

Integrating hydrological modeling and hydro-social analysis for transboundary flood risk reduction in the Ruzizi–Tanganyika basin

Benjamin Mukasani*^{1,2,3}, Esipoir Bagula Mukengere², Guy Ilombe Mawe³, Charles Bakundukize⁴,
Caroline Michellier⁵

¹ *University of Notre Dame of Tanganyika, Uvira, Democratic Republic of the Congo*

² *Higher Institute of Rural Development of Uvira, Uvira, Democratic Republic of the Congo*

³ *Official University of Bukavu, Bukavu, Democratic Republic of the Congo*

⁴ *University of Burundi, Bujumbura, Burundi*

⁵ *UCLouvain / Royal Museum for Central Africa, Belgium*

*Corresponding author: bmukasani@gmail.com

ABSTRACT

The Ruzizi River basin and the northern Lake Tanganyika region are increasingly exposed to recurrent floods driven by climate variability and rapid land-use change. These dynamics affect densely populated areas where livelihoods depend on water systems. Recent events have caused major disruptions, including infrastructure damage, displacement, and public health crises

Current flood risk assessments in the region rely primarily on hydrological modeling and remote sensing. These approaches provide robust estimates of runoff dynamics but insufficiently capture the social production of risk. This study advances a coupled human–water system perspective by integrating process-based hydrological modeling with a hydro-social analytical framework. The objective is to improve flood prediction, spatial risk characterization, and early warning system effectiveness in a transboundary setting

The study builds on the RUZIZI-LINK project, which develops a transboundary hydro-social observatory combining scientific and community-based data. The methodology follows three integrated components

- Hydrological modeling using rainfall-runoff simulations to estimate discharge variability and flood occurrence under variable precipitation regimes
- Geospatial analysis using remote sensing and GIS to map land-use dynamics, flood-prone zones, and exposure patterns
- Participatory approaches including household surveys, community mapping, and citizen observatories to document local knowledge and impacts
- Hydrological models are calibrated using available hydroclimatic data and satellite rainfall products. Outputs are integrated with socio-territorial indicators in a GIS to produce spatially explicit hydro-social risk assessments

Results show that flood risks emerge from the interaction between hydrological processes and territorial dynamics. Land-use change, informal urbanization, and governance gaps significantly alter runoff response and amplify exposure. Purely hydrological approaches underestimate risk in socially vulnerable areas

The integration of modeling and hydro-social data improves predictive capacity and enhances the operational relevance of early warning systems. The co-produced observatory supports data sharing, strengthens local ownership, and enables coordinated transboundary risk governance

This study contributes to the operationalization of hydro-social theory in African basins and proposes a transferable framework for integrating modeling and participatory data in data-scarce environments

Keywords: Flood modeling, Hydro-social systems, GIS, Citizen Science, Ruzizi basin.