Towards a Conceptual Framework for Participatory Mapping in Developing Countries

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Summary

The success of crowd-sourced mapping is now evident in the developing world, where data from OpenStreetMap can at times exceed the quality of data produced by National Mapping Agencies and proprietary data providers. In certain countries, this crowd-sourcing has been delivered through community mapping, which has enabled the creation of highly detailed maps of ever expanding urban environments, created by communities themselves. In turn, this enables further participation in the resolution of challenges faced by the community, such as flooding. Accordingly, this paper presents an investigation into the effectiveness of participatory mapping of flood prone areas and supporting conceptual framework.

KEYWORDS: *Participatory Mapping, Crowd-Sourcing, Volunteered Geographic Information, Community Mapping, Disaster Resilience.*

1 Introduction

Dar es Salaam, Tanzania is one of the fastest growing cities in Africa. With a current population of 5.5 million, it's projected to hit megacity status by 2030. Maps and geographic information are critical to the development of any city, vital for placing public services and ensuring the safety of its citizens. However, numerous factors add complexity to the security of Dar es Salaam's residents: The rapid population growth of Dar es Salaam, from a population of roughly 300,000 in 1970 to the present day; the paralleled rapid urbanisation in an unplanned, informal manner; and highly variable climatic environment all contribute to a high risk of flooding.

In response to this, in 2015 a consortia of local academic institutions and NGOs working with the Commission of Science and Technology, the Red Cross, World Bank and community members formed

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Ramani Huria[1], a community mapping project in Dar es Salaam. As of January 2017, Ramani Huria has mapped neighbourhoods covering roughly 3.5million residents in over 40 communities, in a process that combines students and community members. As such, we present an investigation into the effectiveness of participatory mapping of flood prone areas and a conceptual framework to support future iterations and other cases.

Community mapping is defined in Perkins (2007) as the *"local mapping, produced collaboratively by local people and often incorporating alternative local knowledge"*. According to Hagen Hagen (2011) this form of engagement is an emergent phenomenon that not only "empowers communities" but generates hard-to-obtain data - describe amenities and features such as water taps, toilets, pharmacies, schools and land usage. Importantly, these are the exact features and information that are most relevant to the community producing the maps.

The first large-scale community mapping project with the explicit aim of producing VGI data in a developing nation is arguably Map Kibera in 2009 Hagen (2009). While several mapping projects have followed, most are typified by *responses* to crises (Goolsby (2010)). In Soden and Palen (2014), the case of the Haitian earthquake is examined, where a cadre of global volunteers combined with a local community members to provide geographical data to humanitarian rescue workers (Goolsby (2010); Meier and Munro (2010)). Following the earthquake, this local community stayed together forming the *'Cite Soleil'* mapping group. This phenomena is similar to community mapping projects that have emerged in Nepal (Soden and Palen (2016)) and Kenya (Hagen (2009)), which have focused purely on field based mapping for local communities by those communities.

The Tanzanian Ramani Huria case differs from these activities, as mapping is conducted with the explicit purpose of preparedness and resilience to flooding. This enabled mapping to move past the collection of basemap data, towards the collection of ephemeral data such as flood extents. [2]. This raises the question of the quality of this data and its the usefulness of ephemeral data collected through participatory means. This is now examined.

2 Method

To assess participatory mapping for understanding the extent of flooding, a mixed methods approach was used. Firstly, the task was designed by the authors; Secondly, observation of the process and impact of participatory mapping and interviews with participants was conducted in one neighbourhood, Tandale. Participants included community members and government officials; Fourthly, the resulting data was digitised; and finally assessed through comparison with a hydrological model of flood extents.

Figure 1 details the various stages participatory flood mapping:

1. Using the map created by community mapping, convene community members and other community stakeholders together (Figure 1a);

[1] http://ramanihuria.org/

[2] roughly, as accurate population statistics in Tanzania are unavailable

2. Annotate the map, capturing community knowledge that delineates historical flood extents onto the map (Figure 1b);
3. Digitise the annotated data, creating a GIS layer of community derived inundation areas. (Figure 1c).

Following this, using an 8cm resolution Digital Terrain Models openly available for Dar es Salaam[3] and the Height Above Nearest Drainage (HAND - Nobre et al. (2011)) hydrological model was developed to model probabilistic flood scenarios [4] quantitatively. Figure 2 shows the various flood extents, and the various flood scenarios at 1m, 2m, and 4m flooding for the HAND model. The participatory extent has no flood depth value, it is collected on a shared community knowledge, in effect representing the maximum extent of flooding experienced by the community - ie. 4m.

