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Integrating Digital Technologies and Nature-Based Solutions for Climate-Resilient Urban Water Infrastructure Planning in African Cities: A Conceptual Framework

G. Laolang[1*] and N. X. Mashwama[1]

[1]*Iyunivesithi Walter Sisulu, Faculty of Engineering, Built Environment & Information Technology, Department of Built Environment, East London, South Africa*

**Corresponding author: glaolang@wsu.ac.za*

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Abstract

African cities face escalating climate-related water challenges, including flooding, drought, water scarcity, ageing infrastructure and inadequate stormwater management, intensified by rapid urbanisation and constrained municipal capacity. The literature review identifies nature-based solutions (NbS) urban wetlands, green roofs, rain gardens and bioswales as increasingly documented options for African cities, nonetheless finds their institutionalisation restricted by poor land-use and infrastructure planning mandates, limited access to localised climate-risk data, weak technical capacity within municipal engineering departments, and constrained coordination across water, planning and environmental authorities. From the review analysis, the study found that digital technologies, particularly GIS-based spatial risk mapping, remote sensing, IoT-enabled monitoring and predictive analytics, emerge as key enablers for hazard visualisation, real-time infrastructure monitoring and evidence-based decision-making, though their uptake is constrained by limited digital infrastructure, data governance gaps and municipal skills shortages. Building on these findings, this paper proposes a conceptual framework comprising four interlinked components: (1) a climate-risk and vulnerability assessment layer mapping exposure of urban water systems using digital spatial tools; (2) an NbS infrastructure integration layer matching NbS typologies to context-specific risk profiles alongside conventional grey infrastructure; (3) a digital decision-support layer using monitoring and predictive analytics to guide adaptive infrastructure management; and (4) a governance and institutional-coordination layer aligning municipal, provincial and community stakeholders around shared data platforms. The framework contribution lies in positioning digital technologies as the connective mechanism that enables NbS and grey infrastructure to function as one adaptive system, rather than treating digitalisation and NbS as parallel interventions, as in much existing climate-resilient infrastructure literature. The study offers a conceptual, context-responsive basis for municipalities, planners and infrastructure practitioners in Africa to plan urban water systems capable of anticipating, withstanding and adapting to climate-related water risks.

Keywords: *Africa; climate adaption; digital transformation; infrastructure resilient; urban water management*