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Urban Flooding in Kisangani, Democratic Republic of Congo: Current Knowledge and Gaps

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***Abstract*: Urban flooding has become an increasingly recurrent and disruptive phenomenon in Kisangani, Democratic Republic of Congo (DRC), driven by a combination of climatic variability, rapid and unregulated urbanization, and inadequate drainage infrastructure. This narrative mini review synthesizes the current state of knowledge on the causes, impacts, and management strategies of floods in Kisangani. It highlights the predominance of rainfall intensity, land cover change, and poor urban planning as key drivers of flood risk. The review also examines the socioeconomic and health impacts on vulnerable populations, as well as the limited and often reactive institutional responses. Importantly, it identifies several methodological approaches—such as remote sensing-based flood mapping and integrated urban planning models—widely applied in similar African contexts but not yet adopted in Kisangani. The study concludes by emphasizing the need for context-specific, anticipatory flood management strategies supported by modern geospatial and participatory tools.**

***Keywords*: Flood risk management, Kisangani, urban flooding.**

1. Introduction

A. Context and Recurrence of Flooding in Kisangani

Kisangani, the capital of Tshopo Province in the Democratic Republic of Congo (DRC), is frequently exposed to flood hazards due to a combination of natural and anthropogenic factors. Geographically located along the Congo River and its tributaries, the city is characterized by a humid equatorial climate with high annual precipitation exceeding 1,700 mm, peaking during the two rainy seasons (March–May and September–November) [1]. The low-lying topography, especially in densely populated informal settlements near riverbanks, increases the city's vulnerability to riverine and pluvial flooding [2].

The recurrence of flooding in Kisangani has intensified in recent decades, partly due to land use change, deforestation in upstream catchments, and poor drainage infrastructure. Inadequate urban planning, informal housing expansion, and the absence of effective storm water management have also aggravated runoff and surface water accumulation [3]. Observational records and reports from local authorities highlight that floods occur almost annually in certain districts such as Mangobo, Kabondo, and Tshopo, often resulting in property damage, population displacement, and disruption of essential services [4].

Despite the high frequency and socio-economic impacts of floods, Kisangani lacks a robust flood early warning system or risk zoning plans, making local communities highly exposed and poorly prepared. Moreover, climate change is expected to exacerbate flood risks by increasing the intensity and unpredictability of rainfall events in Central Africa [1]. These recurrent flood events in Kisangani necessitate urgent and integrated approaches to urban resilience, land use regulation, and infrastructure adaptation.

B. Objective of this Review

This review aims to provide a concise yet comprehensive synthesis of the current knowledge on flood hazards in Kisangani, with particular emphasis on the causes, impacts, and management approaches documented in existing literature. While several local studies have identified the frequency and drivers of flooding in the region [2], [3], there remains a lack of comparative analysis of the methods and frameworks used to address similar challenges in other flood-prone tropical cities.

The first objective is to consolidate findings from previous empirical studies and reports that have examined the hydro-climatic, geomorphological, and anthropogenic factors contributing to flood events in Kisangani. The second is to assess the socioeconomic and public health impacts of recurrent flooding, particularly in informal settlements where vulnerability is highest [4].

Thirdly, the review evaluates the existing flood management strategies adopted in Kisangani—whether governmental, community-based, or supported by NGOs—and identifies gaps or limitations in these approaches. Finally, the review seeks to highlight advanced or context-relevant methodologies that have been successfully applied in comparable urban flood settings elsewhere in Sub-Saharan Africa or Southeast Asia but have not yet been implemented in Kisangani.

By doing so, this review intends to inform future research directions and practical interventions aimed at enhancing urban flood resilience, risk reduction, and sustainable planning in Kisangani and similar secondary cities.

2. Methodology

This review adopts a narrative, non-systematic approach, with elements of a mini-review, to synthesize available literature on urban flooding in Kisangani. Rather than relying on a rigid protocol such as PRISMA or the use of systematic

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review software, the selection of sources was guided by thematic relevance, contextual significance, and geographic focus. The narrative nature of the review allows for the integration of diverse types of literature, including peer-reviewed journal articles, technical reports, and regional case studies from grey literature. This flexibility is particularly useful given the scarcity of highly formalized scientific studies on flooding in Kisangani.

