. While differing social and institutional factors are important, the ways in which knowledge practices produce these diverse perspectives have been overlooked. To address this gap, this paper focuses on the role of spatial knowledge and mapping practices for resilience and disaster risk reduction. Traditionally, much of the spatial data used for planning has been quantitative and at broad, city-level scales. However, although experiential understandings of resilience have been widely identified, there have been few attempts to integrate these perspectives, often relying on qualitative andexperiential knowledge, into city-level resilience planning.

Bringing together insights from Science and Technology Studies and Human Geography, this paper explores the opportunities that different mapping techniques provide for resilience thinking and planning. Our starting point is that science and technology are not neutral for governance and can both open up or close down governance options. Using case studies from Nairobi and Cape Town, our findings show that mapping practices are heterogeneous and produce diverse understandings of resilience. Although traditional methods dominate city mapping in these case studies, we find innovation at both the city and finer spatial scales. Maps and mapping offer opportunities for resilience via connecting diverse actors, scales and forms of knowledge. We suggest that more work is needed on how to include non-traditional methods, from those that value local experience and the voice of the marginalized to more quantitative mapping methods. While fully integrating diverse approaches may not be possible, nor desirable, bringing them into conversation helps open-up deliberative spaces for resilience.

1. Introduction

Can we visualize resilience? What would a map of resilience look like? The power of visuals, including maps, has long been recognized. Jasanoff (2004a) suggests, for example, that the picture of the Earth seen from the moon facilitated the emergence of a *global* form of environmentalism. While visuals are powerful and capture our imagination, maps in particular are often linked with ideals of objectivity and rational management (Bowker 2000; Wood & Fels 1992; Harley 1989). Such ideals underpin traditional approaches to using Geographical Information Systems for urban planning, focusing on physical

infrastructure (e.g. Yeh 1999). In this context, efforts to measure, quantify, and map resilience are multiplying (e.g. Li et al., 2014). Although maps and mapping are recognised as important for understanding hazards and risk, their use for understanding resilience remains a challenge (Cutter et al., 2008; Heesen et al., 2014). Here, we show that resilience does not have a single heuristic cartographic representation but rather multiple, potential representations that depend on who, and how, they are generated. We understand maps as both outcomes and processes and suggest that it is not possible to find a single way to map resilience because resilience has varied meanings and is not simply tied to the location of physical objects (e.g. Wilson,

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2018; Meerow and Newell, 2016). Drawing on two case studies in sub-Saharan Africa cities, we show how diverse, non-traditional[1] potential representations of resilience result in differing implications for urban populations.

Cities in developing countries in particular are experiencing rapid urbanization, with the result that marginalized and vulnerable communities are becoming increasingly exposed to a range of shocks and stresses (e.g. Pelling et al., 2018; Ziervogel, 2018). Improving the well-being of low-income urban populations at risk from environmental hazards and political marginalization is key to achieving Sustainable Development Goals. Against this background, resilience is increasingly used as a frame to shape urban governance and is mobilized by actors and organizations from both science and policy backgrounds with different purposes and meanings (Borie et al., 2019; Leitner et al., 2018). Brown (2014) inventories at least five different fields using the concept of resilience including international relations, socio-ecological systems, human development and climate change, all operating with different definitions. While these share some similarities – in particular, emphasizing the ability to recover and bounce back from a particular event – they also differ in that while some authors talk about the resilience of ecosystems others focus on the resilience of people (social resilience or community resilience), yet others emphasize the hybrid nature of resilience, developing the notion of socio-ecological resilience.

If finding a unique way to account for all these perspectives via mapping is impossible, we contend that resilience thinking is an invitation to think about cities in a more holistic manner and to identify the challenges and opportunities that different mapping techniques open-up in this respect. This approach can usefully be connected to Harvey's (1970) distinction between the sociological imagination that concerns individual experience, relations and history, and the spatial imagination of the city concerned with space and place. These imaginations are associated with different disciplinary and methodological approaches and we explore here whether, and how, mapping techniques help bring the two into conversation.