These extents were then compared with the participatory derived data using a Jaccard Index. A Jaccard Index compares the similarity and diversity of different datasets, by dividing the intersection by the size of the union. In this scenario, two polygons one of the HAND derived flood extent and the participatory mapping derived flood extent are compared against each other. This is repeated for each flood depth scenario. To prepare data for analysis, a 500m buffer was applied to the administrative boundary of Tandale and flood extents from both approaches were clipped[5].

Alongside this quantitative approach, a qualitative approach where 20 mapping participants were interviewed using semi-structured interviews[6]. Responses were then grouped thematically and used to further support the development of the conceptual framework discussed later.

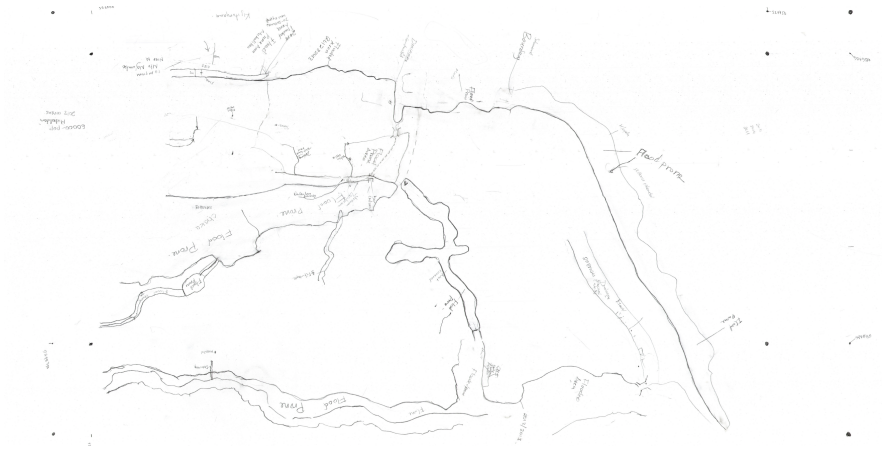
[3] OpenAerialMap.org

[4] This was selected as the hydrological model due to the lack of supplementary data, such as rainfall data that would enable the creation of a more complex and accurate hydrodynamic model - such as ANUGA.

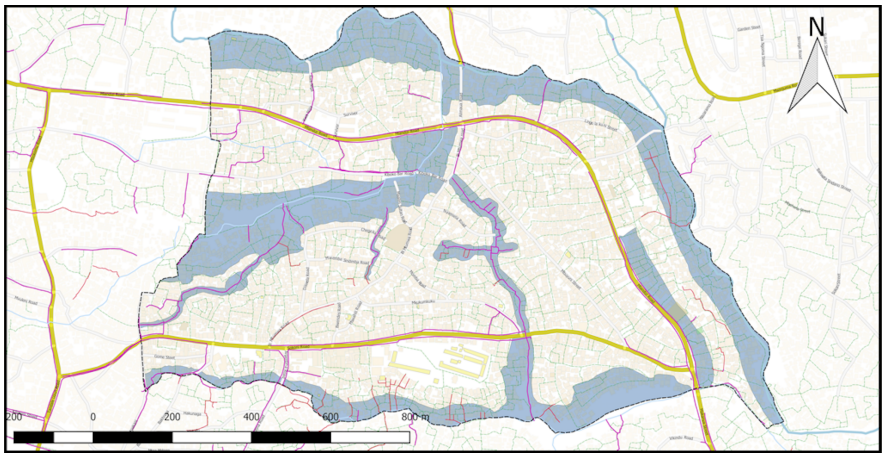
[5] While the process of community mapping and participatory mapping was conducted across Dar es Salaam, the availability of the processed 8cm DTM for hydrological analysis was limited.

[6] Structured interview questions specifically gauging what participants thought about the process were asked, with the interview then proceeding based on responses.