The mini-review component focused on identifying methods used elsewhere in similar urban flood-prone contexts that have not yet been implemented in Kisangani, such as remote sensing for flood mapping, community-based early warning systems, and hydrological modeling tools. This dual-level approach—descriptive for Kisangani and comparative for external cases—enables both a contextual diagnosis and an exploration of transferable methodologies

The findings are structured into thematic sub-sections covering (i) the drivers of flooding in Kisangani, (ii) its impacts, (iii) current management responses, and (iv) approaches applied in similar contexts that may offer valuable insights for future research and practice in Kisangani.

A. Main Causes of Flooding in Kisangani

Flooding in Kisangani is a recurrent phenomenon driven by a combination of natural and anthropogenic factors that interact in a context of rapid urban growth and inadequate infrastructure. The city, located at the confluence of the Congo River and several tributaries, is naturally predisposed to fluvial and pluvial flooding, especially during the peak rainy seasons from March to May and from October to December [2].

One of the most frequently cited drivers is intense and prolonged rainfall, which often exceeds the infiltration and drainage capacity of the urban landscape. Rainfall events are increasingly irregular and extreme, in part due to climate variability linked to the El Niño–Southern Oscillation and regional deforestation [3]. However, natural precipitation alone does not fully explain the severity of flooding in Kisangani.

Uncontrolled urban expansion is a major aggravating factor. Large parts of the city have grown informally along floodplains, riverbanks, and wetland zones, with little regard for hydrological suitability. These settlements typically lack proper drainage infrastructure, increasing surface runoff and ponding [4]. Furthermore, deforestation and land degradation in peri-urban catchments, driven by charcoal production and small-scale agriculture, have reduced the soil's water retention capacity, accelerating runoff toward urban zones [5].

Another key contributor is the deficiency or dysfunction of drainage systems. Existing channels are often undersized, poorly maintained, or clogged by waste, which obstructs flow and causes water to back up into residential areas [6]. In many neighborhoods, especially in the communes of Makiso and Tshopo, there is a near-total absence of storm water management infrastructure, despite being among the most flood-prone zones.

Lastly, hydrographic complexity, including the presence of numerous low-lying areas and backwater effects from the Congo River and its tributaries, contributes to prolonged water stagnation and flash floods. These geographic features, combined with anthropogenic pressures, form a compound flooding regime that is not well documented or modeled at present.

In summary, the causes of flooding in Kisangani are deeply multi-dimensional, involving hydro meteorological, geomorphological, and human-induced factors. Addressing them requires a holistic understanding that integrates both climate and land-use dynamics.

B. Socioeconomic and Health Impacts of Flooding in Kisangani

Flooding in Kisangani has far-reaching consequences on both the socioeconomic stability and public health of affected communities. Recurrent flood events, often unanticipated and poorly managed, exacerbate poverty, increase disease burden, and undermine the resilience of urban households and institutions.

On the socioeconomic front, floods regularly damage or destroy informal housing, particularly in low-income neighborhoods situated in flood-prone zones such as Kabondo and Makiso. Because many of these dwellings are constructed with non-durable materials like mud bricks and wood, they are especially vulnerable to structural collapse during periods of inundation [4]. Rebuilding costs can absorb a large share of household income, leading to a vicious cycle of vulnerability. Additionally, floods disrupt livelihoods, particularly for those engaged in informal economic activities such as street vending and small-scale commerce [3]. Marketplaces and transport networks are often flooded, preventing economic transactions and impeding access to work.

Floodwaters also damage educational and healthcare infrastructure, forcing the closure of schools and health centers. In some areas, education is suspended for several weeks after major flood events due to unsafe access routes or damaged facilities [2]. Such disruptions have long-term impacts on human capital development, particularly among children from already disadvantaged backgrounds.

In terms of public health, flooding in Kisangani significantly increases the risk of waterborne and vector-borne diseases. Standing water becomes a breeding ground for mosquitoes, increasing the transmission of malaria, while contaminated water sources contribute to outbreaks of cholera, typhoid, and diarrheal diseases [5]. The lack of sanitation infrastructure in many flooded areas worsens exposure to pathogens. Notably, most informal settlements have no protected latrines or septic systems, allowing floodwaters to carry human waste into living areas [6].