The relationship between mapping and urban design is ancient, with early cities being organised around the physical layout of defenses and resources (Verebes, 2013). The development of contemporary masterplans and land-use surveys frequently use Geographic Information Systems (GIS) to store, manipulate, manage and display spatial data for making urban planning decisions about physical infrastructure and risk management. Continuing Harvey's distinction between sociological and spatial imaginations, debates have examined the ability of GIS to incorporate social theory and critique about tendencies toward quantitative, positivist understandings of the urban space (Pickles, 1999). There have been moves to mobilize GIS in the context of public participation efforts (Ghose, 2007), with city officials as well as NGOs beginning to explore the use of participatory mapping techniques for data collection (e.g. Kahila-Tani et al., 2016; Livengood and Kunte, 2012; Hagen, 2011). However, there is still work to be done in connecting these heterogeneous and local sources of data and mapping practices to the more typical city-level physically-oriented maps produced by urban planners that are generated, manipulated and visualized through traditional GIS. While fully integrating standard, traditional GIS approaches focused representing physical objects with heterogeneous, non-traditional approaches representing social processes may not be possible, nor desirable, bringing them into conversation provides a range of opportunities for resilience thinking and practice.

We contend that resilience thinking asks us to shift perspectives to see cities systematically, recognizing the importance of different types of knowledge and experiences to understand where change is necessary (see also Jon, 2018; Moglia et al., 2018; Muñoz-Erickson et al., 2017).

This perspective demands interrogation of our current knowledge systems[2] (Tengö et al., 2014; Cornell et al., 2013) and how to integrate more appropriate ways of capturing and spatially mapping diverse forms of knowledge in order to identify opportunities for transformation. In part to explore how this potential could be realised, we reflect on the use of spatial knowledge and maps for resilience planning, using Cape Town and Nairobi as case studies. Our questions are:

1 How have spatial data and maps been used to understand urban resilience in Nairobi and Cape Town?
2 What are the shortfalls with current approaches?
3 How can new methods open-up new, more inclusive ways to envision urban resilience, taking into consideration the voices of vulnerable residents?

After presenting our conceptual approach, we introduce our methods and describe different kinds of mapping techniques used in Nairobi and Cape Town before discussing the challenges and opportunities that they open for resilience.

2. Conceptual approach

According to the Rockefeller 100 Resilient Cities programme, urban resilience is:

'The capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience.' (100 Resilient Cities, 2018)

While this definition seems consensual, urban resilience has different meanings and applications (e.g. Borie et al., 2019). For example, some focus on the urban resilience of infrastructure. In this view a resilient city is one in which networks of supply for basic services can be restored quickly after a failure. Others focus on the transformative potential of urban resilience, paying particular attention to social justice and inequalities (e.g. Pelling, 2010; Forsyth, 2018). While both perspectives matter and are not necessarily mutually exclusive, this paper aims at examining the role of mapping practices in facilitating more holistic approaches to resilience.

Drawing on STS, we understand resilience as a constructed concept which is not neutral to risk governance. Particular ways of knowing the city, and risks, produces particular ways of governing risk and resilience (Farias and Blok, 2016). The co-productionist idiom, whose purpose is to provide a framework to analyze critically the role of science in society, provides a useful point of departure here. This idiom refuses the idea that 'science' is a neutral, objective activity producing transcendental kinds of truth that can be developed without affecting the ordering of society (Jasanoff, 2004b). It thus builds on a conception of science as constructed, in contrast to positivist accounts which posit that science directly reflects reality or nature. This implies that there is no linear relation between science and policy (Kovacic, 2018). Rather, science and technological developments constitute social life, and vice-versa, with good and bad, intended and unintended consequences: examples supporting this point are countless, including the development of nuclear power, GMOs, internet or sustainable cities (e.g. Bijker et al., 1987). From this standpoint, maps are not an objective, nor neutral, representation of cities but visual representations embedded in specific worldviews.

Critical geographers have long underlined the reductionist nature of maps, emphasizing that they are always selective representations of

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[1] Throughout the paper we use 'traditional' as a shorthand for conventional GIS practices focused on physical objects vs. 'non-traditional' approaches that aims to include experiential knowledge and qualitative content.

[2] Following Cornell and colleagues we understand "knowledge systems as something broader than science. Knowledge systems are made up of agents, practices and institutions that organize the production, transfer and use of knowledge." (2013:61)

