Integrating Satellite-Derived Imagery and Aerial Drone Mapping With Wave Data for the Analysis of Coastal Erosion Dynamics

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Coastal erosion presents a critical environmental challenge for the world, where shifting weather phenomena driven by climate change threatening vital ecosystems and infrastructure. The study integrated high-resolution (10x10m) Sentinel-2 satellite imagery, NOAA-CARICOOS wave data, and aerial drone mapping to analyze shoreline dynamics at three different sites in Puerto Rico, north, west and south from 2017 to 2025. The procedure employed SNAP for precise land-water separation and QGIS to generate vector outlines of the changing coast that were combined with current drone maps. Additionally, the wave height, period, direction and power were extracted and used to create maps that show how they behaved. Analysis revealed that coastal change is not solely determined by wave power but also heavily influenced by wave direction and longshore sediment transport. Findings showed that high wave power (14.07 kW/m at the north) does not inherently cause land loss; constructive southern trajectories (180°–230°) which facilitated an estimated 102,000 m² land gain. In contrast, the south and its nearby areas experienced severe erosion, losing approximately 512,300 m² due to persistent sediment stripping by northwesterly trajectories (300°–325°), despite recording the study's lowest energy levels (0.15 kW/m). The west exhibited linear erosion, totaling 253,300 m². By synthesizing remote sensing data with current drone maps, this research provides quantitative data for developing worldwide coastal preservation and management strategies that can protect lives, ecosystems and infrastructure. This investigation is the baseline for a continuation that will use more wave and satellite data to create a predictive model of costal erosion.

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