



Going beyond generalisation: perspective on the persistence of urban floods in Dar es Salaam

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Abstract

The paper discusses the persistence of floods focusing attention on the city of Dar es Salaam (DSM), where over 10% of the Tanzanian population resides. Beyond the metaphor of exploding population growth, the city has witnessed recurring floods. Whilst studies abound on the vulnerability and socio-economic losses associated with flood hazards, limited studies exist about the persistence of flood hazards in DSM. This study attempts to analyse (i) the various factors that exacerbate flooding in Dar es Salaam; and (ii) the extent of interdependency and interconnection of the various factors. A thorough systematic desk review of the literature was conducted focusing on Dar es Salaam. The literature surveyed shows how colonial planning legacy has (in)directly shaped the geomorphology of DSM, and instigated the persistence of present-day floods. Specifically, rapid spatial urbanization in informality, weak capacity in spatial development control, limited coverage of drainage infrastructure, geomorphology, climate change and variability, and low coverage of solid waste collection were discovered as the major factors exacerbating floods in DSM. Besides the interdependency and interconnected nature of these factors, the review showed how the persistence of flood hazards in Dar es Salaam is influenced by the coexistence and synergistic forces of the aforementioned: rapid spatial urbanization with informality, weak capacity in spatial development control, limited coverage of drainage infrastructure, geomorphology, climate change and variability and low coverage of solid waste collection. The study recommends that urban planners pay attention to city-specific context and the interlinked nature of the factors exacerbating floods in tailoring interventions.

Keywords Urban flooding · System theory · Sub-Saharan Africa · Dar es Salaam · Global south

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1 Introduction

This paper, through a systematic review of literature, demonstrates the factors that exacerbate floods in Dar es Salaam (DSM). Drawing perspective from the system theory (von Bertalanffy, 1969), we conclude by providing place-specific policy planning implications for urban flood hazards in cities of the global South.

In this study, we used the term “urban flood” to refer to the overflow of water in urban areas that are not usually submerged by water or streams (Herold and Johns, 2007; Brown and Murray, 2013; Ardaya et al. 2017; Chan 2015). Globally, flooding is one of the most common urban development challenges, shaped broadly by natural and human factors (Brown and Murray 2013; Douglas 2017; Mu et al. 2021; Ntajal et al. 2017; Salazar et al. 2019; Zehra et al. 2019; Twum and Abubakari 2019). The world witnessed flood-related disasters that affected about 4 billion people and resulted in the death of about 1.2 million people between 2000 and 2019 (Jha et al. 2011; CRED and UNDRR 2020). Scholarly analysis of these statistics shows how the flood has had a greater effect on humanity compared with other hazards (Mandira 2008; CRED and UNDRR 2020). The International Federation of Red Crescent Societies demonstrated the persistence of floods by highlighting how they affect millions of people each year, especially between 1993 and 2002 (Lane et al. 2013). Beyond the global manifestation, floods have become more or less endemic in cities of the global South (Shrestha 2008; Fraser et al. 2017; Tasantab 2019). Over the years, urban floods-related studies in the global South have highlighted the severity and frequency of flood hazards, and how they affect urban residents (Mu et al. 2021). Some scholars have highlighted how the persistence of floods has the possibility of (re)shaping the destinies of cities (Jha et al. 2011; Brown and Murray 2013). In Mumbai, India, Lakshmi et al. (2019) and Gupta (2007) report how residents have routinely been affected by floods, especially during the monsoon. During this period, floods are either occasioned by high-intensity of rainfall, or by high tide. These tend to overflow due to the low capacity of drainage networks. Findings of these studies suggest how the persistence of floods in Mumbai, India, has been shaped more or less by the poor design of irrigation schemes and congestion due to land scarcity (Jha et al. 2013; Zope et al. 2015 2016). In Africa, related studies have demonstrated how floods have had a devastating effect on the socio-economic well-being of residents in cities such as Maputo, Accra, Lagos, Bamako and Dar es Salaam. These studies highlight varied losses associated with the annual manifestations of flood events (Boadi and Kuitunen 2003; Mbura 2014; Erman et al. 2019; Tvedlen et al. 2018; Melkiory 2020; Echendu 2020). A report of the UN-Habitat (2012) justifies this claim by revealing that about 70% of the flood-related fatalities occur in metropolitan areas and cities, demonstrating the persistence of floods in cities across the globe.

Studies analysing the relationship between flood incidences and health in Sub-Saharan Africa have highlighted how floods tend to mediate the surge of infections such as cholera, scabies, taeniasis, Rhodesian sleeping sickness, malaria, alphaviruses and flaviviruses (Wanie and Ndi 2018; Suhr et al. 2020; Tasantab et al. 2020). These studies reveal how flood incidence has persistently exposed residents in sub-Saharan African cities to varied illnesses. Others have shown how water-borne, rodent-borne, and vector-borne diseases are highly associated with flooding, especially in cities (Brown and Murray 2013). In East Africa, Magadza (2000) and Erman et al. (2019) report how the 1998 ENSO floods contributed to human misery, deaths and catastrophic harm to infrastructure and crops in Kenya and Tanzania. Following hazards associated with losses of Tanzania between 1990 and 2014, Mbura (2014) shows how flood-related losses accounted for about 62% of damages

cost nationwide. Studies referring to the super storm, Sandy, in New York City in 2012 highlighted how flood incidence contributed to wreaking havoc in several towns, causing fatalities, injuries, and power blackouts; and resulted in huge private and public financial losses (Rosenzweig et al. 2009; Staff 2012). Observably, the findings of the aforementioned studies demonstrate the geographical variations and the socio-economic inequalities associated with floods, the differentiation in terms of impacts and losses, and how the varied adaptive capacities shaped variation in flood-associated losses.