reality (Kwan, 2002; Crampton and Krygier, 2006; Kitchin et al., 2012). Cartographic representations of the world fascinate and capture attention. They play a key role in articulating and justifying particular political projects such as in the case of the colonial empires (Harley 2009) and national territories (Leuenberger and Schnell, 2010). Although these political dimensions are not always explicit, they explain why maps are often contested. Maps can be both empowering or disempowering. In Indonesia, Peluso shows how some local organizations decided to adopt mapping to 'speak the language of power' and engaged in their own counter-mapping efforts to contest official government maps (Peluso, 1995). Maps are always interpreted in light of particular contexts and can also have unintended consequences. In Kenya, some maps of the Mau Forest produced by an indigenous conservation programme actually ended up being used to justify deforestation (Klopp and Sang, 2011). In post-apartheid South Africa, GIS was used to redraw the contours of municipalities in Johannesburg - yet although the initial idea was to use GIS to depoliticize the discussions (on how to delineate the different districts of the city differently), alternative maps were interpreted in light of what they implied for local elections (Lupton and Mather, 1997). GIS is not merely a tool that is useful for problem-solving but a technology with societal implications (Sheppard, 1995; Desportes and Colenbrander, 2016).

With regards to resilience, hazard maps are routinely used for planning purposes (Burby et al., 2000; Godschalk, 2003). But these contribute to a specific understanding of resilience, one which emphasizes predominantly natural hazards and physical exposure, rather than livelihoods and social networks. At the same time, this perspective is associated with particular mapping techniques and geophysical expertise. Yet, risk mapping practices and the delineation of hazard lines are often contested and different approaches exist (Haughton and White, 2017; Desportes and Colenbrander, 2016). In contrast, many studies emphasize the need to consider alternative definitions and perceptions of risks (McEwen et al., 2017; Lane et al., 2011) and underline the social and political aspects of urban resilience (Meerow and Newell, 2016; Ziervogel et al., 2017). Reflecting on urban mapping, Dovey and Ristic (2017) underline the ontological and epistemological aspects, and how they contribute to specific ways of knowing and seeing the city, while also having the potential to reveal 'capacities for urban transformation - the city as a space of possibility' (2017:15). Although, traditionally greater emphasis has been placed on quantitative data and scientific knowledge in city planning (linked to a rise in 'evidence-based' planning), mapping also provides opportunities to create collaboration between different actors and bridges between disciplines (Harvey and Chrisman, 1998). It is these opportunities we explore here.

3. Methods

Cape Town and Nairobi face major resilience challenges including significant urbanization rates as well as high levels of inequality, numerous informal settlements and poor communities (Amin and Cirolia, 2018; Watson, 2014). In both locations disaster risk is a concern at the city level, and particularly salient in informal settlements where it hampers development and wellbeing. However, the cities differ in the availability and access to integrated city-level GIS data; while civil servants in Cape Town have access to a wide range of datasets (see Fig. 1), Nairobi has no integrated GIS infrastructure. Some initiatives exist and are developing (e.g. Kenya Data Portal) but are not fully implemented to date (Okuku et al., 2014; Williams et al., 2014).

To explore how resilience is understood in these cities, with a particular focus on the role of maps, we conducted 19 semi-structured interviews (8 in Nairobi, 11 in Cape Town) between January and June 2017. Our interviewees were predominantly professionals working for public authorities at the municipal level and representatives of NGOs and the private sector. Our interview guide is presented in the supplementary material as well as a table summarizing our interviewees'

profiles and the mapping products mentioned in our results.

In each city, we also organized two workshops to explore the potential of qualitative GIS to provide new ways to visualize resilience, building on the idea of 'thick mapping[3] ' – the use of multiple, contextual, map layers including more qualitative information (Presner et al., 2014). The first workshop focused on arts-based approaches at a neighbourhood scale and combined creative practices (e.g. theatre, performances) with participatory mapping to surface people's values regarding resilience and connect everyday lived reality with resilience thinking. The second workshop was with 'expert' city stakeholders and gathered around 20 people. The purpose of this workshop was to prompt a conversation on resilience with people working in urban and resilience planning from a range of sectors, using maps to facilitate the discussion. While we draw predominantly on data from the interview, these workshops also inform our thinking.

4. Case studies

Although reliance on spatial data is different in Nairobi and Cape Town at the municipal level, in both cases there is a wide range of civil servants and practitioners with expertise on resilience and mapping. Both cities offer examples of actors and organizations engaging with maps and spatial knowledge to better connect informal settlements and neighborhoods to the city government. In what follows we outline examples that illustrate different mapping techniques and forms of engagement with resilience.

4.1. Cape Town

The city of Cape Town is home to over 4 million people. High levels of inequality characterize the city. Better off residents live in formal housing but around half a million people living in informal dwellings, made of corrugated iron, often on marginal land with poor access to services (UN Habitat, 2016a). Drought, experienced in 2017 and 2018, has been widespread across the city and region, leading to significant restrictions (household and businesses had to cut back significantly) and tariff increases across the city (Muller, 2018; Ziervogel, 2018). These did have a significant impact on poor households. Flooding, on the other hand, although it occurs annually, is localised and mostly felt in poor neighbourhoods (Ziervogel et al., 2016). It has not received the same amount of attention that drought has.

