

Urbanization dynamics and evolution of runoff hazard in Abidjan : a spatio-temporal analysis based on satellite imagery

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ABSTRACT

In Abidjan, the rapid transformation of the urban landscape over the last two decades has profoundly altered surface runoff processes. This study analyses the spatio-temporal evolution of surface runoff between 2002 and 2024 in two urban catchments, the Gourou basin (26 km²) and the Bonoumin basin (46 km²), using satellite imagery and the SCS-CN approach, which models runoff dynamics. Three reference dates were considered: 2002 (Landsat 7 ETM+), 2016, and 2024 (Sentinel-2A). The images were classified using the Random Forest algorithm, a machine learning method recognized for its robustness, into four land-use/land-cover classes : water, urban built-up areas, vegetation, and bare soil. Native spectral bands and derived indices (NDVI, NDBI, MNDWI, SAVI, NDVI_texture) were combined to improve spectral separability between classes. The classification achieved an overall accuracy greater than 96%, a Kappa coefficient above 0.90, and an average F1-score of 0.94, demonstrating the reliability of the results. The results reveal a marked increase in built-up surfaces at the expense of vegetation and natural areas. Between 2002 and 2024, the proportion of built-up areas increased from nearly 45% to more than 70% in the Gourou basin, and from 38% to over 65% in the Bonoumin basin, reflecting strong urban imperviousness dynamics. This evolution directly affects hydrological parameters: the mean Curve Number (CN) increased from 76 to 93.7 in the Gourou basin and from 73 to 93.9 in the Bonoumin basin, indicating a progressive reduction in soil infiltration capacity. The estimation of direct runoff, calculated from local rainfall data and CN values using the SCS-CN model, highlights a non-linear increase in runoff for identical rainfall events. Rainfall–runoff (P–Q) relationships show that extreme rainfall events now generate runoff volumes up to twice those estimated in 2002, revealing the increasing sensitivity of the basins to urban imperviousness. This approach, based exclusively on satellite data and accessible GIS tools (Google Earth Engine, ArcGIS, QGIS), provides a reproducible methodological framework for assessing the evolution of urban runoff in tropical cities or urban basins that are mostly ungauged or poorly gauged. The results provide scientific evidence useful for urban planning, stormwater management, and the development of Early Warning Systems (EWS) in West Africa. This study provides quantitative indicators useful for the calibration of runoff forecasting models and for strengthening Early Warning Systems in West Africa.

Keywords: urban runoff, imperviousness, Curve Number, Random Forest, satellite imagery, hydrological hazard.