Therefore, following the geographical variations and adaptive capacities to flood hazards and disasters (Grasham et al. 2019; Adnan et al. 2020) some urban scholars in the global South have begun advocating for a place-centred analysis and understanding of flood incidences (Jha et al. 2013). Related studies have shown how certain hazards and disasters have been more or less peculiar to some geography (Kareem et al. 2020). For instance, the World Bank report has shown how Southeast Asia cities such as Bangkok, Ho Chi Minh City and Jakarta are amongst the top ten cities that persistently experience floods due to their location in the flood-prone zone (World Bank, 2010; Adnan et al. 2020). Asia accounts for about 60% of the global economic damages arising from floods (Mandira 2008). These scholars reveal how human and natural phenomena, such as flooding, may be exacerbated or mediated by geographical or location-centred conditions, as well as differentiated shocks and vulnerabilities (Grasham et al. 2019). Additionally, further studies have shown how severe flash floods tend to manifest in some parts of the globe due to rainfall and rainstorm intensity (Jha et al. 2013). Flood hazards and disaster-related impacts are much felt in geographies with topography issues, and areas characterized by loss of vegetation or plant cover (Tasantab 2019; Mngumi 2021). Further studies have demonstrated geographical variation in terms of flood persistence by revealing how countries in Africa Asia and the Pacific (such as South Africa, Mali, India, Indonesia, Bangladesh, Vietnam, Thailand and Pakistan) tend to witness more frequent and severe flood hazards (Mandira 2008; Jha et al. 2013; Twum and Abubakari 2019). They also show the diversities in terms of flood-associated losses by revealing that cities in the global North tend to experience greater loss of lives in the event of floods, whilst that of the global South experience greater losses in terms of properties (Jha et al. 2013). In effect, they suggest the need to move beyond the generalization of the manifestation of hazards and disasters towards a more place-specific understanding of hazards and disasters. Already some urban scholars have argued for a geographical specific analysis of urban phenomenon (Robinson 2006; Tasantab et al. 2020). Correspondingly, system theorists draw our attention to the interconnected nature of phenomenon (von Bertalanffy, 1969) especially urban challenges. Yet, limited studies exist offering place/geographical specific factors that exacerbate floods and the extent of interdependency and interconnection. In this study, we argue that although urban floods constitute a global phenomenon, place/city-specific conditions matter in our understanding of the persistence of floods, especially in cities of the global South that are more or less characterized by socio-economic and spatial inequalities (Mbura 2014). In Dar es Salaam, flood is the most common urban hazard that has received considerable scholarly attention over the years (Kebede and Nicholls 2012; Kwayu et al. 2019; Anande et al. 2019; Smiley 2020). Moreover related studies on urban flood in Dar es Salaam have focused on how it impacts social service and infrastructure such as water and electricity (Smiley 2019), and the vulnerability and socio-economic impacts of flood hazards on residents (Mutanga and Mwiruki 2013; Hambati 2019). As a result, limited studies have shed light on the factors shaping the persistence of flood hazards in Dar es Salaam and the extent of interdependency and interconnections of the underlying factors. Therefore, through a systematic review of floods-related literature about Dar es Salaam,

and a perspective from system theory (von Bertalanffy 1969), this study attempts to provide a nuanced understanding of (i) the factors that exacerbate flooding in Dar es Salaam; (ii) the extent to which they are interdependent and interconnected; and (iii) conclude with the policy planning implications towards flood hazards in global South cities. The paper is organized as follows: Sect. 2 presents a review of flood occurrences and the associated factors in the global South cities; Sect. 3 presents the methods, and how literature was selected; Sect. 4 presents results about the factors associated with the persistence of floods in Dar es Salaam; and Sect. 5 presents the conclusion and policy planning implications for flood hazards in cities of the global South.

2 Understanding the persistence of floods in cities of the global South

Over decades, studies have flourished on urban flood, its dominance and frequency in cities of the global South. These studies demonstrate the seasonality, regularities and how the overflow of rivers mediates flood hazards, especially during intense rainfall or groundwater flooding, coastal storms and coastal erosion and subsidence (Jha et al. 2011; Dodman Kibona and Kiluma 2011; Smiley and Hambati 2019; Echendu 2020). In 2007, major floods occurred in Accra, Ghana, attributed to clogged drains exacerbated by inefficient waste management (Boadi and Kuitunen 2003). Likewise, research conducted by Adelekan (2011) in Lagos, Nigeria, shows how flooding was a major challenge to people living in informal settlements along the coast. Setchell (2008) observes how the 1999 flooding in Bamako (Mali's capital) culminated in deaths and damage attributed to inefficient waste disposal. In Managua, the population increase resulted to shortage of public infrastructure and ineffective urban government, leading to increasing littering of waste (Habitat 2010; Lamond et al. 2012). Cities such as Rio de Janeiro in Brazil, Pakistan, South Africa, and Sri Lanka have witnessed manifolds of floods over the years (Jha et al. 2013). In these cities, the persistence of flood was attributed to inadequate waste disposal and clogged drains. Other scholars argue about how rapid urbanization tends to influence hydrology, and how drainage-related challenges mediate floods in highly populated urban areas (Ali et al. 2011; Dewan and Yamaguchi 2009). Concerning Mumbai, India, Zope et al. (2016) show how land use intensity is closely linked to an increase in run-off speed and exposure to flood hazards in urban areas. Given the increasing frequency of urban flooding and other hazards, some studies have demonstrated the agency to formulate and implement resilience policy, flood risk management strategies towards withstanding the persistence of disasters and hazards, especially urban floods (Ranganathan 2015; Frick-Trzebitzky et al. 2017; Laeni, van den Brink, and Arts, 2019; Adnan et al. 2020; Tasantab et al. 2020). Others have demonstrated how cultural beliefs influence placed-specific vulnerability to floods and the impact on infrastructure, such as energy/electricity, communication lines, and road networks, by showing how they contribute to the dysfunction of the flow of these services (Ahadzie and Proverbs 2010; Smiley and Hambati 2019; Dodman et al. 2011; Kwayu 2019; Tasantab et al. 2020; Kayaga et al. 2021; Edward 2022). Related studies have recounted experiences of flood-related displacement; the socio-economic losses; humans, materials/property, and health associated with floods incidences in global South cities (Shrestha 2008; Jha et al. 2011; Mallett and Etzel 2018; Tasantab et al. 2020; Echendu 2020). Others provide a differentiated analysis revealing how the urban poor are often the most affected by the persistence of flood hazards (Echendu 2022; Kayaga et al. 2021). More recently, studies have shown how colonial planning ideologies shape cities' morphology, placing them in a