The municipality of Cape Town is equipped with a sophisticated online GIS system (CTMV) which is widely used by local civil servants and feeds into different conceptions of resilience, ranging from planning and infrastructure to biodiversity. Routine practices include the use of maps to monitor changes (e.g. urban sprawl; building size), collect revenues from rates, and provide evidence for courts (e.g. showing cadastral boundaries). These maps are also being used in more innovative ways to understand, for example, the green infrastructure of the city for water management. For informal settlements, however, the situation is different. Although they fall under the jurisdiction of the city, the level of detail on the maps of these areas is sometimes limited. The informal nature of settlements and quality of some services are hard to see spatially. For example, although it might look as though there are sufficient numbers of toilets and taps on the map, these are often not in working order, which is not represented visually. The municipality has detailed flood risk and water infrastructure maps, but most are not publicly accessible because of concerns about sharing this data that might lead to vandalism.

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[3] Thick mapping has been defined as 'The processes of collecting, aggregating, and visualizing ever more layers of geographic or place-specific data…[to]… embody temporal and historical dynamics through a multiplicity of layered narratives, sources, and even representational practices.' (Presner et al., 2014, 15)
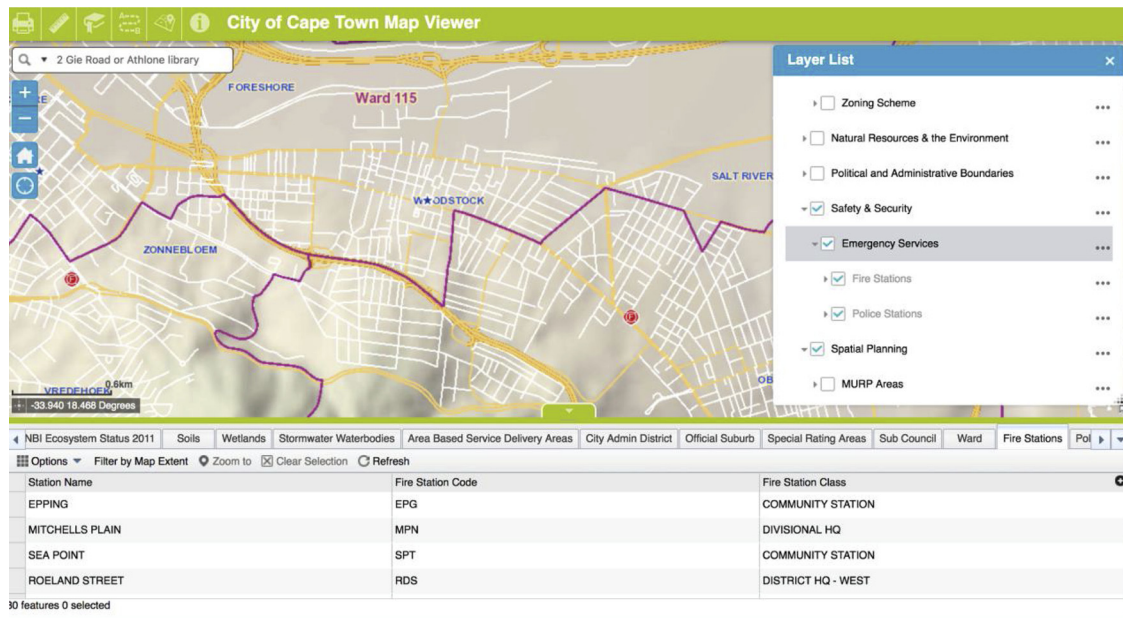
Fig. 1. Screenshot of the City of Cape Town Map Viewer (CTMV) (available at: https://citymaps.capetown.gov.za/EGISViewer/) showing data layers of roads, ward boundaries and fire stations for an area of Cape Town. The portal is open for anyone to view, query and download spatial data.
Source: City of Cape Town (2018).

4.1.1. Mapping the lived experience of people in informal settlements

Different NGOs operate in Cape Town informal settlements and mobilize a diversity of techniques involving spatial knowledge to help secure land and advocate for services. Slum Dwellers International (SDI), for example, has routinely used participatory mapping techniques and worked with the municipality to enumerate some areas (SDI, 2018). However, their mapping data is not publicly accessible and integration of local maps developed by NGOs and community organizations with city maps is lacking.

