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Building socio-hydrological resilient cities against flash floods: Key challenges and a practical plan for arid regions

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ABSTRACT

The objective of this research is to improve the understanding and recognition of the management challenges to flash flooding hazards and the potential adaptive measures within the arid urban areas through a socio-hydrological framework. Considering the capital of Sudan, Khartoum, as an example of urban arid areas with increasing flash flood risk, the analysis was founded on expert views and opinions collected from a range of different flood management actors following the 2013 and 2014 flash flood events. The qualitative research methods included participant observation, expert interviews and focus groups. The main themes of management challenges recorded included weak institutional capacity, bad governance, limited resources, and poor urban planning. These four themes, in turn, included different types of challenges, among which lack of: civil society engagement and coordination of actors, political will, data and tools, and effective urban development strategy shared the highest number of comments from the professional actors in each theme, respectively. These findings presented a management perspective to the lessons previously established and learned from an impact assessment. Accordingly, the amalgamation of all the lessons learned from the flood research findings enabled a suitable Master Flash Flood Management Plan (MaFFMaP) to be proposed as a final product. This plan would operate within an Integrated Flash Flood Management (IFFM) framework. The facets of the MaFFMaP include steps toward improving the quantity and quality of data resources regarding this hazard, aspects for use of these new datasets within a mixed-measure (structural and non-structural) approach from the authorities, and programmes for building community and civil society capacity through improving awareness and engagement. Furthermore, it is intended that this plan would be a replicable design, which could therefore be adopted and implemented in the wider context of the urban arid regions.

1. Introduction

When recognizing that climate predictions warn of an increased frequency of extreme rainfall events, it is important to understand that rainfall-driven flash floods have been identified as the type of natural hazard most likely to increase in severity as a result (Houston et al., 2011; IPCC, 2012). One line of thought is that the increasing risk and impacts of global flood events is an effect of the intensifying role of climate change and variability creating greater probability levels of flood hazards (Kundzewicz et al., 2014). It is also key to recognize that any intensification in a region's rainfall regime will put the highly populated urban areas, in particular, under increased risk from flash flood events as the effects of urban development have increased their vulnerability and exposure to such hazards (IPCC, 2012; Kundzewicz et al., 2002, 2014). Some of the main impacts of urban floods include the threat of fatalities, destruction of homes and livelihoods, and damages to economic assets and primary importance infrastructures (Douglas et al., 2008).

Africa – reported to be the world's fastest urbanizing continent – has already experienced the effects of growing urbanization and the level of flood impacts. Di Baldassarre et al. (2010) directly connect the rapidly increased number of flood fatalities to the steady growth of urban population in Africa for the period 1950–2010. For example, 23 flash floods were recorded during the period 2003–2010 in some parts of Ethiopia due to increase in rainfall intensity paired by a marked change in land use/cover and management practices (Billi et al., 2015). Fatal and damaging floods due to heavy rainfall have also occurred in other parts of Africa where populations have experienced increasing growth rate (Danumah et al., 2016). Epule et al. (2017) report increasing frequency of floods over time in the African Sahel, and therefore recommend careful consideration of adaptations and land use policies to reinforce resilience to floods.

A recent integrated assessment of flash flood impacts on society, property and infrastructure for the capital of Sudan (Khartoum) has

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estimated the risk as a function of hazard, sensitivity, vulnerability and adaptive to be 46.4% (Mahmood et al., 2017). The same study has enabled deriving a number of 11 lessons that make similar areas to have faced increasing risk of this hazard (Mahmood et al., 2017). Rainfall in Khartoum is characterized by irregular behaviour, extreme seasonality such that almost all rain falls in 1–2 months, and dependency of the annual rainfall on the very strong records, i.e. daily rainfall of more than 30 mm (Mahmoud et al., 2014). The rapid urbanization within Khartoum (Hafazalla, 2008; Eltayeb, 2003; Hafazalla, 2008; Bannaga, 2012) is symbolic of many other cities throughout Africa, as environmental (e.g. drought or desertification), socioeconomic and civil war refugees migrate from rural to urban areas (Babiker, 1982; El Nour, 1989; Verhoeven, 2011) to escape the devastating problems, only to put themselves within the risk of another type of problem, such as the hazard of urban floods (Douglas et al., 2008). The mass influx of migrants, then exposed to already flood-prone areas, are made further vulnerable by the quick-fix creations of informal settlements to accommodate them – usually lacking any kind of planned drainage system (WMO, 2008). Recognizing both lines of argument and the evidence of the recent severe flood events, it could thus be argued that the combined impacts of climatic variability and anthropogenic pressures are increasing the risk of flash floods for Khartoum (Mahmood et al., 2017). Therefore, it can be assumed that: (1) business-as-usual reactive flood management practice is unsustainable; and (2) proactive flash flood planning should be adopted to build Khartoum's preparedness and resilience to future heavy rain and flash flood events.