more vulnerable position to flood hazards. Edward reveals how colonial masters turned a blind eye to drainage infrastructure in colonial Dar es Salaam, a condition that still exists in the present-day (Edward 2022). However, there are only a few studies (see Amoako and Boamah 2015; Echendu 2020) detailing the factors that exacerbate floods at the city scale, and the extent to which they are interconnected and interdependent. Therefore, this paper contributes to evolving debates by drawing a review of literature in Dar es Salaam to offer a nuanced understanding of place-specific factors/conditions that exacerbate floods and the extent of interdependency and interconnectedness of such factors.

Studies have revealed varied factors that tend to exacerbate hazards and disasters in the global South cities, which include poor physical planning, rapid population growth, unplanned or uncontrolled urbanization/poor physical planning, informal housing/slum development, waste management challenges, and climate change-related factors such as rainfall intensity (Amoako and Boamah 2015; Antronico and Marincioni, 2018; Tvedten and Candiracci 2018; Dos Santos Peumi and Soura 2019; Twum and Abubakari 2019; Echendu 2020; Kayaga et al. 2021). In Nigeria, Echendu reveals how weak implementation of planning legislation and corrupt practices challenge the efforts of local government authorities in regulating expansion (Echendu 2020). Ranganathan (2015) argues that in Bangalore (India) storm water aggravates floods due to poor drainage collection capacity. Tasantab (2019) shows how institutional inefficiencies associated with land use planning processes, such as delays in the approval of housing permits together with inadequate monitoring and inspections of spatial development within urban spaces, contribute to the development of informal settlements in Ghanaian cities. Further studies reveal that the weak capacity to enforce building regulations contributes to the development of houses in flood-prone areas, waterways, and swamps areas that sometimes act as catalysts of flood hazards, via blockages of waterways (Antronico and Marincioni 2018). Related studies show how rapid urbanization contributes to urban flooding by revealing how haphazardly developed urban areas instigate environmental degradation (Jha et al. 2011; Amoako and Boamah 2015; Tasantab 2019). In the case of Southeast Asia, studies have shown that climate change, physical infrastructure, and rapid urbanization are key drivers of flood hazards (Jha et al. 2011; Laeni et al. 2019; Adnan et al. 2020). These studies have shown how low water collection and holding capacities of dikes, sluices, water pumps and drainage tunnels contribute to the overflow of water across urban settings. Besides the aforementioned factors, high-density urban development and increasing land use conversion, especially from agriculture to residential areas, tend to increase run-off due to limited absorption capacity/infiltration of excess water, especially in impermeable concrete floors areas (Shrestha 2008; Amoako and Boamah 2015; Adnan et al. 2020). However, in some instances, new infrastructure development projects aimed at safeguarding perennial floodings and/or facilitating mobility tend to exacerbate flood hazards (Kwayu 2019). Large-scale new transportation infrastructure projects tend to contribute to the development of elevated structures that tends to obstruct natural water runways and paths (ibid).

Studies on climate change and variability reveal how sea level, prolonged/rainfall intensity, increasing overflows of rivers and snowmelt, and geographical location tend to exacerbate floods (Amoako and Boamah, 2015; Antronico and Marincioni 2018; Adnan et al. 2020; Echendu 2022). With reference to natural features and geographic specific context, Kareem et al. (2020) observe that cities located around rivers, and creeks tend to experience more flood hazards than others. Through the experiences of Mumbai, they reveal how the city has historically experienced diverse reams of floods occasioned by the overflow of the river water. Others have attributed the persistence of floods to environmental degradation, land subsidence, and poor drainage infrastructures that characterize many cities of

the global South. They noted how clogged drains and settlements in low-lying flood-prone areas with defunct infrastructures tend to contribute to perennial floods (Antronico and Marincioni 2018 Adnan et al. 2020). In Accra (Ghana), Amoako and Boamah (2015) show how flood hazards were influenced by poor physical planning, including poor drainage network, poor management (especially indiscriminate disposal of waste in surface water sources) and informal urbanization. Wanie and Ndi reveal that the limited capacity of local planning authorities, especially in fragile ecological settings, resulted in the persistence of flood hazards. They show how ongoing drainage infrastructure occasionally acts as a catalyst for flood hazards due to several delays in the construction processes (Wanie and Ndi 2018). Others have shown that constructed drainage systems/infrastructure are either narrowed or shallow to enable adequate collection of run-off or storm water (Antronico and Marincioni 2018). Similarly Amoako and Boamah (2015) and Tasantab et al. (2020) contributed to the geographical situated nature of flood hazards by revealing how heavy rainfall, spillage of dams and overflow of lagoons exacerbate floods in nearby communities, and how residents are often disproportionately affected by flood hazards due to varied locational situations.