While sometimes it was the *process* of mapping which enabled conversation and engagement between different actors, in other instances it was the *format* in which information was presented and mapped that was used to trigger conversations:

'Visuals do not show everything. You also need to show the networks of connections, the sets of relations between people. And maps shouldnot be static but dynamic, show how things change. We need to move beyond easy mapping approaches.' (Interviewee C1)

A local NGO has created their own maps to contest official municipal maps (Interviewee C8). According to the official maps there were sufficient toilets for the number of households in Hangberg informal settlement. On the ground, however, some households were complaining that this was not the case. This NGO then mapped who did and did not have access to toilets, rather than where they were located. This mapping revealed some of the micropolitics taking place in the area that resulted in some households being unable to access certain toilets. This helped to provide an alternative understanding of access to services and was used to lobby for more facilities.

4.1.2. Opening-up conversations around resilience: mapping for public participation

Different actors and organizations have explicitly used mapping as a way to create a conversation between different actors, as shown by two examples from Cape Town municipality. Emphasizing some of the difficulties associated with planning in informal settlements, an engineer working for the municipality explained how maps have been used to identify places where houses could be moved to distribute services, in conversation with the community:

'With regards to planning in informal settlements one of the difficulties relates to density. To provide access to services you need to have less dense areas so need to reorganize the way in which shacks are distributed. It is very hard to transform a space from informal to formal. (…) Sometimes I knows what a solution could be but I need to let the community come up with it, and sometimes they come up with new points that I had. not thought of. Dialogue is needed. We need to use both technical and local knowledge.' (Interviewee C9)

Another technique mentioned by a local civil servant (Interviewee C3) was the use of a game to gather people's view on the future of the Gordons Bay area: 'This game was designed to allow landowners, ratepayers associations, local government officials and politicians an opportunity to guide how the greater Gordon's Bay area could be developed' (City of Cape Town (CoCT, 2017: 1). In groups, participants placed different land use tiles on different parts of the map (Picture 1). The placement of tiles, including where high and medium density housing and industry might go, was accompanied by a discussion on why they thought these locations were suitable. They were then asked to think specifically about storm water issues and whether the water could be collected. Players appreciated the experience and learned a lot. For example, they reflected on their surprise at how much space stormwater attenuation takes up, prompting them to support investment in stormwater facilities as multi-purpose, rather than uni-functional, public spaces.

4.2. Nairobi

Nairobi is home to about 3.9 million people (UN Habitat, 2016a, 2016b) and faces different types of resilience challenges including issues associated with traffic and the lack of public infrastructure, poverty, and floods (Bull-Kamanga et al., 2003). Within Nairobi, Kibera is the largest informal settlement in Eastern Africa, with many residents disconnected from, or having poor access to, basic services and public authorities. Flooding is one of the main risks for Kibera residents and is closely linked to other issues including public health - being associated, for example, with outburst of cholera (KDI, 2016).

Nairobi is not equipped with the same spatial data infrastructure as Cape Town. However, a range of mapping initiatives exist, at the

community level (e.g. MapKibera, Know Your City), municipal level (e.g., Safetipin, The Nairobi Masterplan), and beyond. The recent Constitution (2010) has initiated a decentralization process and given more power and responsibilities to local actors. This devolution process presents the opportunity for greater collaboration between different actors, allowing more conversations with communities prior to developing projects and infrastructures. At the same time, expertise and resources associated with these new responsibilities remain uneven at the municipal level.

4.2.1. Making the invisible visible: mapping urban flood risk in Kibera

Kounkuey Design Initiative (KDI) is an NGO operating in Kibera. Working along with residents, KDI has been key in providing detailed hazard maps for Kibera. Interviews with KDI often emphasized the value and accuracy of local knowledge:

> 'People living in Kibera have the map in their head, it is crazy how much they know about the area and how they remember things.' (Interviewee N5)

In 2015, KDI undertook extensive data collection to document the extent of previous floods in Kibera (BurroHappold 2017). The flood maps produced were 'conventional' maps, i.e. documenting the extent of floods based on geophysical criteria, accompanied with spatial data collection on flood impacts (Fig. 2). This work demonstrated that 50% of Kibera residents experienced flooding during the rainy season, with flooding area extending well-beyond the river, revealing the cumulative effects of infrastructural developments taking place within – but also outside – the boundaries of Kibera (Fig. 3).