Children, the elderly, and immunocompromised individuals are particularly at risk. In flood-prone communities, increased malnutrition is also observed due to food insecurity and disrupted access to markets [7]. These health impacts are compounded by the limited capacity of local health systems, which often lack the resources to respond to disaster-induced disease outbreaks.

In sum, the socioeconomic and health consequences of flooding in Kisangani are multi-layered and chronic, affecting

both immediate well-being and long-term development prospects. The cumulative nature of these impacts underscores the urgency of implementing risk reduction strategies that are not only infrastructural but also social and institutional.

C. Current Flood Management Approaches in Kisangani

Flood management in Kisangani remains largely reactive and fragmented, with limited integration of structural and non-structural measures. Municipal and provincial authorities have struggled to implement comprehensive risk reduction strategies due to institutional, technical, and financial constraints [2].

One of the main approaches has been manual and emergency-based drainage clearance, often carried out during or shortly after flood events. Local authorities and community members clean obstructed culverts, gutters, and open drains to restore water flow and reduce localized flooding [6]. However, these interventions are often short-lived and do not address the root causes of drainage failure, such as poor maintenance, informal construction, and lack of urban planning.

Some structural interventions have been implemented, including the rehabilitation of small-scale culverts and roadside drainage systems in central neighborhoods. Yet, most of these interventions lack hydrological design standards and are frequently overwhelmed by even moderate rainfall events [5]. Additionally, the city lacks retention basins, embankments, or flood diversion infrastructure, leaving low-lying settlements fully exposed.

On the institutional side, flood risk management suffers from poor coordination among key stakeholders. The Division Provinciale de l'Environnement, the Direction Générale des Voies de Desserte Agricole (DGVDA), and local communes all have overlapping but uncoordinated responsibilities [3]. No dedicated municipal disaster risk reduction unit exists, and urban development continues with minimal integration of flood risk zoning.

In terms of community-based efforts, informal coping mechanisms such as temporary relocation, sandbagging, and self-funded house elevation are common in high-risk areas like Kabondo and Lubunga [4]. However, these actions are typically not guided by technical knowledge and offer limited protection.

Furthermore, early warning systems are practically non-existent. There is no localized flood forecasting system in place, and rainfall monitoring infrastructure is outdated or non-functional in most areas [7]. As a result, residents are often caught unaware by rising water levels, especially those living near the Congo River and its tributaries.

In summary, current flood management in Kisangani is hampered by limited institutional capacity, lack of planning, absence of early warning systems, and inadequate infrastructure. Without a shift toward integrated, multi-hazard, and community-inclusive planning approaches, the city will remain vulnerable to increasingly frequent and severe flood events.

D. Methods Used Elsewhere Not Yet Applied in Kisangani

While Kisangani continues to rely on reactive and low-tech approaches to flood management, various innovative and integrated methods have been successfully implemented in other flood-prone urban contexts across sub-Saharan Africa and beyond. These methods, though suitable for adaptation in Kisangani, remain largely untested locally.

One promising approach is the integration of nature-based solutions (NBS) such as urban wetlands restoration, green belts, and permeable surfaces to increase infiltration and reduce runoff. Cities like Kampala, Uganda, have implemented wetland buffers and urban greening to mitigate urban flooding and enhance ecological resilience [8]. Kisangani, though surrounded by abundant wetland ecosystems, has seen rapid encroachment without policies for ecosystem-based flood control.

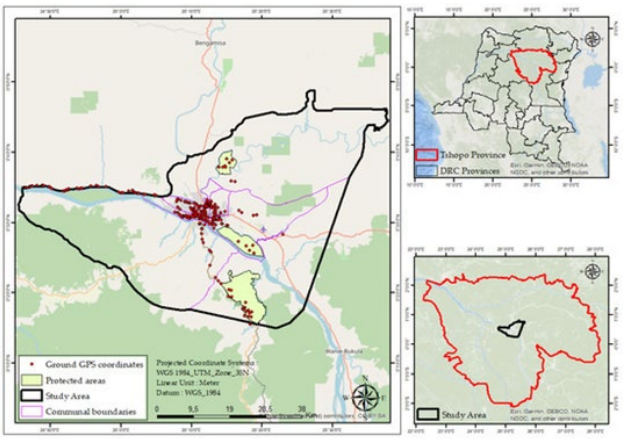

Fig. 1. Urban green infrastructure land-use map in Kisangani (1986–2021) [13]