3 Methods

The study was underpinned by the conduct of a systematic review of existing literature on about flood hazards in Dar es Salaam between 2000 and 2022. This period was chosen because although the city witnessed several floods in the past decades, flood hazards became more dominant in Dar es Salaam in the 2000s (Anande and Luhunga 2019) when the city's population grew more rapidly (Erman et al. 2019). The articles were sourced from google scholar and sorted based between the year 2000 and 2022. An interrelated set of search terms and concepts about urban flood hazards in Dar es Salaam were used. Specifically, the key search words used included “floods”, “flood hazards”, “urban floods”, “persistence of floods”, “causes of flood”, “influencers of floods”, “factors associated with flooding”, “Floods and Dar es Salaam” and “flooding in Dar es Salaam”. In the first step, the search using the aforementioned keywords, 542 articles were generated focusing broadly on floods in Dar es Salaam. In the second step, the main or broader research question of the study was used for the search. Questions such as “What are the major factors exacerbating floods in Dar es Salaam?” or “what are the causes of the persistence of flood hazards in Dar es Salaam?” These questions were aimed at gaining a wider coverage of articles published about floods in Dar es Salaam that were not captured by the keywords used. The additional search resulted in the discovery of 82 related articles, bringing the total to 622 articles, all written in the English language. In the third step, the scanning technique was used to gain a preliminary overview of the “topics” and “abstracts” of the articles before the download. Through the preliminary scanning, 589 articles were excluded. They were either focused on “vulnerability of residents to floods”, “coping and adaptation strategies of residents to floods”, “Factors influencing residential development in flood-prone areas”, “socio-economic losses during floods”, “Climate-induced displacement in flood-prone areas”, and “community resilience to floods”, amongst others. Overall, 33 articles were found relevant to the focus of this study; factors shaping the persistence of floods in Dar es Salaam. These were evaluated in varied ways. Firstly, they were uploaded in Mendeley, a referencing and citation software for step-by-step evaluation. The content of each of the articles was evaluated, analysed and summarized based on their relevance to

the persistence of floods in Dar es Salaam. The factors related to the persistence of floods in Dar es Salaam were collated from the selected articles, summarized and categorized into themes and substantiated by providing evidence for the selected articles.

4 Results and Discussion

4.1 Factors exacerbating the persistent floodings in Dar es Salaam

Dar es Salaam is one of the largest cities in Africa, with land area of about 1,800 square km. It is the major commercial and industrial city of Tanzania, and contributes significantly to the national economic growth. Similar to several cities in the global South, Dar es Salaam is rapidly urbanizing with a population growth rate of about 8%, influenced by migration from rural areas and other towns as well as the increasing birth rate (Mutanga and Mwiruki, 2013). Presently, Dar es Salaam is home to Africa's fastest expanding metropolitan areas (Lugakingira et al. 2020; Mbura 2014). Erman et al. (2019) report that as of 2012 the population of Dar es Salaam has been growing at the rate of 6.5% per year and had reached 4.4 million. This growth rate is comparatively six times that of Mwanza, which is the next largest city in Tanzania (Erman et al. 2019). Dar es Salaam is projected to become a megacity with more than 10 million population before 2030 (Toesland 2019). The city is governed by five municipal councils, Temeke, Ilala, Kinondoni, Ubungo and Kigamboni. Residents in all municipal councils in Dar es Salaam are exposed to flood hazards and have, over the years, witnessed several flood events. Like in many cities of the global South, perennial flood events often result in loss of lives and properties (Kebede and Nicholls 2012). Through literature survey, areas such as *Msasani Bonde la Mpunga*, *Magomeni Mapipa*, *Jangwani Valley* adjacent *Muhimbili* and *Hannanasif*, amongst others, have habitually witnessed severe floods events over the years (Kebede and Nicholls, 2012; Mutanga and Mwiruku 2013; Kwayu 2019). The review of the literature shows that the persistence of flood hazards in Dar es Salaam is shaped by varied interrelated factors (See Fig. 1).

These include rapid spatial urbanization in informality, weak capacity in physical development control, geomorphological factors, climate change and variability, limited coverage of drainage infrastructure and low capacity in solid waste collection. The review also suggests that these factors are inseparable from the colonial planning legacy.

4.2 Rapid spatial urbanization in informality

Dar es Salaam is one of the fastest-growing cities in sub-Saharan Africa, characterized by a rising urban population shaped by the influx of migrants and a rising birth rate (Kebede and Nicholls, 2012). More recently, the city was host to about 7 million people. Whilst urbanization is a critical asset for maximizing economic growth, urbanization in the case of Dar es Salaam is manifesting more informally. About 70% of residents in Dar es Salaam live in informal settlements, where residential facilities are developed via self-help arrangements, and without adequate infrastructure and services (Dodman et al. 2011; Mutanga and Mwiruki 2013; Anande et al. 2019). Often, informal housing development manifests without the consent of the planning authorities. Lands are purchased individually or as a family, and houses built incrementally (Andreasen and Møller-Jensen 2016). See Fig. 2.