By engaging with mapping KDI provided the municipality with data that they did not have access to previously, while creating an advocacy tool for the community. Although focused on the micro-scale, these maps revealed larger-scale issues and opened up conversations with Nairobi City County (e.g. public works department). This work revealed the need for integrated planning and allowed identification of areas lacking functional drainage infrastructure. This study also documented the wide range of coping strategies undertaken at the household or community level to deal with floods, making a case for community responsive adaptation (KDI, 2015; Mulligan et al., 2016).

Fig. 2. Game board used to discuss different planning options for the Gordon Bay area.
(*Source:* Marco Geretto; City of Cape Town 2017).

4.2.2. Mapping to open-up a space for holistic resilience thinking

Another example was the *Nairobi City-wide Open Public Spaces: Inventory and Assessments* initiative that was coordinated by UN Habitat and Nairobi City County (UN Habitat, 2016b). The purpose of this initiative was to provide evidence that public spaces existed in Nairobi and that it was worth investing in them. As emphasized by one of the managers of the programme:

> 'Public spaces serve a variety of purposes, they allow people to do sport and be healthier, also to exchange ideas, build a sense of place and community. They also contribute to the air quality of the city, facilitate infiltration and evacuation of rain and storm water. So public spaces present many advantages and despite being often pictured as not cost-effective or productive in the short term, they present actually a diversity of benefits. There is a need to find ways to make public spaces attractive to politicians and decision makers.' (Interviewee N3)

This initiative invited students in urban studies and other backgrounds to map public spaces, contributing to the construction of a dataset that was not available before while also building capacity. Taking inspiration in the free software tools used to map Ebola in East Africa, they combined different techniques using GPS, GIS and photography. Over 1798 public spaces were surveyed, and different types of maps produced (e.g. showing the type of public space, their location, who has access, etc.) to make the case for a greener, and fairer, city (Fig. 4).

5. Discussion

The structure of this section follows the three questions outlined in Section 1. First, we reflect on the value of maps and mapping for resilience. Second, we summarize the main challenges that current approaches face with regards to knowledge integration. Finally we reflect on the potential of new methods, in particular creative practices, to facilitate the articulation of diverse forms of knowledge and help capture less tangible aspects of resilience.

5.1. The connective power of maps

The examples described above give a sense of the diversity of mapping practices and uses of maps relevant to resilience planning. Importantly, in each case these maps become part of broader narratives that contribute to the construction of different understandings of resilience (Borie et al., 2019). For example, in the Nairobi *City-wide Open Public Spaces* initiative, maps were used to articulate evidence that a greener Nairobi was possible, advocating for a holistic understanding of resilience in which social and environmental concerns were not perceived as in opposition. Examples of NGO-led mapping initiatives in informal settlements served to direct attention towards interventions needed to improve well-being in marginalized areas, emphasizing the social dimension of urban resilience. This suggests that maps play a multi-faceted role, being neither good or bad in themselves, and can contribute to diverse understandings of resilience and potentially become articulated in contradictory narratives – therefore 'opening-up' or 'closing down' conversations (Stirling, 2008). For example resilience understood in terms of geophysical risks only may be used to justify relocation whereas alternative approaches would emphasize social aspects such as livelihoods and social networks (e.g. Mitra et al., 2017).

Maps were interpreted differently depending on who was reading them. For some they were a 'true reflection of what is on the ground' (Interviewee C4) while others emphasized that maps 'can be very reductionist sometimes, there are many layers to a map and many invisible ones. Relationships and stories are important to highlight' (Interviewee C8). These two quotes highlight opposite understandings: maps as objective representation of reality versus maps as always subjective and partial. Despite these differences, one aspect which

Fig. 3. Map of modelled flood risk and records of past flooding in Kibera.
(*Source:* KDI).

seems consensual is the ability of maps to focus attention and to open up conversations: 'No one reads anything, but maps grab people's attention' (Interviewee C8); 'A picture is worth 1000 words, maps are useful tools' (Interviewee C6). In this respect, several interviewees emphasized the value of maps to create a deliberative space and facilitate exchange, between different disciplines and actors: 'My maps help make the social stuff visible including to technical oriented people' (Interviewee C1). For example they can 'Create a common language in places were many people are not or hardly literate' (Interviewee C6). Among the multiple uses of maps and mapping, their connective power offer several opportunities for resilience thinking and planning (Table 1).