(a) Participatory Mapping

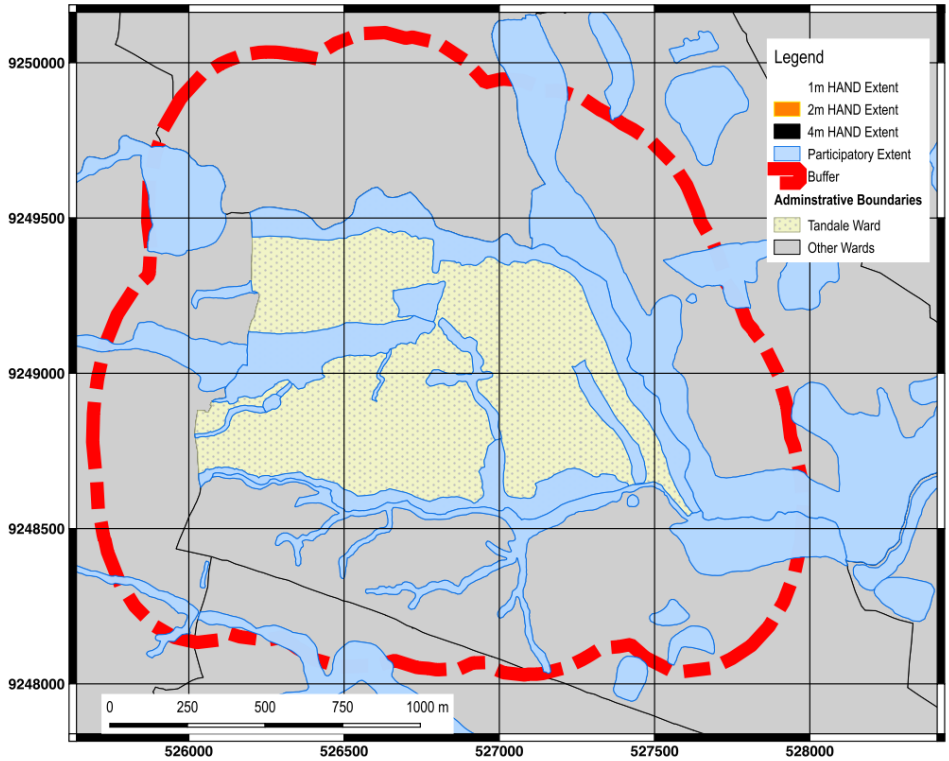


(b) Historical Flood Extent Annotations

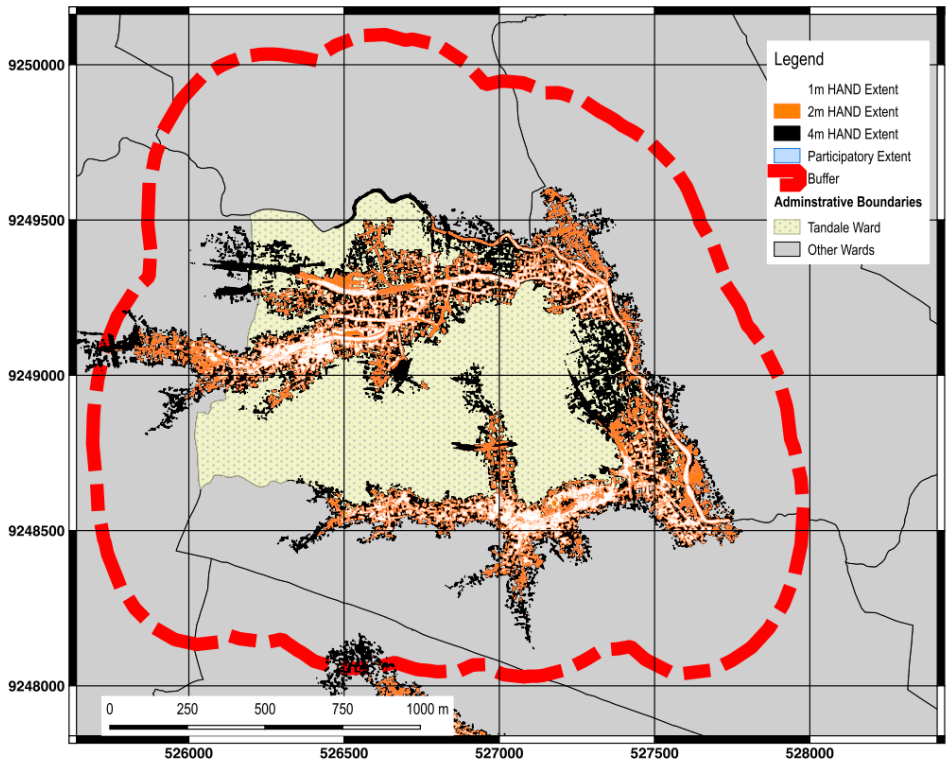


(c) Historical Flood Extent

Figure 1: Participatory Flood Mapping



(a) Participatory Mapping



(b) HAND Extent

Figure 2: Comparison of Flood Extents

3 Results

Table 1: Jaccard Index

Flood Extent	Jaccard Index
1m	68%
2m	79%
4m	86%

The similarity between the scenarios, demonstrates **fitness for purpose** of the participatory mapping approach. While there is not a direct 1:1 overlap between the participatory mapping derived flood extent and the various flood inundation scenarios, there is still significant overlap. This validates the potential of participatory mapping to inform on flood extents where traditional forms of data, such as DTMs, are not available with a clear avenue forward for future research.

The impact of this participatory process also resonates within the community, allowing actions to be identified and taken allowing for more resilient community:

> *"We have already identified areas where we can construct drainage systems... community mapping helps people to understand their problems because when you see the maps, you can see the areas which gets damaged through the floods. People decided to clean the stream that was full of garbage, so when the rains came yesterday, it did not cause any damage as the area was already cleaned"* - Tandale Ward Executive Officer

The combination of rapid urban growth and climate change will only serve to raise the risk for unplanned communities such as Tandale. However, as demonstrated in this comparative analysis and through interviews, the outputs of participatory mapping can be comparable to traditional analyses and enable communities to take action.

4 A Conceptual Framework for Participatory Mapping

Figure 3 details a conceptual framework for supporting participatory mapping[7]. This framework lays a foundation that would allow for the extension of participatory mapping in other cases and developing countries that are following the community mapping methodology. In particular, this framework is not predicted on traditional hydrological datasets and/or DTMs being available, instead taking a community-led participatory approach, complementing traditional methods.

[7]This framework is more fully supportable with thorough interview analysis conducted in support of this research, but is out of scope for an extended abstract - in keeping with the public forum nature of participatory mapping, partial interviews with participants are released openly - https://www.youtube.com/watch?v=TdPdO7EWCxo&t=3s