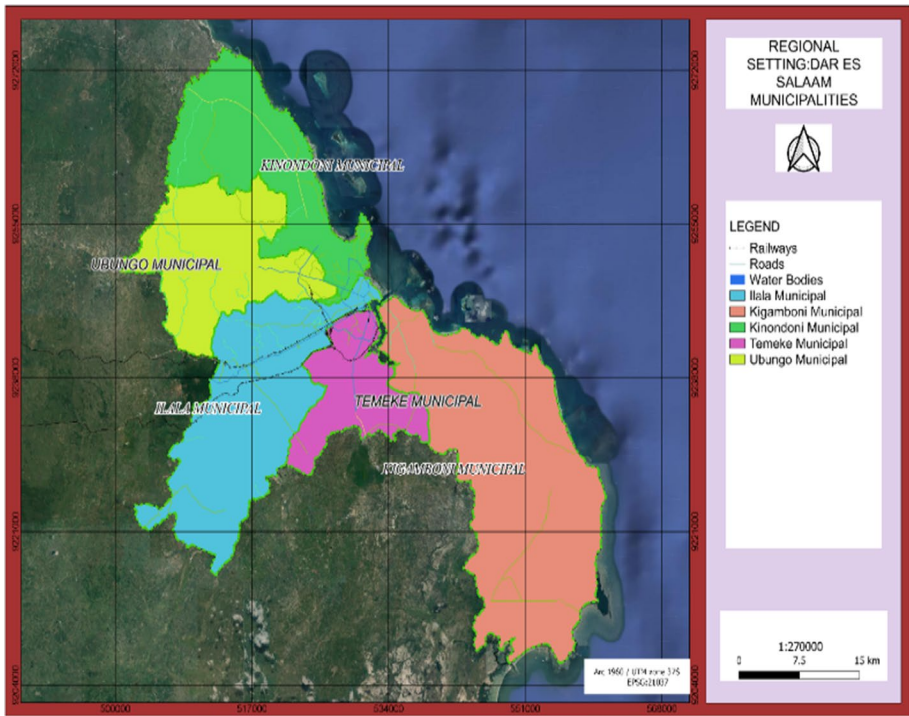


Fig. 1 Map of Dar es Salaam



Fig. 2 Informal settlements inundated by flood water

Although major parts of Dar es Salaam experience flood hazards, the review reveals that informal settlements such as *Msasani Bonde la Mpunga*, *Magomeni Mapipa*, *Jangwani* Valley adjacent *Muhimbili* and *Hannanasif* are the major flood hotspots. These settlements are located in low-lying areas, valleys or floodplain zones serving as a blockage to run-offs water, especially during intensive rainfall (Mutanga and Mwiruku 2013; Kwayu 2019; Anande et al. 2019). As expected, water tends to flow from highly elevated areas towards low-lying areas. Unfortunately, most unplanned settlements in the inner city are located in low-lying areas characterized by steep slopes, which are more prone to run-off (Kwayu et al. 2019). Increasing density in unplanned areas influence to the degradation of lands, especially green spaces that initially serve as breaks to run-off water (Kebede and Nicholls 2012). Although informal settlements are a peculiar phenomenon in most cities of the global South, informal development in Dar es Salaam is increasingly contributing to the loss of wetlands, rising salinization of groundwater and soil, as well as the depletion of mangrove forests in the coastal areas that initially served as natural breaks for run-off water (Dodman et al. 2011). Forest reserves are declining due to increasing logging of trees for firewood by residents, charcoal, and for building boats. Consequently, these factors aggravate run-off during intensive rainfall. The review reveals that mangrove forest areas that initially impeded run-off and storm water have become more vulnerable due to degradation caused by high-density informal settlement development (Kebede and Nicholls 2012; Kwayu et al. 2019).

4.3 Weak capacity in physical development control

Physical development control is a critical tool for facilitating and (re)shaping the morphology of cities, especially against flood hazards. Unfortunately, in Dar es Salaam, existing studies suggest that the ability of local authorities to regulate physical expansions and development remains problematic (Kebede and Nicholls 2012). The historical inclination of colonial spatial planning practices reveals that spatial expansion of Dar es Salaam has largely been uncoordinated, and less guided by workable engineering solutions in the (post)colonial era (Edwards 2022). Edward shows that the persistence of flood hazards in Dar es Salaam dates back to the 1890s, when colonial masters showed less desire and interests for physical planning and development control. He further reveals that colonial governments made little effort in the provision of drainage infrastructure provision in Dar es Salaam, even when the city's population was relatively small. Similarly Mburu (2014) adds that flood recurrences in Dar es Salaam have escalated through poor governance, and a lack of capacity amongst the personnel tasked with the responsibility to oversee flood hotspots. In post-colonial Dar es Salaam, local government authorities, especially the departments of physical planning in the various municipal councils, are the major institutions with the legal power to implement physical development control measures. They are tasked to monitor, regulate, restrict and act against residential and commercial development in unplanned areas, natural waterways and flood-prone areas. Unfortunately, the local government authorities have demonstrated low capacity to undertake mass physical development including the provision of drainage infrastructure and re-engineering of the city to redress the physical orientation of the city (Edwards, 2022). Municipal councils are less equipped technically and financially to implement development control measures such as clearing unauthorized housing structures in valleys and waterways to increase the water holding capacities of valleys in seasons of intensive rainfall (Mutanga and Mwiruki 2013). The weak financial and technical capacities of the physical planning departments have