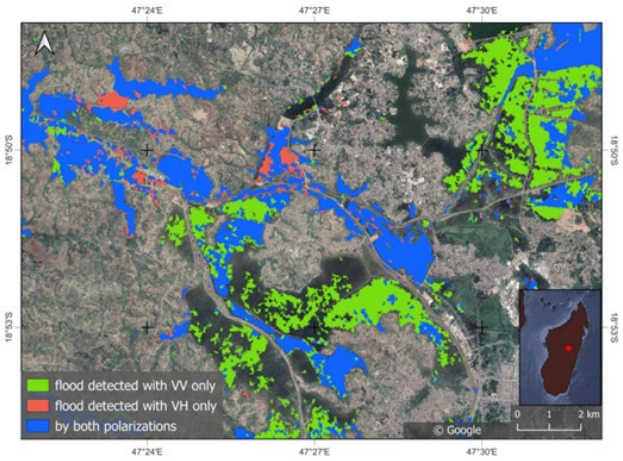

Fig. 2. Example of flood detection in Antananarivo, Madagascar using Sentinel-1 dual-polarization (VV/VH). the method allows flood extent extraction even under dense cloud cover. such techniques are applicable to Kisangani but remain largely unexplored locally [14]

A second method involves the use of hydrological and hydraulic modeling tools like HEC-RAS, SWMM, and LISFLOOD-FP to simulate flood scenarios, identify vulnerable zones, and plan infrastructure accordingly. For instance, Dar es Salaam has applied the SWMM model to map flood-prone areas under various rainfall intensities and urban growth projections [9]. In contrast, Kisangani lacks up-to-date spatial flood modeling, which limits its capacity to forecast and manage flood risks strategically.

Community-based early warning systems (CBEWS) have also proven effective in improving flood preparedness in informal settlements. In Mozambique, for example, riverine communities along the Buzi River participate in flood forecasting and alert dissemination using mobile technology and local risk mapping [10]. Kisangani, with recurring floods along the Congo River and its tributaries, could greatly benefit from such participatory systems to reduce casualties and enhance community response.

Furthermore, some African cities have adopted risk-sensitive urban planning using geospatial analysis and flood risk zoning. Accra and Lagos have developed urban planning frameworks that incorporate digital elevation models (DEMs), land cover maps, and flood recurrence intervals to guide settlement expansion and infrastructure location [11]. Such data-driven approaches are lacking in Kisangani's urban planning processes, where informal settlements often expand into flood-prone riverbanks and lowlands.

Lastly, payment for ecosystem services (PES) and community incentive programs have been used in Rwanda and Kenya to promote upstream land conservation and prevent sedimentation and downstream flooding [12]. Given the erosion-prone uplands surrounding Kisangani, such programs could reduce siltation in rivers and urban drains if adapted to the local governance context.

In summary, despite a high potential for replication and contextual adaptation, Kisangani has not yet adopted key tools and strategies widely tested elsewhere in Africa. These include modeling-based risk mapping, nature-based infrastructure, community early warning systems, and integrated land use planning. Incorporating these approaches could significantly improve flood risk reduction in the city.

3. Recommendations for Future Research

Given the persistent and complex nature of flood risk in Kisangani, future research should adopt a more interdisciplinary, predictive, and community-oriented approach. Several key research gaps have been identified that, if addressed, could significantly enhance flood risk reduction and resilience planning in the city.

Firstly, future studies should prioritize the development of spatially explicit flood hazard and risk models using hydrological-hydraulic simulations, high-resolution topographic data (e.g., UAV-based DEMs), and land use projections. Currently, the absence of such models limits the capacity to simulate future flood scenarios and evaluate the effectiveness of mitigation strategies [9]. Incorporating climate change projections and urban growth scenarios into these models would enable a more forward-looking and adaptive planning framework.