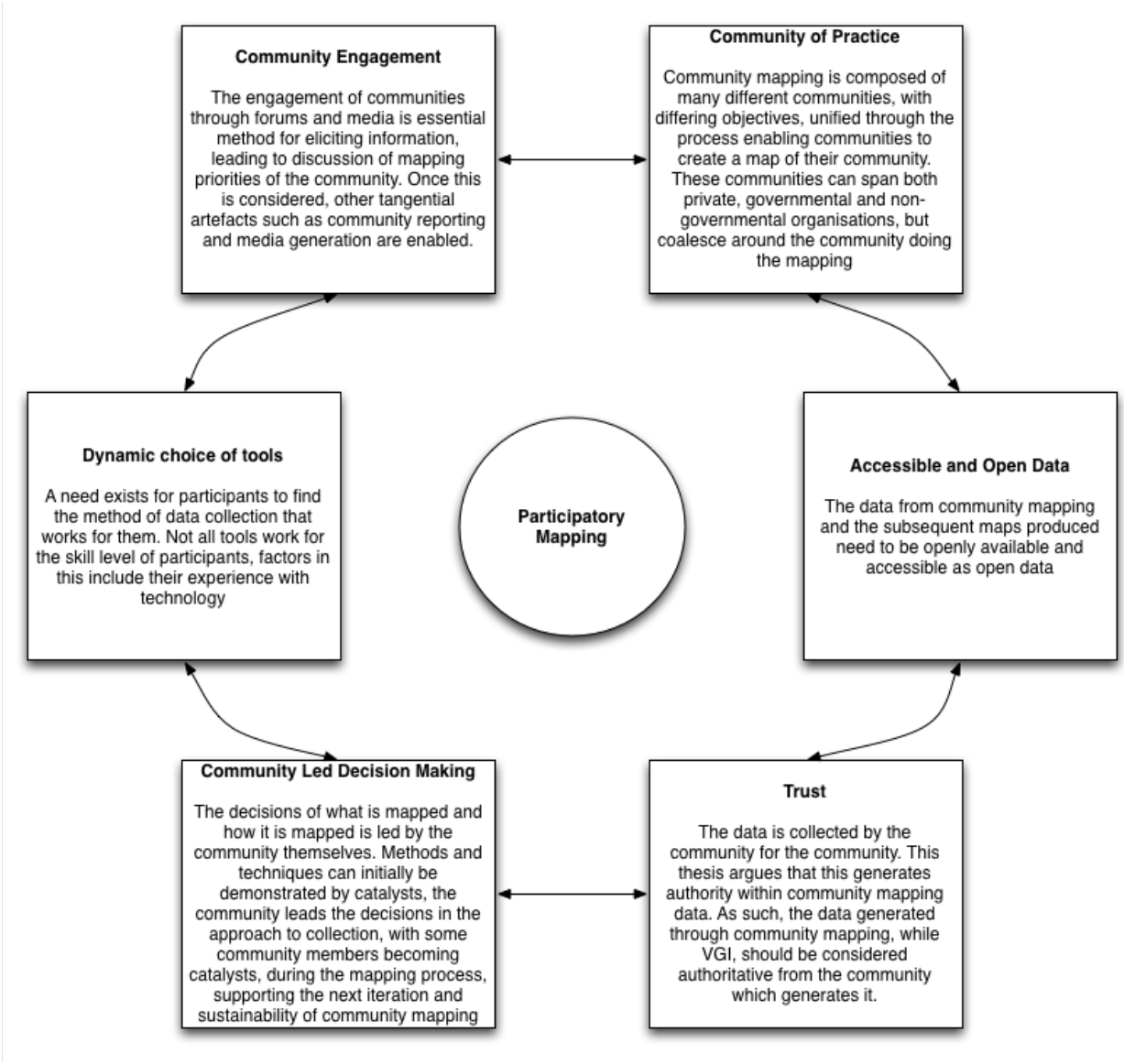


Figure 3: Conceptual Framework

5 Conclusion

By working with at-risk communities with community and participatory mapping activities, the engagement enables communities to further understand the challenges of rapid urbanisation and identify measures that enable resilience to hazards such as flooding. These measures could include the construction of new infrastructure, such as drains or solid waste collection sites or community driven activities such as waster collection and retrieval from already built infrastructure and

environmental features (as in this case).

This space is where the fusing of participatory and traditional techniques can have the largest impact, not all places will have Dar es Saalam's numerous data streams. In these cases, the concepts above will enable other places to leverage participatory techniques to deliver fit for purpose results. From this point, communities and government officials can then make decisions and take action to improve resilience and reduce risk.

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7 Biography

Mark Iliffe is the Geospatial Lead at the N-LAB, a Centre for International Data Analytics at the University Of Nottingham. He has a particular interest in harnessing new and existing geospatial data streams for international development and investigating novel participatory approaches.

James Goulding is assistant professor and deputy director of N-LAB, a new centre for International Analytics at Nottingham University Business School, specializing in novel forms of data science - time series analysis, summarisation and visualisation of mass data sets. His work focuses on how closed source, commercial dataset can be harnessed to promote of international development and social good.