occasioned the proliferation of informal settlements across the city (Mutanga and Mwiruki 2013). Although the departments still hold the power to demolish housing structures in waterways, there is no apparent effort at present to do so. Even international funding programmes aimed at augmenting the capacities of local government authorities have proved futile. For instance, in the 1960s, Slum Clearance Programme (SCP) was introduced with funding support from the World Bank to ensure spatial order in areas prone to floods as well as the upgrading of existing informal settlements to minimize flood hazards, including the provision of waterways (Mutanga and Mwiruki 2013). Unfortunately, the slum clearance – squatter area upgrading programme was abandoned by the Municipal councils after the exit of the World Bank for reasons of financial incapacity (ibid). Since then, efforts by municipal councils towards curtailing unauthorized physical development have been reactive and very feeble (see Fig. 3).

In rare cases, Municipal councils embark on the demolition of unauthorized housing structures in waterways during socio-economic losses, especially during the 2011 flood hazards. This effort was marked by a temporary approach such as the provision of temporary structures/dwelling areas for the residents who had been displaced by flood (Anande and Luhunga 2019). Despite the associated losses, the physical development planning units sometimes propose the development of temporary housing structures in unplanned areas, without improving or providing drainage infrastructure. For example, the study finds that residential blocks were constructed in Msasani Bonde la Mpunga, an informal settlement located in a natural waterway, to house some residents displaced by the 2011 flood hazards, without the provision of any drainage infrastructure. Alem and Namangaya (2021), reveal



Fig. 3 Settlements located in low-lying areas inundated with flood water

how the ambitious 20,000 plots project commenced in Mbweni in 2008 with the aim of controlling the development of flood-prone informal settlements in turn serve as spaces of floods. They noted that the settlement gets flooded and become inaccessible for several months during the rainy season (March–June). This suggests that post-colonial practices are not exempted from present-day flooding, as they either turn a blind eye to the hazardous physical developments of the city (Edward, 2022) or lack the technical capacity to control physical development in waterways and floodplains to curtail flood hazards. In effect, spatial planning decisions are more or less connected to the persistence of floods in present-day Dar es Salaam. For example, Jangwani flooding severely impacts Morogoro arterial road making it impassable when water crosses the valley running westward from the city centre. Public officials later cleared the Jangwani slum in a bid to reduce flooding. However, the very same officials who cleared the slum because it impeded streams and the Msimbazi River's flow permitted the development of concrete structures and steel that further contributed to the reduction of depth of the valley. As a result, annual flooding has persisted in the valley bringing havoc to the surrounding areas. Notably, floods have not been able to wash away the bus depot, which caused a massive loss of equipment, including buses and spares (Mwananchi Newspaper 2021).

4.4 Geomorphology, climate change and variability

The review furthermore suggests that a city's form, climate change and variability influence the persistence of flood hazards. Although climate change and variability are global challenges (Amoako and Boamah 2015), the geomorphology of Dar es Salaam makes it more or less vulnerable to short-term rainfall. German and British colonial planning practices in 1892/93 contributed to shaping the morphology of Dar es Salaam, especially the planning of streets in low-lying plains that serve as water collection ways in present-day Dar es Salaam. The review suggests that about 8% of the residents in the city dwell in the low elevation zone below the 10-m contour line (Kebede and Nicholls 2012; Mutanga and Mwiruki, 2013; Anande et al. 2019). The gently rising nature of the streets quicken the collection of run-off water, but at the same time serve as blockage points where waste materials are accumulated in gutters and waterways. Topographical analysis suggests that floodplains in Dar es Salaam are not sinking nor bowl in shape but flat in form. This kind of topography is observed to accelerate the speed of storm water due to the relatively low capacity of the drainage systems (Kikwasi and Mbuya 2019). Consequently, increasing the volume of water in rivers often results in the backward flow of water into further low-lying areas due to the low capacity of rivers and valleys to contain the run-off (Kwayu et al. 2019). Edward (2022) reveals that even in the colonial era, short periods of light rainfall were enough to translate into floods in Dar es Salaam. This suggests that colonial city formation efforts have had a detrimental effect on present-day flooding in Dar es Salaam. Silt and sand eroded by running water have been the major obstacles to adequate drainage in streets. Torrential rains contribute to the disruption of roads and drains (Edward 2022). Presently, spatial development, such as housing and transport infrastructure, has significantly shaped Dar es Salaam geomorphology. Kwayu et al. (2019) reveals how the development of buildings and the Dar es Salaam transport infrastructure in floodplain areas has aggravated perennial flooding over the years. They show that the Bus Rapid Transit (BRT) infrastructure facilities, such as embankments, impede the flow of water by collecting run-off in its surrounding