5.2. Challenges with current approaches and knowledge-integration

Maps and mapping processes present opportunities for resilience planning, in particular through their ability to connect different dimensions, either directly, via the process of mapping, or by what is actually connected, and made visible, on the maps. Although not particular to resilience, these qualities are useful in relation to the cross-disciplinary and holistic approach that resilience demands (Eakin et al., 2017; Elmqvist et al., 2014). At the same time, difficulties regarding the ability of maps to integrate different types of knowledge exist.

Although there is often agreement regarding what resilience means broadly, there are different understandings regarding what it means to
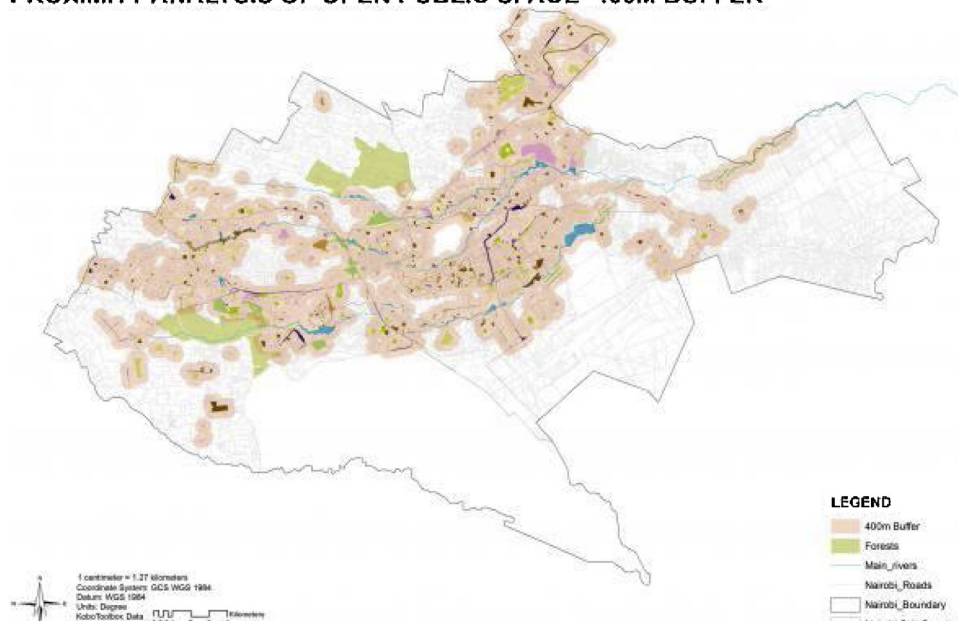

Fig. 4. Proximity analysis of Open Public Spaces (5 minutes walk, 400 m).
(*Source*: UN Habitat 2016b: 85).

Table 1

Opportunities for connections provided by maps and mapping processes.

Source: Own table, based on interview analysis.

Connections	How?
Actors	By starting a conversation or a consultation
	Engaging multiple actors from different educational backgrounds who can all relate to a place through spatial representation
	Engaging on complex topics that are abstract
	Providing a communication tool
Scales and Places	Making local concerns visible at the city scale (or other scales)
	Visualizing who is included/excluded across the city
Disciplines & Databases	Creating a common language
	Overcoming the divide between quantitative and qualitative data
	Provide flexibility to visualize a range of formats of evidence (e.g. picture/sounds)
	Connect and display heterogeneous datasets in a common format

implement resilience (e.g. personal vs. systemic; supporting the status quo vs. radical change; ability to deal better with current stresses vs. preparing for future uncertainties; cf. Borie et al., 2019). Tensions also exist between different approaches because ways to capture and represent knowledge vary and are often built on different worldviews (Bowker, 2000; Goodwin, 1995). Technical systems can make it difficult to integrate data that do not fit a particular format (narrative vs. numbers). As emphasized by an interviewee working for an NGO based in Cape Town: 'The City does not integrate our data with their database [CTMV]. There is no interface' (Interviewee C8). This talks to challenges of data management and integrating different types of knowledge into one mapping system.