Hessel Winsemius is an expert in the field of hydrology, with particular applications in global and regional flood risk modelling and analysis. He frequently publishes about these subjects in international peer reviewed journals. He is a member of the Young Scientific Council of Deltares.

References

Goolsby, R. (2010). Social media as crisis platform: The future of community maps/crisis maps. *ACM Transactions on Intelligent Systems and Technology (TIST)*, 1(1):7.

Hagen, E. (2009). Putting Nairobi's Slums on the Map. *Development Outreach*, 12(1):41–43.

Hagen, E. (2011). Mapping Change: Community Information Empowerment in Kibera (Innovations Case Narrative: Map Kibera). *Innovations: Technology, Governance, Globalization*, 6(1):69–94.

Meier, P. and Munro, R. (2010). The unprecedented role of sms in disaster response: Learning from haiti. *SAIS Review of International Affairs*, 30(2):91–103.

Nobre, A., Cuartas, L., Hodnett, M., Rennó, C., Rodrigues, G., Silveira, A., Waterloo, M., and Saleska, S. (2011). Height above the nearest drainage–a hydrologically relevant new terrain model. *Journal of Hydrology*, 404(1):13–29.

Perkins, C. (2007). Community Mapping. *The Cartographic Journal*, 44(2):127–137.

Soden, R. and Palen, L. (2014). From crowdsourced mapping to community mapping: The post-earthquake work of openstreetmap haiti. In *COOP 2014-Proceedings of the 11th International Conference on the Design of Cooperative Systems, 27-30 May 2014, Nice (France)*, pages 311–326. Springer.

Soden, R. and Palen, L. (2016). Infrastructure in the wild: What mapping in post-earthquake nepal reveals about infrastructural emergence. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 2796–2807. ACM.