Following on from these broad disaster management concepts to combat the increased levels of flood risk, the Integrated Flash Flood Management (IFFM) approach has been generally accepted as the doctrine to follow for actors working within the flood management field. As noted above, it is believed that IFFM operates within the framework of socio-hydrology. Socio-hydrology is defined by Sivapalan et al. (2012) as an "interdisciplinary but quantitative science [focusing] on observing, understanding and predicting future trajectories of co-evolution of coupled human-water systems", thus underpinning the practice of Integrated Water Resources Management (IWRM), i.e. underpinning sustainable water management. In the context of socio-hydrological analysis of flood risk, Di Baldassarre et al. (2013) presented a conceptualization of the dominant dynamics in floodplains as fully coupled human-flood systems with hydrological, economical, political, technological, and social processes simplified as much as possible. Another fundamental principle underpinning IFFM is the adoption of a participatory approach, engaging with the community to build preparedness and resilience to flood events. Furthermore, IFFM should implement a mix of strategies to reduce flood risk – meaning both structural and non-structural measures (WMO, 2009). In the development of urban floodplains, another study analysed the interplay of community risk coping culture, flooding damage and economic growth in a conceptual way to create a socio-hydrological discussion among researches from natural and social sciences (Viglione et al., 2014). Viglione et al. (2014) recommended further interesting research directions, such as using an "analogous conceptual framework to investigate how communities adjust (or may adjust) toward developing a suitable culture for their environment". They also recommended a focus on which role different community agents (e.g. institutions and public) have in the process of decision making regarding, for example, flood risk management. While examples of the emerging challenges for flood-risk management and relevant strategies are available for some developing regions in the humid environments (e.g. Hoang et al., 2018), such challenges have rarely, if ever, been identified and addressed in developing arid regions. The establishment of flood resilient communities provides an added value and effective means to operational and adaptive management of flood disasters in a changing world (Schelfaut et al., 2011).

Therefore, the objective of this study is to build a good level of understanding over the management challenges to flash floods from the Khartoum case of arid regions to be able to design and propose a practical adaptive management plan, which would aim to reduce the risk to flash flooding. There are various components to the importance of this study. First, there is a need to recognize the relevance and applicability of integrated management principles as a suitable framework for proactive adaptive flash flood management measures to operate within. This improves preparedness and resilience to future flood events. Second, this study represents an amalgamation of all the lessons learned from flood research findings in the case study area. Finally, the proposed plan should be replicable to be adopted and implemented beyond the confines of the case study area, i.e. in the wider arid region context. This is fundamental to the building of a body of work related to the often marginalized increasing risk of urban flash flooding in arid regions to challenge the current dominant discourse of water scarcity issues (Tarhule, 2005; Tschakert et al., 2010; Epule et al., 2017).

2. Methods

This study analyses the main issues of a socio-hydrological event faced within the capital of Sudan (Khartoum) in 2013 and 2014 based on a recent assessment of the risks and impacts and herein explored management challenges and potential adaptive measures to flash flooding events affecting the city. The analysis was founded on expert views and opinions collected through qualitative research methods, including participant observation, expert interviews and focus groups. It was important to speak to a range of different professional actors, including those from governmental bodies, research institutions, academia, international agencies, non-governmental organizations (NGOs) and independent national experts, in order to gain a well-rounded, holistic perspective on the subject. Schelfaut et al. (2011) consider increasing the participation of all stakeholders and bottom-up involvement as important factors in increasing the ownership of solutions and resilience to flood risk. Research involving stakeholder interviews was undertaken by McEwen and Jones (2012) to explore the build-up of sustainable local knowledge into community flood resilience planning after flood events in UK. In the present study, targeted flood management actors and the corresponding category of qualitative research methods conducted for them are listed in Table 1. The targeting of experts should theoretically mean that the data collected are of higher quality as the interviewee will be more informed and interested in the subject matter (Dorussen et al., 2005).

2.1. Participant observation

Participant observation involves the researcher not only observing, but also participating to some extent in the activities in order to gain a better understanding of the phenomenon from the inside (Myres, 2009). Within this study, the technique of participant observation was used effectively with two different actors in two events. The first piece of participant observation took place in a public Eco-Sustainability Monthly Forum hosted by the United Nations Office for Project Services UNESCO Cousteau Eco-Technie Chair (UCEC) at the Future University, Sudan. Through participating in 'Forum No. 67: Weather Extreme Events in Sudan – Recent Khartoum Floods as an Example', valuable insight could be gained into the current debate over the risks, causes, impacts and management of flash flooding in Khartoum. The different concerns and opinions expressed from forum participants were recorded to be used later within the data analysis. Another use of participant observation was applied while partaking in a workshop on flood management organised by United Nations Office for Project Services (UNOPS) for the Khartoum State Ministry of Planning and Infrastructures (MoPI). The MoPI is tasked with the job of designing and constructing flood mitigation structures including protection dams, dykes, and collection drainage channels. Participating in this workshop provided the opportunity to document the key flood management challenges faced by MoPI as well as the potential adaptive measures