Secondly, there is a need for research on the effectiveness of nature-based solutions (NBS) in Kisangani's urban hydrological context. Empirical studies could assess how interventions such as riparian buffer zones, constructed wetlands, or urban green corridors affect flood peak attenuation and infiltration rates. These studies should include cost-benefit analyses and consider social acceptability, especially in informal settlements [8].

Thirdly, more research is required to map social vulnerability and flood exposure at the neighborhood level, integrating socio-economic, demographic, and infrastructural variables. Participatory GIS and household-level surveys could help identify the most at-risk populations and guide targeted interventions [11]. This line of research should also explore gendered and age-specific vulnerabilities, which are often underreported in flood studies.

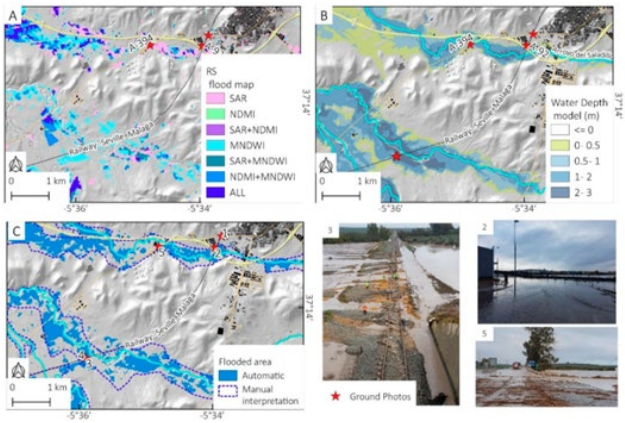

Fig. 3. Results of an automated flood mapping chain using Sentinel-1 SAR imagery, showcasing its application for rapid emergency response during flood events. this method remains underutilized in the context of Kisangani [15]

Fourth, community-based early warning systems and risk communication strategies have yet to be tested or localized for Kisangani. Future research should explore the design, implementation, and evaluation of low-cost, community-led systems for flood forecasting and alerts. This includes evaluating mobile-based systems, flood markers, and traditional knowledge integration [10].

Fifth, institutional and governance studies are needed to analyze the coordination and capacity of flood risk management institutions in Kisangani. Such research should assess legal frameworks, budget allocations, inter-agency coordination, and policy implementation gaps. Comparing Kisangani with cities that have adopted flood risk-sensitive governance (e.g., Kigali, Accra) could yield valuable insights for institutional reform [12].

Lastly, research should explore payment for ecosystem services (PES) and other incentive-based mechanisms for flood mitigation. Studies could investigate the potential for upstream watershed conservation in exchange for downstream flood protection, using hydrological modeling and socio-economic feasibility assessments [12].

In summary, future flood research in Kisangani must move beyond descriptive assessments toward integrated modeling, participatory planning, and socio-ecological resilience frameworks. Emphasis should be placed on data generation, community engagement, and policy-relevant outputs to foster an inclusive and science-based approach to flood risk reduction.

4. Conclusion

Flooding remains a persistent and multifaceted hazard in

Kisangani, exacerbated by rapid urbanization, weak land use planning, inadequate drainage infrastructure, and increasing climate variability. This review has highlighted the complexity of flood dynamics in the city and the wide-ranging social, economic, and environmental impacts that recurrent inundations impose on vulnerable populations.

Current management strategies remain largely reactive, fragmented, and under-resourced, relying on post-disaster response rather than proactive risk reduction. While some initiatives—such as community awareness campaigns and small-scale drainage projects—have been implemented, the absence of robust hydrological modeling, spatial risk assessment tools, and integrated institutional coordination has significantly limited the city's ability to anticipate, prepare for, and mitigate future flood events [9].

The review further shows that several methods successfully applied in similar urban African contexts—such as participatory GIS, hydrological-hydraulic simulations, early warning systems, and nature-based solutions—have yet to be introduced or adapted to Kisangani's socio-ecological and infrastructural realities. This gap offers a compelling opportunity for researchers, policymakers, and urban planners to rethink flood management in the city through science-based, inclusive, and forward-looking strategies.

Future research must therefore focus on spatial modeling, vulnerability mapping, governance diagnostics, and the co-creation of adaptive flood resilience pathways. Such interdisciplinary efforts, supported by reliable data and strong stakeholder engagement, are essential to reducing flood risk and enhancing urban resilience in Kisangani.

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