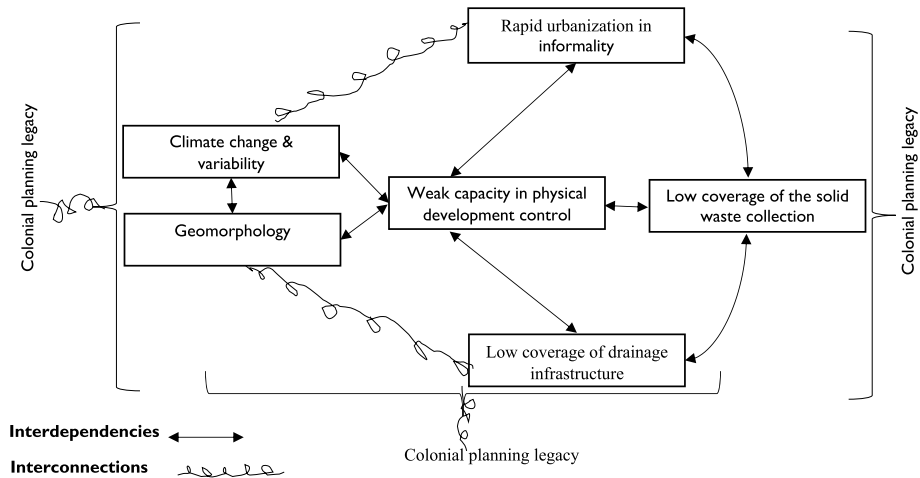


Fig. 4 Interdependency and interconnections of the factors exacerbating floods in Dar es Salaam

areas during rain (Kwayu et al. 2019). These demonstrate how poor engineering solutions in turn make cities more vulnerable to flood hazards (Edward 2022). See Fig. 4.

Beyond these, Dar es Salaam is a coastal and tropical city, located approximately 7 degrees South of the equator. Rainfall ranges from about 66 mm to 116 mm in a lower range to as much as 136 mm to 1146.8 mm (Anande et al. 2019). Dar es Salaam is also characterized by diverse natural water sources such as beaches, mangroves, corals, coastal wetlands and estuaries (Kebede and Nicholls 2012). Although the city witnessed a short seasonal rainfall pattern usually between October and December, and a longer duration between March and May every year in the past, external factors such as climate variability have (re)shaped the rainfall pattern as well as the flooding seasons known by residents. Heavy precipitation tends to manifest and intensify in periods known for light rains (Kebede and Nicholls 2012). Intensive/heavy rainfall is not in itself a facilitator of flood hazards in Dar es Salaam, but the geomorphological features of the city such as sand, waste, topography, rivers and valleys and slit act as catalysts for the persistence of flood hazards. Others include the degradation of coastal areas and salt-water intrusion (Anande et al. 2019). Sand, slit and waste collected by run-off water are accumulated in the few drainage systems causing their blockage. The situation gets compounded by the increasing variability of rainfall patterns in recent times, which frequently contributes to a rise in sea level and coastal erosion (Dodman et al. 2011; Kwayu et al. 2019; Kabanda 2020). Rainfall intensity has exponentially risen in the past 15 years, associated with flood hazards (Mutanga and Mwiruki 2013). In the event of rainfall, the water level tends to increase in volume due to the limited water holding capacities of valleys and rivers such as *Msimbazi*, *Ng'ombe*, *River China*, and *Kibangu*. The overflow of rivers and shallow valleys in Dar es Salaam contributes to the inundation of low-lying areas (Dodman et al. 2011; Kwayu 2019; Anande et al. 2019). The review also reveals how floodplain slopes tend to impede the discharge of run-off water into the Indian Ocean, but instead serves as a barrier redirecting water towards the low-lying areas (Kwayu 2019). Others have shown that topography, infrastructure and low altitude of major dwelling areas in Dar es Salaam makes the incidence of floods more persistent (Anande et al. 2019).

4.5 Limited coverage of drainage infrastructure

Drainage systems are critical infrastructures not only for cities' health but also for facilitating storm water collection and limiting incidences of floods (Sakijege 2013; Edward 2022). Unfortunately, in Dar es Salaam, drainage infrastructures are limited in the inner city, and non-existence especially to in the outer and peripheral zone of the city. Most streets lack drainage and sewerage systems (Anande et al. 2019). Consequently, some scholars conclude that the Dar es Salaam drainage infrastructure is "incomplete". The "incomplete" nature of the drainage infrastructure contributes to the overflow of water during light rainfall. Most urban roads in Dar es Salaam have been built to facilitate the movement of goods, services and people devoid of drainage infrastructure consideration (Edward 2022). The review further suggests that the colonial planning legacy that persists in present-day Dar es Salaam is heightening flood hazards (Edwards 2022). Edward reveals that colonial masters, particularly the Germans, did not consider drainage as a critical infrastructure in their planning until the nineteenth century. Roads were constructed without surface drainage infrastructure to facilitate adequate water holding and collections against flooding of neighbourhoods (Edward 2022). Even where drainage infrastructures were constructed, they were highly segregated, favouring the German neighbourhoods to the neglect of the African and Asian neighbourhoods. Although the segregation in the provision of drainage infrastructure did not directly facilitate flood prevalence, the delay in terms of the provision of drainage systems led to population out-pass and congestion that hinders the construction of drainage infrastructure in present-day Dar es Salaam. Whilst drainage infrastructure construction has been ongoing in many parts of the inner and outer zone of the city as future stop-gaps, they are more or less aggravating floods. Sand from ongoing drainage infrastructure projects is increasingly being collected by storm water into gutters, and obstructing the flow of run-off as rainfall intensifies. Correspondingly, the 2011 flood was caused by the blockage of drainage, sewage systems and an ocean surge (Anande and Luhunga 2019). In addition, the lack of an organized storm water management scheme, insufficient housing facilities, and blockage of water streams due to irresponsible waste disposal drainage infrastructure factors exacerbate flood in Dar es Salaam (Sakijege et al. 2012).

