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A methodology for multitemporal analysis of hydraulic dynamics of water bodies using satellite radar imagery: a case study of the Bajo Cauca region in Antioquia-Colombia

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ABSTRACT

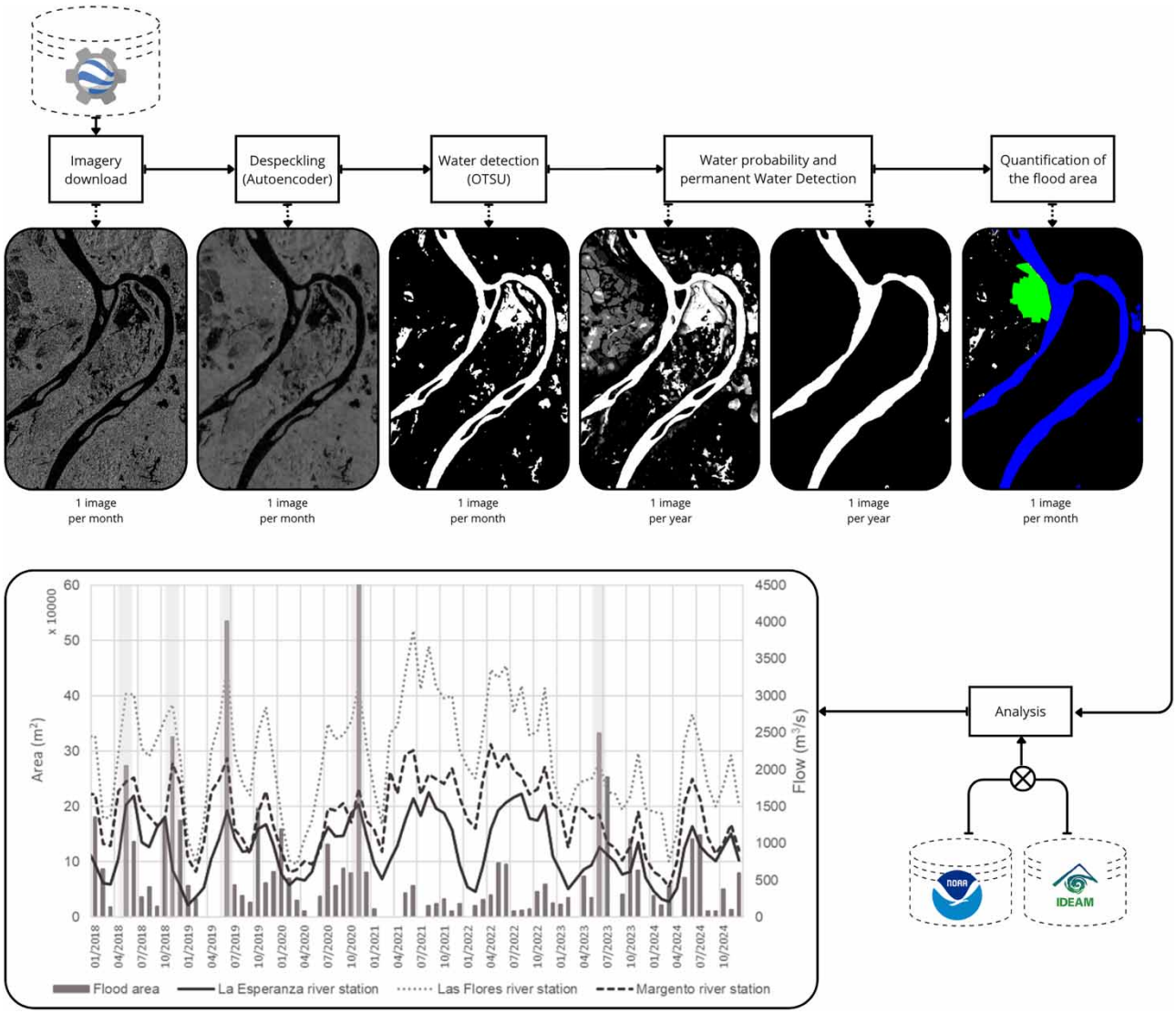
This study evaluates the use of synthetic aperture radar imagery for detecting and monitoring periodic flooding in Nechí, Colombia, where persistent cloud cover limits the use of optical images. A classification method combining autoencoder-based despeckling and Otsu thresholding was applied, achieving 91.16% overall accuracy, 95.33% specificity, 86.80% recall, and an F1-score of 90.58%. Flood mapping from 2017 to 2024 revealed strong interannual variability, with the largest event in 2017 (average extent 3.59 million m^2; peak 12.95 million) and the second largest in 2020 (average 124,442 m^2; peak 746,100 m^2). Seasonal patterns were bimodal, with peaks in June (190,557 m^2) and November (186,171 m^2), coinciding with maximum river discharges above 3,500 m^3/s. Wet conditions associated with La Niña increased flood extent, while dry El Niño years reduced it. Spatial analysis showed that embankments influence flooding patterns and that urban expansion between 2017 and 2025, with an approximate increase of 0.33 km^2 (26%), invaded flood-prone areas. The findings demonstrate the value of radar imagery for continuous flood monitoring and its potential to strengthen early warning and risk management strategies in tropical river basins.

Key words: despeckling, flood mapping, multitemporal analysis, remote sensing, Synthetic Aperture Radar (SAR)

HIGHLIGHTS

- SAR-based flood detection enables analysis even when cloud cover is present.
- Autoencoder despeckling and Otsu thresholding achieved an overall accuracy of 91.16% in identifying flood extent.
- Flood dynamics in Bajo Cauca are driven by ENSO and seasonal river peaks.
- SAR helps assess flood risk from urban growth and weak defenses.
- Post-2017 informal settlements increased exposure in Nechí.

GRAPHICAL ABSTRACT



1. INTRODUCTION

The Bajo Cauca Antioqueño, located in northern Antioquia, Colombia, is a floodplain formed by several rivers, including the Cauca and Nechí. The region exhibits complex environmental, socioeconomic, and cultural dynamics that significantly affect natural resources and local communities (Restrepo-Jimenez & Restrepo-Londoño 2024). Its topographic setting, between the final foothills of the Central and Western Andes, along with the indirect influence of both Atlantic and Pacific oceans, results in persistent cloud cover. This, combined with frequent and intense rainfall from deep convective clouds, hinders reliable surface observation using optical satellite imagery.

Monitoring the Bajo Cauca Antioqueño region, with its high levels of natural and anthropogenic dynamism, presents significant challenges. The area, characterized by numerous still bodies of flowing and water currents, is prone to rapid hydraulic changes that pose risks to the communities settled there. These changes, which can manifest within a few days, are difficult to observe using optical images, since cloud cover prevents visibility (Figure 1). Therefore, there is a need for information from remote satellite sensors with greater frequency and quality, capable of penetrating cloud cover up to a certain density, is urgent. This necessity highlights the potential of using satellite images from active sensors such as Synthetic Aperture Radar (SAR) (Fonseca Arroyave 2020; Lang *et al.* 2024; Li *et al.* 2024).