Geospatial–Optimization Framework for Identifying Optimal Reservoir Sites for Flood Mitigation in the Upper Benue River Basin, Nigeria
(Oral)

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ABSTRACT

Flooding has become an increasingly destructive environmental hazard across the Benue River Basin, threatening settlements, agricultural systems, and regional livelihoods. In the Upper Benue River Basin of Nigeria, recurrent flood events are intensifying due to a combination of climate variability, expanding land-use pressures, and insufficient watershed management infrastructure. Despite the strategic importance of the basin to national food production and regional water security, systematic identification of suitable sites for flood-control reservoirs remains limited. This study therefore develops an integrated geospatial–optimization framework to identify optimal reservoir locations capable of reducing flood vulnerability within the basin. The research combines remote sensing, geospatial analysis, and computational optimisation to evaluate the spatial suitability of potential reservoir sites. A multi-criteria decision-making framework was developed using the Fuzzy Analytical Hierarchy Process (FAHP) to account for uncertainties in environmental variables influencing reservoir placement. The final set of conditioning factors was established through an expert-driven Delphi process and included rainfall, river discharge, bedrock lithology, slope, elevation, soil type, stream order, and proximity to settlements and geological fault lines, while the river network served as a spatial constraint. Pairwise comparison matrices were generated to determine the relative importance of each factor. These weights were subsequently refined using a Particle Swarm Optimisation (PSO) algorithm implemented in MATLAB, enabling a robust optimisation of site suitability across the basin. Results indicate that topographic conditions exert the strongest control on reservoir suitability. Surface slope received the highest weighting (27.67%), reflecting its critical role in controlling water accumulation and storage potential, while stream order contributed the least influence (2.40%). The spatial suitability model identified eleven optimal reservoir sites distributed across strategic sections of the basin. The estimated storage capacities of these potential reservoirs range from 330,509 m^3 to 29,751,823 m^3, with surface areas between 201.235 and 784.268 hectares. These locations demonstrate favourable geomorphological and hydrological conditions for effective flood retention and controlled water release. Beyond site identification, the study highlights the value of integrating fuzzy logic and swarm-based optimisation within geospatial hydrological analysis. Such approaches allow uncertainty in environmental parameters to be addressed while improving the reliability of decision-support tools for watershed planning. The findings provide a scientifically grounded framework for flood-mitigation infrastructure planning in the Upper Benue River Basin and offer practical guidance for basin-scale water management strategies under increasing hydro-climatic stress. More broadly, the study demonstrates how advanced spatial modelling can support resilient water-resource planning in rapidly changing African river systems.

Keywords: Flood vulnerability; reservoir site selection; Fuzzy Analytical Hierarchy Process; Particle Swarm Optimisation; Benue River Basin.