4.6 Low coverage of solid waste collection

Solid waste such as plastics, metals, bottles, garden waste, food waste, grass and wood are major drivers of floods in Dar es Salaam (Kebede and Nicholls 2012). Despite the population of about 7 million, solid waste collection and disposal has been an individual household affair. Private truck operators act as agents that mobilize solid waste from households for onward transportation and disposal at Pugu Kinyamwezi, the only landfill/dump site located 30 kms from the centre of the city. (Kihila 2021). Trucks collect solid waste generated from industrial sites, commercial areas, and residential as well as institutions (Kirama and Mayo, 2015). Households bear the cost of paying private truck operators for routine waste collection (ibid). Considering that about 70% of the city's population dwells in informal settlements, solid waste collection by private truck operators has been limited to planned urban areas due to the inability of trucks to navigate very dense informal settlements (Kihila 2021). Only households that can afford the monthly payments for refuse collection fees contract the services of the private truck's operators for solid waste collection (Kazuva and Zhang 2019). This has contributed to the increasing littering of solid

waste in the city. The review reveals that only 37% of waste generated in Dar es Salaam is collected and disposed of in the dump site, with about 63% of the solid waste remaining scattered and uncollected (Kassim and Kayaga 2019). Solid waste does not manifest into floods; however, scattered or uncollected solid waste in Dar es Salaam aggravates floods in two major ways: firstly, often through blockages of drainage/open gutters and waterways, and secondly, the filling of rivers and valleys by accumulated solid waste (Sakijege et al. 2012). In both cases, dispersed/scattered waste is collected and accumulated by storm water as rainfall intensifies, often into floodplains, rivers, valleys, and oceans that reduce the volume of run-off water collection. Solid waste carried and accumulated in valleys and rivers tends to contribute to the reduction of the water collection volume of rivers and valleys, resulting in the overflow of water. Kwayu et al. reveal how the increasing collection of solid wastes into the river Msimbasi has led to backward flow/overflow of water to residential areas of the city due to the reduction in the volume of water collection (Kwayu et al. 2019). The review moreover finds that the collection of varied waste substances into rivers and valleys contributes to the growth of mangroves, trees, and grass in rivers and valleys has reduced their depths and water holding capacity contributing to the overflow of water during intense rainfall. Even when efforts are made towards deepening rivers and valleys to increase water collection and holding volume, solid waste substances removed are often left at the embarkment of the floodplains and later carried into rivers during rainfall (Kwayu et al. 2019); and sluggish materials in valleys and floodplain areas often act as barriers to the discharge of water into the ocean. Unfortunately, as the city's population continues to grow solid waste is increasingly generated.

4.7 Interdependency and interconnection of the factors exacerbating flooding in Dar es Salaam

As indicated above, rapid spatial urbanization in informality, weak capacity in physical development control, geomorphology, climate change and variability, low coverage of solid waste collection, and limited to non-existence of drainage infrastructure are key factors exacerbating floodings in Dar es Salaam (see Kebede and Nicholls 2012; Mutanga and Mwiruki 2013; Anande et al. 2019; Edwards 2022). In effect, these factors are largely interdependent, interconnected, and shaped by colonial planning legacy. The review shows that rapid spatial urbanization, low coverage of capacity city authority in solid waste collection and management and limited coverage of drainage infrastructure are interrelated. This interconnectedness serves as a collective strength through which flood hazards are produced, especially in event of rainfall intensity. (Edward 2022). Mtwangi-Limbumba et al. (2019) suggest that although flood recurrences are connected to climate variability, it is more likely instigated by the weak capacity of spatial development control. Others have shown that informal housing development, especially in the informal settlements, is interconnected with climate change, as climate-induced rainfall intensity tends to instigate floods in the settlements due to high density and the haphazardly developed housing structures (Kikwasi and Mbuya 2019; Pasquini et al. 2020). See Fig. 4

Others disclose the interconnection between flood recurrence, urban planning practices and population by highlighting how the rising population contributes to the increasing littering of solid waste in cities with limited capacity and coverage of solid waste collection facilities (Mtwangi-Limbumba et al. 2019). Furthermore, rapid urbanization and rainfall intensity within limited drainage infrastructure are mutually interdependent factors that tend to facilitate flood hazards (Smiley and Hambati 2020). As such, recurrent floods are

not aggravated by a single factor but by the collective and synergetic effects of the aforementioned challenges.

5 Conclusion

5.1 Implications for urban planning

The paper attempted to analyse the various factors that exacerbate flooding in Dar es Salaam; and the extent of interdependency and interconnection of the various factors. This was shaped by the limited studies that theorize the underlying factors exacerbating floods, especially in Dar es Salaam. Through a systematic review of 33 articles selected and evaluated about floods in Dar es Salaam, the study finds how colonial planning legacy has (in)directly shaped the geomorphology of DSM, and instigated the persistence of presence floods. Specifically, rapid spatial urbanization in informality, weak capacity in spatial development control, limited to non-existence of drainage infrastructure, geomorphology, climate change and variability, and low coverage of solid waste collection were discovered as the major underlying factors exacerbating floods in present-day DSM. Besides the interdependency and interconnection of these factors, the review suggests that the coexistence and synergetic roles of these challenges mediate the persistence of flood in Dar es Salaam. Given this, we argue that the system approach to problem solving is imperative for furthering understanding of the impacts of the varied and interconnected factors exacerbating floods in Dar es Salaam. The study conclude that urban planners and city authorities pay attention to the interdepending relationships and the interconnected nature of the factors exacerbating flood hazards in place-specific contexts beyond generalization. However, we suggest future research pay attention to the extent of influence of each of the aforementioned factors on floods persistence in cities of the global South.

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Declarations

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Ethical approval This article is based on analyses of secondary data and does not contain any experiments conducted on human participants or animals.

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