Moreover, data availability is often uneven. For example, in Nairobi data on solid waste management exists for the business district but is not collected for other areas (Interviewee N2). Data-led approaches often focus on wealthier or formal areas, leaving out informal settlements such as Kibera. Yet, informal areas are an integral part of African cities (UN Habitat, 2016a). In some instances, data may simply not be available, rendering integration impossible. This point was well emphasized by an engineer working in Nairobi:

'It does.n't matter if you have a spreadsheet or a GIS software, if you do.n't have any data to put in it. This is the main issue for me, there is no comprehensive datasets of anything.' (Interviewee N7)

In Cape Town, the CTMV flood hazard maps indicate flood risk across the city but do not reflect what actually happens in neighbourhoods. In contrast, NGOs understand the challenges of living with flooding and local flood risks but do not necessarily know how this connects up to the whole city system. These different approaches could be brought into conversation more as they offer complementary insights and to encourage relevant authorities to take responsibility. Finding ways to integrate local knowledge in city maps would provide a more complete picture about the level of urban risk and resilience that is not currently captured in CTMV. Holistic understanding requires integration across scales which is challenging. Moreover, maps, as explained in Section 2, are not neutral to resilience planning: they are necessarily reductionist and render certain things visible while making other invisible.

5.3. Overcoming reductionism: exploring the potential of creative practices to visualize resilience

Decision-making based on top-down processes of planning that is informed by scientific data alone may produce inappropriate interventions (e.g. Leitner et al., 2018). Some of these interventions might actually reduce resilience if questions around trade-offs and whose resilience is being influenced are not asked (Harris et al., 2017). The role of arts in producing transformative knowledge is being increasingly recognized the world over (e.g. Heras and Tàbara, 2014; Brown et al., 2017). In particular, when it comes to engaging different epistemic communities, arts-based methods enable democratic spaces for

encounter that may be more conducive to knowledge coproduction than normative types of research. Essentially the role of arts-based experimentation is to introduce new starting points for thinking and engaging with people and places (Heras and Tàbara, 2016). Arts-based practices can contribute to: (i) creating non-threatening spaces for engagement with diverse participants around complex issues; (ii) fostering inclusion and deal with lack of consensus. Diverse participants will mean a range of perspectives that may be irreconcilable, (iii) thus; revealing and diffusing societal power dynamics (see Sitas and Pieterse, 2013).

With regards to resilience mapping, thick mapping and experimentations in GIS are finding new ways of representing spatial knowledge (Presner et al., 2014).[4] How this data is developed can benefit from arts-based conceptual mapping techniques and make tangible other types of connections (e.g. social networks, power dynamics). This is essential to allow multiple interpretations to co-exist and avoid reductionism, therefore helping to develop more inclusive, and reflexive, resilience planning (on the value of complexity see Stirling, 2010).

6. Conclusion

Our findings suggest that spatial knowledge and maps are mobilized in diverse ways for resilience planning and policy. Different mapping techniques contribute to different representations and understandings of resilience. For example, mapping the lived experience of people in informal settlements will help to understand resilience in relation to social concerns. Such concerns are not usually accounted for on maps which circulate an understanding of resilience around natural hazards and safety. Intentions and interpretations between those who produce and those who read maps can also be very different. Only by acknowledging and accounting for this plurality of perspectives can urban resilience strategies be developed in a way which is legitimate and inclusive of people's concerns.

In addition to their heuristic potential, maps and mapping techniques are effective engagement tools that can usefully connect diverse actors, scales, and disciplines. For this reason, we suggest that the transformative potential of maps and mapping for resilience is due in particular to their ability to (i) act as a conversation opener and deliberative space and (ii) render visible alternative connections. Opportunities to map resilience across city scales and across the spectrum from the material to the lived reality exist in both Nairobi and Cape Town. These emerging and experimental approaches have the potential to facilitate a more holistic approach to resilience thinking and planning.

Although much emphasis is placed on the potential of quantitative

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[4] For a good example of this approach see: https://uploads.knightlab.com/storymapjs/2c35cb16e8a4ba0f38b455018607aa14/battle-in-kenya-slum-over-bulldozing-of-schools-and-heritage/index.html (Last accessed May 18th, 2019).

tools and indicators to provide credible, policy-relevant, knowledge, our results show that there is appetite for alternative ways of mapping, using for example creative practices in combination with other techniques. Despite the best attempts at participatory processes, there is an inevitable disjuncture between scientists, engineers, city planners and their institutions, and those eking out a living, often in the margins of cities. It is therefore important to develop new research and resilience thinking strategies that better weave together spatial data about physical structure at the city-level with lived experience at the local level. Alternative approaches can strengthen the integration of bottom-up, participatory, qualitative knowledge with quantitative, technical, top-down data to better capture the cross-scalar multifaceted nature of resilience and usefully open-up conversations on what resilience might look like. Spatial knowledge and maps are one way to articulate diverse perspectives - but reflection on other tools and ways to open up deliberative spaces is needed.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2019.05.014.

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